Time-Varying Estimation of Crop Insurance Program in Altering North Dakota Farm Economic Structure

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Abstract

This study examines how federal farm policies, specifically crop insurance, have affected the farm economic structure of North Dakota's agriculture sector. The system of derived input demand equations is estimated to quantify the changes in North Dakota farmers' input use when they purchase crop insurance. Further, the cumulative rolling regression technique is applied to capture the varying effects of the farm policies over time. Empirical results from the system of input demand functions indicate that there is no moral hazard since North Dakota farmers will increase fertilizer and pesticide use in the presence of crop insurance. Results also indicate that farmers in this state will not increase the use of land.

Time-Varying Estimation of Crop Insurance Program in Altering North Dakota Farm Economic Structure

Among the first pieces of the New Deal legislation proposed by incoming President Franklin D. Roosevelt in 1933 was a farm program designed to address declines in farm prices and net farm income. The federal crop insurance program was initiated in 1938 to provide protection to farmers against crop loss due to natural disasters, including drought, excessive moisture and unusual weather (Shaik, Helmers and Atwood, 2005). Since 1933, the design of federal agricultural policies, including farm programs and crop insurance programs, are amended or new programs are introduced with the authorization of a new farm bill.

Although federal agricultural policies in the United States are rarely intended to alter the structure of agriculture, the effect of these policies and/or technology on the farm economic structure has long been an economic and political concern. According to the United States Congress, Office of Technology Assessment report (1986) the three main determinants are 1) Technology and associated economies of size, specialization and capital requirements; 2) Institutional forces; and 3) Economic and political forces. The widely held view is that a major, if not the most significant mechanism for changes in farm economic structure, is the effect of institutional forces like federal agricultural policies. While the causes of the switch to different kinds of programs are still controversial, as are the predicted outcomes, there is strong interest in the potential effects of farm programs and crop insurance on the farm economic structure.

In the last century, the farm structural changes in input use in North Dakota had experienced a morphotic[1] transition; early agriculture was labor intensive, using animal labor rather than machines, and the acreages were much smaller than today's average size. Farm production was diversified as farmers sought to protect themselves against potential risks. Parallel changes were also occurring simultaneously at a national level, as the plentiful small farms that were home and the main source of employment to almost half of the nation's population began to decline rapidly. In 1900, there were 7 million farms in the U.S., and agriculture employed 41 percent of the nation's workforce; by 1930, only 21.5 percent were employed. In 1970, a total of 4 percent of the workforce was still in agriculture, and in beginning of the 21st century, only 1.9 percent of the workforce was in agriculture (Dimitri, Effland and Conklin, 2005). Today, the United States'. agriculture has transformed into a small number of large, capital-intensive, specialized farms in rural areas and are home to less than 2 percent of the population (Lobao and Meyer, 2001). Given these changes, an interesting question is: did technology and/or agriculture policies lead to changes in the use of farm and nonfarm inputs, including seeds, feed, fertilizer, chemicals and energy? Similarly, it would be interesting to see if farm structural changes in output production led to North Dakota state being the leader in the production of flaxseed, canola and durum wheat; all dry edible beans, all dry edible peas, spring wheat, honey, lentils, sunflowers, barley and oats (*State fact sheet: North Dakota*, 2008). The state is also among the top producers of livestock such as beef, dairy cattle, and hogs and of recent has played a major role in the new oil and fuel production.

Studies have examined the importance of technology on farm economic structural changes in input use [Key and McBride (2008); Hoque and Adelaja (1984); Thirtle,

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[1] A sequence of developmental changes occurring in the input and output for North Dakota farms' over time.

Schimmelpfennig and Townsend (2001)] and output production mix [Holland and Martin (1993); Fuglie, MacDonald and Ball (2007)] using primal production function [(Solow (1957); Griliches (1963)], and dual cost function [Binswanger (1974); Kumbhakar (1997)] or profit function [Ball (1988); Lau and Yotopoulos (1972)].

Many studies have documented crop insurance issues related to experiential phases (Gardner and Kramer, 1986), moral hazard (Chambers, 1989), adverse selection [Shaik and Atwood, (2002); Quiggin, Karagiannis and Stanton, (1994)], demand for crop insurance [Coble et al, (1996); and Shaik et al, (2008)] and the effects of insurance availability upon resource allocation (Horowitz and Lichtenberg, 1993). Young, Vandeveer and Schnepf (2001) examined how regional patterns of production would change with the use of crop insurance. They estimated the "changes in acreage, production, price and net returns directly attributable to Federal crop insurance… using a simulation model". Ahsan, Ali and Kurian (1982) theoretically examined a model for crop insurance and recognized that there was an output increasing effect. Chambers and Quiggin (2001) examined the effects of crop insurance under a multi-input, multi-output framework and found ambiguous effects.

Current research has addressed crop-specific effects of insurance programs on farm economic structure, including adverse selection, moral hazard, demand for insurance, rating methodologies and potential environmental effects. This line of research is valid due to the current setting of insurance programs that is crop specific. In general, the effects of crop insurance encompass a simultaneous impact on the resource use and output production mix rather than in isolation to individual crops. There is hardly any literature examining the importance of federal farm programs like crop insurance on the changes in farm economic structure except for some anecdotal reference (Shaik, 2001 and 2006).

In the context of farm economic structure, the input and output relationships are assumed to be constant. However, the constant nature of the relationship is questionable due to changes in the industry induced by the advancements[2] in structure of agriculture and policies. Literature in the area of farm economic structure seldom examines the importance of the time-varying effects of technology or farm programs like crop insurance on input and output farm economic structure. Time-varying estimates represent one of the most widely used and well established concepts in finance, risk and time series literature [Rosenberg and Guy, (1976); Fisher and Kamin, (1985); Lawrence and Kamin, (1985); Chiang, (1988); Crockett, Nothaft and Wang, (1991); Groenewold and Fraser, (1999); Smith and Taylor, (2001)]. This research aims to close this gap by empirically analyzing the time-varying estimates of changes in farm economic structure. Following Shaik (2008), a variant of the rolling regression technique of the cumulative rolling regression is applied to estimate time-varying relationships.

Given these changes in input use and output production, interest has grown in understanding how technology and/or federal farm policies like crop insurance have affected or altered the farm economic structure of the North Dakota agriculture sector. Secondly, the time-varying changes in the farm economic structure will be examined using the cumulative rolling regression analysis.

This research will be organized as follows: the second chapter will summarize the literature review of the farm economic structure and rolling regression analysis. This will be followed by the conceptual model, highlighting the hypothesized effects of crop insurance under the duality framework. The empirical methods, data sources and results will be discussed in the fourth chapter, followed by conclusions in the final chapters.

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[2] Total factor productivity

Conceptual framework and data

To examine the effects of crop insurance (CI) on the farm economic structure of North Dakota agriculture, we assume that farms choose both their inputs and outputs with the goal of minimizing cost. Rational producers may choose to purchase crop insurance in an attempt to mitigate risk and minimize cost.

In the agriculture sector, one observes non-allocable[3] input vector, $\mathbf{x} = (x_1, x_2, ..., x_i) \in \Re_+^I$ used in the production of output vector, $\mathbf{y} = (y_1, y_2, ..., y_j) \in \Re_+^J$ and $\mathbf{w} = (w_1, w_2, ..., w_i) \in \Re_+^I$ representing the input price vector. To model the change in production process in the presence of CI, we use the dual cost function and can be represented below.

(1) $$c(\mathbf{w}, \mathbf{y}) = \min_{x \geq 0} \ \mathbf{w} \bullet \mathbf{x} : \mathbf{x} \in V(\mathbf{y})$$

To examine the influence of crop insurance on factor use patterns, net crop insurance is treated as an additional output in the cost minimization input demand function.

(2) $$c(\mathbf{w}, \mathbf{y}, \mathbf{z}) = \min_{x \geq 0} \ \mathbf{w} \bullet \mathbf{x} : \mathbf{x} \in V(\mathbf{y} | \mathbf{z})$$

The cost function in the absence of crop insurance can be represented as $C = (\mathbf{w}, \mathbf{y})$ and $C = (\mathbf{w}, \mathbf{y}, \mathbf{z})$ with **z** representing crop insurance. The cost functions with and without crop insurance must satisfy the properties as defined in Shephard (1970) and Chambers (1988).

Many studies have tried to assess the importance of functional forms in empirical estimation, but the most popularly used forms are the translog and generalized quadratic functional form [Christensen, Jorgenson and Lau, (1973); Yotopoulos, Lau and Wuu-Long, (1976)]. We apply the translog functional form to the cost function because of its flexibility since

[3] Inputs that are not separated for the production of different outputs but are used for the production of all agricultural output.

all the equations to be estimated will be linear in logarithms. Furthermore, the Translog functional form is superior to most other forms; including the Cobb-Douglas multiple-output cost function, because the output possibility frontiers will be concave and not convex as in the Cobb-Douglas form (Greene, 2008).

This study assumes Hicks neutral technical change, satisfying the properties as defined in Chambers (1988) that can be represented in Equation 3.

(3)
$$\begin{aligned}\ln C = {} & \alpha_0 + \alpha_y Y + \sum_{i=1}^{I} \alpha_i \ln w_i + \frac{1}{2}\gamma_{y,y}(\ln Y)^2 + \frac{1}{2}\sum_{i=1}^{I}\sum_{h=1}^{I}\gamma_{i,h}\ln w_i \ln w_h \\ & + \sum_{i=1}^{I}\beta_{i,y}\ln w_i \ln Y + \phi_t \mathrm{T} + \frac{1}{2}\phi_{t,t}\mathrm{T}^2 + \phi_{y,t}\ln Y * \mathrm{T} + \sum_{i=1}^{I}\phi_{i,t}\ln w_i * T + \varepsilon\end{aligned}$$

The logarithmic first-order conditions of the cost function are as follows:

(4)
$$\frac{\partial \ln C}{\partial \ln w_i} = \frac{\partial C/C}{\partial w_i / w_i} = \frac{\partial C}{\partial w_i} * \frac{w_i}{C} = \frac{x_i * w_i}{C} = CS_i$$
$$\frac{\partial \ln C}{\partial \ln w_i} = CS_i = \alpha_0 + \sum_{i=1}^{7}\gamma_h \ln w_h + \beta_y \ln y + \phi_t \ln T + \varepsilon$$

where C is the cost function; y is a vector of outputs comprised of crops and livestock, and other farm related output; w is a vector of input prices for capital, land, labor (hired and unpaid), energy, material, pesticide and fertilizer, and T represents year as a proxy for technology.

Equation 3 can be extended to include crop insurance as an additional output, and this can be represented below.

$$
\begin{aligned}
(5)\qquad \ln C = \alpha_0 + \alpha_y Y + \alpha_z Z + \sum_{i=1}^{I} \alpha_i \ln w_i + \frac{1}{2}\gamma_y (\ln Y)^2 + \frac{1}{2}\gamma_z (\ln Z)^2 \\
+ \frac{1}{2}\sum_{i=1}^{I}\sum_{h=1}^{I} \gamma_{i,h} \ln w_i \ln w_h + \sum_{i=1}^{I} \beta_{i,y} \ln w_i \ln Y \\
+ \sum_{i=1}^{I} \beta_{i,z} \ln w_i \ln Z + \phi_t \mathrm{T} + \frac{1}{2}\phi_{t,t} \mathrm{T}^2 \\
+ \phi_{y,t} \ln Y * \mathrm{T} + \phi_{z,t} \ln Z * \mathrm{T} + \sum_{i=1}^{I} \phi_{i,t} \ln w_i * T + \varepsilon
\end{aligned}
$$

The logarithmic first order conditions of the cost function with net crop insurance are as follows:

$$
(6)\qquad \frac{\partial \ln C}{\partial \ln w_i} = CS_i = \alpha_i + \sum_{i=1}^{7} \gamma_h \ln w_h + \gamma_y \ln y + \beta_z \ln Z + \phi_t \ln T + \varepsilon
$$

Using the translog functional form implies that the following conditions be met.

Homogeneity and symmetry

$$
(7)\qquad \begin{aligned} &\sum \alpha_i = 1 \\ &\gamma_{j,i} = \gamma_{j,i} = 0 \end{aligned}
$$

Given that the translog cost function can accommodate interrelationships between inputs and outputs, the Allen own and cross partial elasticity of substitution and own and cross price elasticity of demand can be derived using Equation 6.

$$
(8)\qquad \begin{aligned} \sigma_{ij}^{AES} &= \frac{\alpha_{i,j}}{CS_i CS_j} + 1 \\ \sigma_{ii}^{AES} &= \frac{1}{CS_i^2} + \alpha_{i,j} + CS_i^2 - CS_i \end{aligned}
$$

The Morishima elasticities are calculated following Binswanger (1974) as represented below:

$$
(9)\qquad \begin{aligned} \sigma_{ii}^{M} &= \sum_i (\sigma_{ii} - \sigma_{ii}) \\ \sigma_{ji}^{M} &= \sum_i (\sigma_{ji} - \sigma_{ii}) \end{aligned}
$$

In looking at the farm economic structure, the input-output relationships derived from the first order input demand function and elasticities were assumed to be constant over time. However, this assumption is questionable because changes in the industry can be induced by the changes in the economic structure of farms and agricultural policies. This research aims to contribute to the sparse literature by empirically analyzing the time-varying estimates of input-output relationships which will be estimated from the first order input demand function and elasticities. Traditionally, methods such as time dummies or testing for breaks using Chow tests and cutting up the estimation into different periods and Bayesian techniques have been used in the literature to examine time-varying input elasticities, technical change, and the returns to scale. These methods are relatively simple but more costly to examine the importance of each additional year of information on the efficiency or coefficient estimates. To examine time-varying parameter coefficients and input elasticities, a cumulative rolling regression of system of input demand equations are estimated. With cumulative rolling regression, a set of coefficients is estimated with each additional year of data. To represent the system of input demand equations in the cumulative rolling analysis framework, equation (6) can be re-written as:

(10) $$CS_{i,t}^{j} = \alpha_i^j + \sum_{i=1}^{7} \gamma_i^j \ln w_{i,t}^j + \beta_t^j \ln Y_t^j + \beta_t^j \ln Z_t^j + \phi_t^j \ln T_t^j + \varepsilon_t^j$$

where $j = 25,.......,T$ and represents the number of rolling regression runs. The first regression starts with a window of the first 25 observations. The second regression includes an additional year of data; that is the first 26 observations. The third regression includes two additional years of data; that is the first 27 observations. The final regression would include all T years of data. This would be equivalent to the traditional regression analysis.

North Dakota Agriculture Sector data

Data for this study were obtained from Eldon Ball of the United States Department of Agriculture- Economic Research Service and can also be accessed on the website at http://www.ers.usda.gov/Data/AgProductivity/. The construction of the variables is also available from the same ERS website.

Annual data for input prices and input quantities include capital (CAP_PI), excluding land; land (LAND_PI), labor including hired and self-employed or unpaid family labor (LAB_PI), energy (ENG_PI), pesticide (PEST_PI), fertilizer (FERT_PI), and materials excluding energy and chemicals (MAT_PI). Output quantity are disaggregated into livestock (LS_QI), crop (CR_QI), other farm related output (OFR_QI) and net crop insurance (NCI_QI) which are the total indemnities and subsidies less premium. The quantity indices are in 1996 thousand dollars. The price indices are based on prices relative to level in Alabama in 1996.

To derive the implicit quantity index for NCI_QI, the log of NCI is divided by the log of Aggregate output price index and mathematically represented as:

$$(11) \qquad \partial \ln NCI\_QI = (\partial \ln NCI - \partial \ln AO\_PI)$$

For each year starting from 1960 to 2004, the input price is multiplied by input quantities to derive the total cost in SAS along with the cost share for each input. Throughout the entire period of study, on average, North Dakota had the highest growth in crop output, followed by livestock, other farm related-output, and then trailed by net crop insurance as reflected in the table below.

Table 3.1. Mean output quantities and input prices for North Dakota agriculture sector.

Roll	CR_QI	LS_QI	OFR_QI	NCI_QI	CAP_PI	LAND_PI	LAB_PI	FERT_PI	ENG_PI	PEST_PI	MAT_PI
1960 - 1985	2,009,173	704,978	158,319	10,254	0.3698	0.1866	0.2352	0.3515	0.5191	0.4775	0.4955
1960 - 1986	2,052,942	704,651	157,581	10,529	0.3859	0.1960	0.2431	0.3545	0.5324	0.4874	0.5057
1960 - 1987	2,084,939	703,693	157,182	10,648	0.4011	0.2033	0.2521	0.3594	0.5444	0.4968	0.5145
1960 - 1988	2,059,019	697,877	159,580	15,647	0.4178	0.2097	0.2589	0.3681	0.5565	0.5074	0.5283
1960 - 1989	2,062,899	692,536	163,280	18,792	0.4337	0.2150	0.2612	0.3780	0.5694	0.5181	0.5448
1960 - 1990	2,094,104	688,100	167,672	19,163	0.4487	0.2200	0.2743	0.3875	0.5843	0.5281	0.5590
1960 - 1991	2,121,666	684,114	171,739	18,284	0.4629	0.2244	0.2790	0.3985	0.5967	0.5382	0.5721
1960 - 1992	2,171,092	680,564	176,061	17,358	0.4762	0.2282	0.2885	0.4079	0.6075	0.5482	0.5825
1960 - 1993	2,189,472	678,194	181,709	19,926	0.4895	0.2319	0.3004	0.4160	0.6186	0.5574	0.5933
1960 - 1994	2,218,687	675,101	186,269	20,225	0.5030	0.2360	0.3164	0.4262	0.6276	0.5662	0.6042
1960 - 1995	2,235,878	672,945	192,252	21,494	0.5171	0.2404	0.3316	0.4375	0.6357	0.5750	0.6152
1960 - 1996	2,270,103	670,004	196,760	20,753	0.5308	0.2450	0.3401	0.4484	0.6475	0.5842	0.6269
1960 - 1997	2,288,666	665,772	200,966	22,817	0.5441	0.2498	0.3674	0.4574	0.6579	0.5944	0.6394
1960 - 1998	2,317,980	664,262	206,893	22,992	0.5564	0.2539	0.3893	0.4617	0.6644	0.6033	0.6496
1960 - 1999	2,340,233	661,993	212,151	34,029	0.5689	0.2588	0.4155	0.4678	0.6701	0.6118	0.6579
1960 - 2000	2,374,814	660,777	217,448	38,353	0.5823	0.2641	0.4311	0.4710	0.6808	0.6198	0.6661
1960 - 2001	2,402,814	659,567	220,928	44,396	0.5948	0.2682	0.4577	0.4741	0.6919	0.6278	0.6755
1960 - 2002	2,423,679	657,962	223,613	50,793	0.6060	0.2708	0.4774	0.4767	0.6994	0.6352	0.6865
1960 - 2003	2,463,604	656,069	226,160	52,152	0.6169	0.2730	0.4891	0.4806	0.7113	0.6417	0.6977
1960 - 2004	2,489,927	654,586	229,703	58,790	0.6267	0.2738	0.4947	0.4849	0.7244	0.6480	0.7091
Mean	2,233,585	676,687	190,313	26,370	0.5066	0.2374	0.3451	0.4254	0.6270	0.5683	0.6062
Std dev	150,256	17,131	25,699	14,738	0.0803	0.0268	0.0886	0.0467	0.0618	0.0541	0.0668
Max	2,489,927	704,978	229,703	58,790	0.6267	0.2738	0.4947	0.4849	0.7244	0.6480	0.7091
Min	2,009,173	654,586	157,182	10,254	0.3698	0.1866	0.2352	0.3515	0.5191	0.4775	0.4955

Table 3.1 shows the average use of inputs and output by each rolling regression period beginning at 1960 to 1985, then moving forward by one year for each regression while leaving the starting period fixed. As can also be seen in the line graph, crop output has the highest output. From 1960-1988 periods, the average crop output increased slightly and then decreased with the addition of 1988 and then increases at an increasing rate thereafter.

Average livestock output in North Dakota saw a steady decrease across all the years, while the other farm-related output generally increased throughout the entire period except in the period from 1960-1987. Average net crop insurance started off with a decrease as 1986 and 1987 are added to the regression, but the period 1960-1989 experiences an increase at an increasing rate with each additional year thereafter. The mean crop output quantity index across all the rolling regression periods is 2,233,585 with the highest standard deviation of 150,256 a maximum of 2,489,927 and a minimum of 2,009,173. The livestock quantity index has a mean of 676,687 which is the second highest average. The standard deviation is 17,131 with a maximum of 704,978 and a minimum 654,586. Another farm-related output index has the third highest mean at 190,313, with the second highest deviation of 25,699. Meanwhile, the net crop insurance index has a mean of 26,370 with a deviation of 14,738, a maximum of 58,790, and a minimum of 10,254.

The line graph of the mean input price index (Figure 3.2) shows a general increasing trend for all input prices. The highest input price is energy, followed by materials, pesticide, capital, fertilizer, labor, and land. The mean for the capital price index is 0.5066 with the second highest standard deviation of 0.0886, a maximum of 0.6267, and a minimum of 0.3698. The land price index has a mean across all rolling regression periods of 0.2374. The mean labor price index is 0.3451, with the highest deviation of 0.0886. The mean for fertilizer, energy, and pesticide and material price index is 0.4254, 0.6270, 0.5683, and 0.6062, respectively.

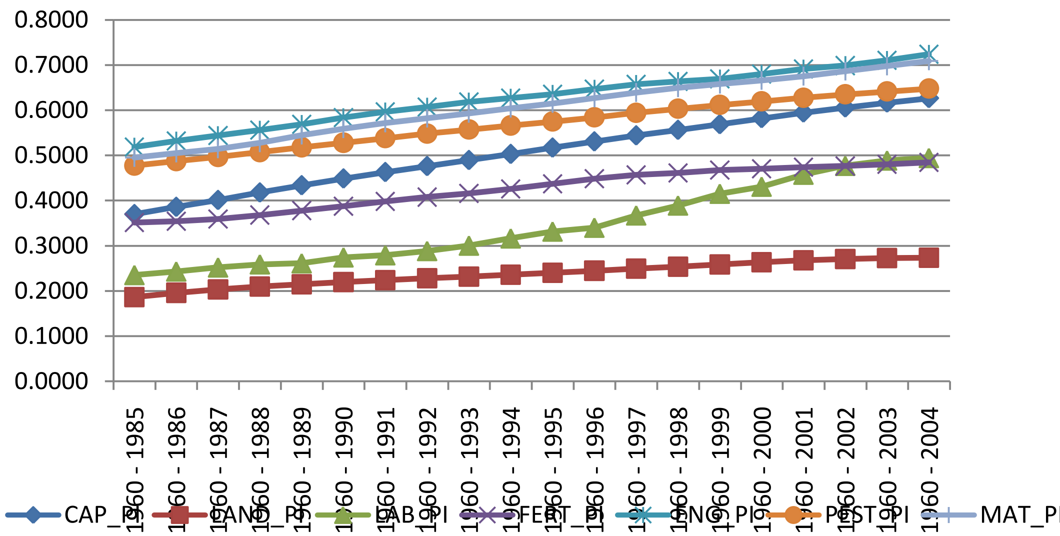

Figure 3.2. Line graph of mean input price index for North Dakota agriculture sector.

The mean cost shares are calculated across all the rolling regression periods and are displayed in Table 3.2. The general trend in Table 3.2 is graphically represented in Figure 3.3. On average, farms in North Dakota allocate relatively more materials and labor and capital compared to other inputs. The average amount of labor allocated by North Dakota farms varies greatly with each additional year throughout the entire period of the study.

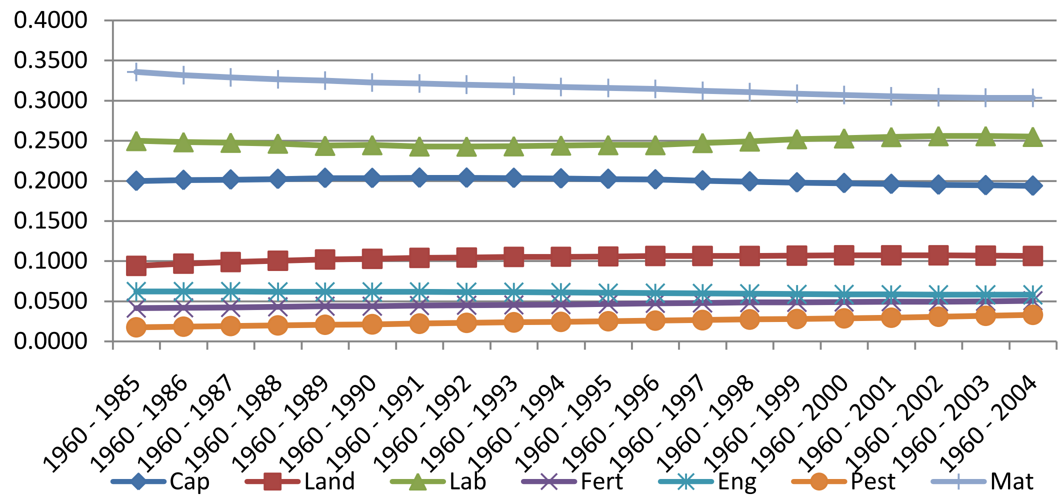

Figure 3.3. Mean cost shares for North Dakota agriculture sector.

Capital shares increase steadily over the period of study except in 1960-1994 where they decrease and, with each additional year, continue to decrease thereafter. The mean across all rolling regression periods for cost share of capital is 0.2002 with a standard deviation of 0.0033, a maximum of 0.2038, and a minimum of 0.1939. Cost share for land generally increases at an increasing rate throughout the years but in the period 1960-2003 declined and continued to do so with the addition of the last year.

Table 3.2. Mean cost shares for North Dakota agriculture sector.

	MEAN COST SHARES						
Roll	**Capital**	**Land**	**Labor**	**Fertilizer**	**Energy**	**Pesticide**	**Material**
1960 - 1985	0.1998	0.0939	0.2498	0.0414	0.0620	0.0173	0.3358
1960 - 1986	0.2009	0.0967	0.2484	0.0419	0.0621	0.0182	0.3319
1960 - 1987	0.2015	0.0988	0.2476	0.0423	0.0620	0.0190	0.3288
1960 - 1988	0.2023	0.1004	0.2466	0.0428	0.0618	0.0196	0.3265
1960 - 1989	0.2035	0.1021	0.2438	0.0436	0.0618	0.0205	0.3248
1960 - 1990	0.2034	0.1029	0.2447	0.0438	0.0617	0.0211	0.3225
1960 - 1991	0.2038	0.1038	0.2431	0.0445	0.0616	0.0219	0.3213
1960 - 1992	0.2037	0.1045	0.2429	0.0448	0.0614	0.0228	0.3199
1960 - 1993	0.2035	0.1050	0.2433	0.0452	0.0611	0.0235	0.3184
1960 - 1994	0.2029	0.1053	0.2442	0.0457	0.0607	0.0242	0.3171

1960 - 1995	0.2023	0.1058	0.2447	0.0464	0.0603	0.0249	0.3157
1960 - 1996	0.2016	0.1063	0.2447	0.0473	0.0600	0.0257	0.3144
1960 - 1997	0.2003	0.1064	0.2473	0.0479	0.0596	0.0263	0.3122
1960 - 1998	0.1991	0.1065	0.2492	0.0483	0.0592	0.0271	0.3106
1960 - 1999	0.1979	0.1067	0.2521	0.0485	0.0586	0.0278	0.3084
1960 - 2000	0.1971	0.1072	0.2530	0.0488	0.0584	0.0286	0.3068
1960 - 2001	0.1961	0.1072	0.2547	0.0492	0.0582	0.0294	0.3052
1960 - 2002	0.1951	0.1070	0.2559	0.0494	0.0579	0.0304	0.3042
1960 - 2003	0.1945	0.1069	0.2559	0.0498	0.0579	0.0315	0.3035
1960 - 2004	0.1939	0.1064	0.2550	0.0505	0.0580	0.0328	0.3033
Mean	0.2002	0.1040	0.2483	0.0461	0.0602	0.0246	0.3166
Std dev	0.0033	0.0038	0.0046	0.0029	0.0016	0.0046	0.0098
Max	0.2038	0.1072	0.2559	0.0505	0.0621	0.0328	0.3358
Min	0.1939	0.0939	0.2429	0.0414	0.0579	0.0173	0.3033

The mean across all rolling regression periods is 0.1040, with a standard deviation of 0.0038, with a maximum of 0.1072 and a minimum of 0.0939. Energy input saw a steady decrease from the beginning of the study period from 1960-1992. When 1993 is added to the rolling regression periods, it experiences an increase at an increasing rate thereafter. The mean across all rolling regression periods is 0.2483, with a standard deviation of 0.0046, a maximum of 0.2559, and a minimum of 0.2429.

Fertilizer and pesticide increased steadily with each additional year, while material and energy decreased throughout the period of study. The mean across all rolling regression periods for fertilizer and pesticide is 0.0461 and 0.0246, with a standard deviation of 0.0029 and 0.0046 respectively. Energy and material has a mean of 0.0602 and 0.3166 with a standard deviation of 0.0016 and 0.0098 respectively.

Empirical Application and Results

To examine the importance of crop insurance on farm economic structure in North Dakota for the period 1960-2004, Equation 11 is estimated as the system of input demand equations using an iterative seemingly unrelated regression in SAS. Specifically, the impact of crop insurance on farm and non-farm inputs such as land, labor capital, seeds, feed, fertilizer, energy, and material is examined. Due to the homogeneity and symmetry conditions, the material equation is dropped. Second, to examine the time-varying importance of crop insurance on the farm economic structure in North Dakota, Equation (10) defined in chapter three is estimated using the cumulative rolling regression technique on the system of input demand equations. Further, since the federal policies including crop insurance programs are amended or new programs are introduced with the authorization of a new farm bill, the effects of these policy changes can be hidden by the traditional regression analysis. By allowing the sample to grow with each additional year of information, the parameter coefficients and elasticities will reflect changes in the impact of crop insurance on input use due to policy changes that occur during a specific year.

Equation 11 below defines the system of derived input demand equations that will be estimated to examine the importance of crop insurance on input demand. The traditional system of the derived input demand equation is also estimated by holding the $\beta_1, \beta_2, ...\beta_6 = 0$.

$$
\begin{aligned}
CS_1^j &= \alpha_1 + \gamma_{11} \ln w_1 + \gamma_{12} \ln w_2 + \gamma_{13} \ln w_3 + \gamma_{14} \ln w_4 + \gamma_{15} \ln w_5 + \gamma_{16} \ln w_6 + \gamma_{17} \ln w_7 \\
&\quad + \beta_{11} \ln Y_1 + \beta_{12} \ln Y_2 + \beta_{13} \ln Y_3 + \beta_1 \ln Z_1 + \delta_1 \ln T_1 + \varepsilon_1 \\
CS_2^j &= \alpha_2 + \gamma_{21} \ln w_2 + \gamma_{22} \ln w_2 + \gamma_{23} \ln w_3 + \gamma_{24} \ln w_4 + \gamma_{25} \ln w_5 + \gamma_{26} \ln w_6 + \gamma_{27} \ln w_7 \\
&\quad + \beta_{21} \ln Y_2 + \beta_{22} \ln Y_2 + \beta_{23} \ln Y_3 + \beta_2 \ln Z_2 + \delta_2 \ln T_2 + \varepsilon_2 \\
CS_3^j &= \alpha_3 + \gamma_{31} \ln w_3 + \gamma_{32} \ln w_2 + \gamma_{33} \ln w_3 + \gamma_{34} \ln w_4 + \gamma_{35} \ln w_5 + \gamma_{36} \ln w_6 + \gamma_{37} \ln w_7 \\
&\quad + \beta_{31} \ln Y_3 + \beta_{32} \ln Y_3 + \beta_{33} \ln Y_3 + \beta_3 \ln Z_3 + \delta_3 \ln T_3 + \varepsilon_3 \\
CS_4^j &= \alpha_4 + \gamma_{41} \ln w_4 + \gamma_{42} \ln w_2 + \gamma_{43} \ln w_3 + \gamma_{44} \ln w_4 + \gamma_{45} \ln w_5 + \gamma_{46} \ln w_6 + \gamma_{47} \ln w_7 \\
&\quad + \beta_{41} \ln Y_1 + \beta_{42} \ln Y_2 + \beta_{43} \ln Y_4 + \beta_4 \ln Z_4 + \delta_4 \ln T_4 + \varepsilon_4 \\
CS_5^j &= \alpha_5 + \gamma_{51} \ln w_5 + \gamma_{52} \ln w_2 + \gamma_{53} \ln w_3 + \gamma_{54} \ln w_4 + \gamma_{55} \ln w_5 + \gamma_{56} \ln w_6 + \gamma_{57} \ln w_7 \\
&\quad + \beta_{51} \ln Y_1 + \beta_{52} \ln Y_2 + \beta_{53} \ln Y_5 + \beta_5 \ln Z_5 + \delta_5 \ln T_5 + \varepsilon_5 \\
CS_6^j &= \alpha_6 + \gamma_{61} \ln w_1 + \gamma_{62} \ln w_2 + \gamma_{63} \ln w_3 + \gamma_{64} \ln w_4 + \gamma_{65} \ln w_5 + \gamma_{66} \ln w_6 + \gamma_{67} \ln w_7 \\
&\quad + \beta_{61} \ln Y_1 + \beta_{62} \ln Y_2 + \beta_{63} \ln Y_6 + \beta_6 \ln Z_6 + \delta_6 \ln T_6 + \varepsilon_6
\end{aligned} \tag{11}
$$

Where CS_i^j = Cost share of capital, land, labor, fertilizer, energy and material in each rolling regression period; w_i = Price of capital land, labor, fertilizer, energy and material; $Y_i =$ Quantities of livestock, crops and other farm related output;

$Z_i =$ Net crop insurance variable for capital, land, labor, fertilizer, energy and material; and T_i = Year in each cost share as a proxy for technology.

4.1. Empirical results of net crop insurance on North Dakota agriculture sector input demand equations

Table 4.1 presents the parameter coefficients of the net crop insurance variable for capital, land, labor, fertilizer, energy and material input demand equations from the cumulative rolling regression. The mean, standard deviation, maximum and minimum values of the parameter coefficients from 1960-1985 to 1960-2004 are also presented in Table 4.1. Standard errors and t-values can be retrieved from the author.

Table 4.1. Net crop insurance parameter estimates for input demand equations .

Roll	**Capital** β_1	**Land** β_2	**Labor** β_3	**Fertilizer** β_4	**Energy** β_5	**Pesticide** β_6
1960-1985	0.0013	-0.0035	-0.0013	0.0020	-0.0009	-0.0001
1960-1986	0.0007	**-0.0034**	-0.0014	0.0020	-0.0008	0.0000
1960-1987	0.0007	-0.0027	-0.0013	0.0021	-0.0006	0.0000
1960-1988	0.0019	-0.0023	-0.0015	0.0025	-0.0002	0.0000
1960-1989	0.0023	-0.0025	-0.0016	**0.0025**	-0.0002	0.0001
1960-1990	0.0024	-0.0026	-0.0016	0.0024	-0.0004	0.0001
1960-1991	0.0024	-0.0026	-0.0016	0.0024	-0.0004	0.0001
1960-1992	0.0024	-0.0026	-0.0016	0.0024	-0.0004	0.0001
1960-1993	0.0024	-0.0027	-0.0019	**0.0025**	-0.0004	0.0002
1960-1994	0.0028	-0.0025	-0.0015	**0.0026**	-0.0003	0.0002
1960-1995	0.0030	-0.0024	-0.0014	**0.0025**	-0.0002	0.0002
1960-1996	0.0030	-0.0024	-0.0014	**0.0025**	-0.0002	0.0002
1960-1997	0.0032	-0.0031	-0.0013	**0.0027**	-0.0003	0.0003
1960-1998	0.0042	-0.0027	-0.0017	**0.0027**	-0.0004	-0.0001
1960-1999	0.0026	-0.0026	0.0001	0.0018	-0.0005	0.0001
1960-2000	0.0022	-0.0029	0.0002	0.0018	-0.0006	0.0002
1960-2001	0.0023	-0.0029	-0.0002	0.0017	-0.0006	0.0001
1960-2002	0.0024	-0.0027	-0.0003	0.0020	-0.0006	0.0000
1960-2003	0.0020	-0.0026	0.0001	0.0023	-0.0005	-0.0002
1960-2004	0.0017	-0.0025	0.0004	0.0023	-0.0005	-0.0003
Mean	0.0023	-0.0027	-0.0011	0.0023	-0.0004	0.0001
St. Dev.	0.0008	0.0003	0.0008	0.0003	0.0002	0.0002
Max	0.0042	-0.0023	0.0004	0.0027	-0.0002	0.0003
Min	0.0007	-0.0035	-0.0019	0.0017	-0.0009	-0.0003

Bold represents the significance level at 10%, 5% and 1%.

The mean parameter estimates corresponding to the net crop insurance variables from each equation vary across the farm and non-farm input cost share. For example, the negative mean coefficient of the net crop insurance variable for the land, labor, and energy equation across all the 20 regressions indicate an increase in net crop insurance would lead to a decrease in the utilization of land, labor, and energy. The mean parameter estimates across all the rolling regression periods for fertilizer, capital, and pesticide cost share indicate an increase in net crop insurance leads to an increase in the use of these input variables.

The net crop insurance parameter estimate in the capital cost share is positive but not significant. The positive sign on the mean parameter estimate for the net crop insurance indicates an increase in crop insurance will lead to increased use of capital on an average of 0.0023. The standard deviation of the coefficient for net crop insurance in the capital cost share is 0.0008 with a maximum of 0.0042, which was estimated in rolling regression periods 1960-1998, and a minimum of 0.0007, which was estimated in the addition of years 1986 and 1987. The time varying estimates for crop insurance in the capital cost share exhibits a decreasing trend with each additional year.

The mean parameter estimate for net crop insurance in the land cost share indicates that as crop insurance increases by 1 unit, the usage of land in agriculture production will decrease by 0.0027 with a standard deviation of 0.0003. A maximum of -0.0023 was estimated in rolling regression periods 1960-1988, and a minimum of -0.0035 was estimated in rolling regression periods 1960-1985. The time varying estimate in rolling regression periods 1960-1986 is statistically significant at a 10% level. The estimate in this period indicates that if crop insurance increases by 1 unit, farmers' spending on land input will decrease by 0.0034. The result of the land cost share implies that participation in crop insurance would not lead to an increase in land use as found by Young, Vandeveer and Schnepf (2001).

Again, the mean parameter estimate for net crop insurance in the labor cost share is not significant but indicates as crop insurance increases by 1 unit, the labor cost share will decrease by 0.0011with a standard deviation of 0.0008, a maximum of 0.0004 estimated in rolling regression periods 1960-2004, and a minimum of -0.0019 which was estimated in the addition of year 1993. The time varying estimates for crop insurance in the labor cost share exhibits a sharp decrease in the period 1960-1999. This may be due to the increase in the use of labor-saving technology.

The mean parameter estimate for net crop insurance in the fertilizer cost share indicates as crop insurance increases by 1 unit, the fertilizer cost share will increase by 0.0023 with a standard deviation of 0.0003, a maximum of 0.0027 estimated in rolling regression periods 1960-1997 and also 1960-1998, and a minimum of 0.0017 which was estimated in rolling regression periods 1960-2001. The time varying estimate in rolling regression periods 1960-1989 and then from the period 1960-1993 for six subsequent periods, the parameter estimates are statistically significant. Initially, the time varying parameter estimates decrease after which they increase until 1960-1998. The estimates in this study are similar to the findings of Horowitz and Lichtenberg (1993). Goodwin and Smith (2003) found that insured farmers spent $4.23 less on fertilizer, but Horowitz and Lichtenberg found a 19% increase in fertilizer use in the presence of crop insurance.

The parameter estimate of net crop insurance in the energy cost share is negative and significant, indicating an increase in net crop insurance will lead to a decreased use of energy on an average by 0.0004. The standard deviation of net crop insurance in the capital cost share is 0.0002 with a maximum of -0.0002 which was estimated in rolling regression periods 1960-1988 and 1960-1989 and a minimum of -0.0009 estimated in the rolling regression periods 1960-1985. The time varying estimates for crop insurance in the energy cost share exhibits a decreasing trend with each additional year until 1960-1996, where it begins an increasing trend.

The mean parameter estimate for net crop insurance in the pesticide cost share indicates as crop insurance increases by 1 unit, the use of pesticide will increase by 0.0001 with a standard deviation of 0.0002, with a maximum of 0.0003 estimated in rolling regression periods 1960-1997 and a minimum of -0.0003 estimated in the last rolling regression periods that utilize the complete data set. The time varying estimates reveal that pesticides have a positive relationship with crop insurance for most years, except in 1960-1985, 1960-1998, and again with the addition of 2003 and 2004. Surprisingly, the results of this study are statistically insignificant but are consistent with that of Horowitz and Lichtenberg (1993) who found that insured farmers spent 21% more on pesticides. The policy implication of these results would mean that the federal crop insurance program encourages fertilizer and pesticide use which can have harmful environmental externalities.

4.2. Empirical results of North Dakota agriculture sector capital input demand equation

Table 4.2 contains parameter coefficients for capital cost shares from the model that has net crop insurance variable. The mean estimate across all rolling regression periods indicates that when capital increases by 1 unit, the capital cost share will increase by an average of 0.0660 for all the rolling regression periods with a standard deviation of 0.0128, a maximum of 0.1046, and a minimum of 0.0449. The time-varying parameter estimates for capital reveal fluctuations with each additional year. Results from several rolling regression periods become significant at 10% or less. During the first period (1960-1985), the estimate is positively significant and suggests that, as the price of capital input is increased, the use of capital will increase by 0.1046. When 1986 is added, the resulting estimate is also significant, but decreases to 0.0640 and continues in that trend until 1996 is added to the roll. Thereafter, it follows an increasing trend.

The mean estimate across all rolling regression periods for land indicates that, if the price of land increases by 1 unit, then the use of capital will increase by an average of 0.0362 for all the rolling regression periods with a standard deviation of 0.0086, with a maximum of 0.0461 and a minimum of 0.0149. The time varying estimates for land reveal changes in the significance level across the periods. The estimates for the first two periods are not significant but become so with the addition of 1987 for the three subsequent periods. In 1960-1994, the coefficient becomes significant again for three periods, and again in the last three periods of the study. From the parameter coefficients for the capital cost share from the model that includes the net crop insurance variable, we can see that when labor input increases by 1 unit, the capital cost share will decrease by an average of 0.0230 for all the rolling regression periods with a standard deviation of 0.0139, a maximum of -0.0030, and a minimum of -0.0458.

Table 4.2. Parameter coefficients for North Dakota agriculture sector capital demand equation.

	capital	**land**	**labor**	**fertilizer**	**energy**	**pesticide**	**material**	**livestock**	**Crop**	**other**	**technology**
Roll	**B11**	**B12**	**B13**	**B14**	**B15**	**B16**	**B17**	**LL1**	**LCR1**	**LOF1**	**T1**
1960-1985	**0.1046**	0.0149	-0.0166	**-0.0279**	-0.0518	0.0058	-0.0289	-0.0739	-0.0255	0.0126	0.0003
1960-1986	**0.0640**	0.0339	-0.0076	**-0.0349**	-0.0337	0.0111	-0.0329	-0.0566	-0.0302	0.0295	-0.0007
1960-1987	0.0509	**0.0414**	-0.0030	**-0.0491**	-0.0268	0.0117	-0.0252	-0.0558	-0.0300	0.0297	-0.0015
1960-1988	**0.0513**	**0.0412**	-0.0046	**-0.0413**	-0.0259	0.0159	-0.0366	-0.0237	-0.0086	0.0215	-0.0025
1960-1989	0.0449	**0.0461**	-0.0071	**-0.0446**	-0.0264	0.0153	-0.0282	-0.0302	-0.0059	0.0313	-0.0027
1960-1990	0.0616	**0.0347**	-0.0150	**-0.0279**	-0.0302	**0.0156**	-0.0389	-0.0266	-0.0067	0.0145	-0.0022
1960-1991	**0.0616**	0.0347	-0.0150	**-0.0279**	-0.0302	**0.0156**	-0.0389	-0.0266	-0.0067	0.0145	-0.0022
1960-1992	**0.0616**	0.0347	-0.0150	**-0.0279**	-0.0302	**0.0156**	-0.0389	-0.0266	-0.0067	0.0145	-0.0022
1960-1993	**0.0611**	0.0351	-0.0161	**-0.0278**	-0.0296	**0.0146**	-0.0373	-0.0338	-0.0072	0.0104	-0.0023
1960-1994	**0.0595**	**0.0378**	-0.0167	**-0.0323**	-0.0282	0.0143	-0.0345	-0.0349	-0.0077	0.0098	-0.0026
1960-1995	**0.0582**	**0.0377**	-0.0182	**-0.0327**	-0.0279	0.0142	-0.0314	-0.0411	-0.0063	0.0071	-0.0027
1960-1996	**0.0582**	**0.0377**	-0.0182	**-0.0327**	-0.0279	0.0142	-0.0314	-0.0411	-0.0063	0.0071	-0.0027
1960-1997	**0.0627**	0.0433	-0.0299	-0.0339	-0.0264	0.0132	-0.0290	-0.0185	-0.0053	0.0145	-0.0030
1960-1998	**0.0709**	0.0413	**-0.0326**	-0.0295	-0.0306	0.0113	-0.0308	-0.0276	-0.0014	0.0094	-0.0033
1960-1999	**0.0749**	0.0401	**-0.0398**	**-0.0284**	**-0.0291**	0.0107	-0.0284	-0.0287	-0.0047	0.0082	-0.0030
1960-2000	**0.0752**	0.0378	**-0.0397**	**-0.0270**	**-0.0304**	0.0104	-0.0263	-0.0357	-0.0062	0.0040	-0.0028
1960-2001	**0.0755**	0.0373	**-0.0390**	**-0.0267**	**-0.0305**	**0.0100**	-0.0265	-0.0351	-0.0061	0.0035	-0.0028
1960-2002	**0.0720**	**0.0379**	**-0.0391**	**-0.0217**	**-0.0301**	0.0120	-0.0311	-0.0304	-0.0067	0.0048	-0.0027
1960-2003	**0.0735**	**0.0324**	**-0.0418**	**-0.0203**	**-0.0314**	**0.0137**	-0.0261	-0.0346	-0.0042	-0.0006	**-0.0023**
1960-2004	0.0772	**0.0243**	**-0.0458**	**-0.0158**	**-0.0317**	**0.0177**	-0.0259	-0.0356	-0.0034	-0.0088	**-0.0016**
Mean	0.0660	0.0362	-0.0230	-0.0305	-0.0304	0.0131	-0.0314	-0.0359	-0.0093	0.0119	-0.0023
St. Dev.	0.0128	0.0068	0.0139	0.0078	0.0054	0.0028	0.0047	0.0130	0.0085	0.0102	0.0008
Max	0.1046	0.0461	-0.0030	-0.0158	-0.0259	0.0177	-0.0252	-0.0185	-0.0014	0.0313	0.0003
Min	0.0449	0.0149	-0.0458	-0.0491	-0.0518	0.0058	-0.0389	-0.0739	-0.0302	-0.0088	-0.0033

Bold represents the significance level at 10%, 5% and 1%.

The time varying estimates for labor reveal a decreasing trend with each additional year from 1960-1985 to 1960-1989, and increase dramatically with the addition of the following year and continues an increasing trend. In 1960-1998, the estimates become significant and remain so with the addition of the subsequent six years.

The fourth input is fertilizer, which has an inverse relationship with the capital cost share. If fertilizer usage increases by 1 unit, the capital cost share will decrease by an average of 0.0305 with a standard deviation of 0.0078, a maximum of -0.0158, and a minimum of -0.0491. The time varying estimates for labor reveal that most estimates remain significant except for three periods. In 1960-1985, the estimate is not significant, but the time varying estimates indicate an increasing trend with each additional year until 1989, thereafter it decreases until the last period of study is added. If energy input increases by 1 unit, then capital cost share will decrease by an average of 0.0304 across all the rolling regression periods with a standard deviation of 0.0054, a maximum of -0.0259, and a minimum of -0.0518. The time varying estimates for energy reveal a decreasing trend with each additional year until 1960-1997, after which it increases and becomes significant with the addition of 1999 and continues increasing with each additional year.

The sixth input is pesticide, which has a positive relationship with the capital cost share. If pesticide usage increases by 1 unit, the farmers will increase spending on capital input by an average of 0.0131 with a standard deviation of 0.0028, a maximum of 0.0177, and a minimum of 0.0058. The time varying estimates for pesticide reveal an increasing trend from 1960-1985 with each additional year until 1960-1992 where it decreases with each additional year until 1985-2001. The time varying estimates following this trend became significant for four periods, beginning in 1960-1990 and ending with the addition of 1994. Furthermore, when 2002 is added to the rolling regression periods, the estimate increases and becomes significant for the two last periods.

The recovered input is material which has a negative relationship with the capital cost share and is not significant during any of the time varying estimates. Similarly, all the output variables are not significant in the capital input demand function. However, new technology will decrease the capital cost by an average of 0.0023. The time varying estimates for the last two periods become significant and decrease in those two periods.

4.3. Empirical results of North Dakota agriculture sector land input demand equation

Looking at time varying estimates of the land cost share, we see that land, labor, pesticide, and fertilizer have the most significant relationships. Table 4.3 contains parameter coefficients for land cost share from the model that includes the net crop insurance variable. The mean estimate across all rolling regression periods indicates that when land increases by 1 unit, the land cost share will increase by an average of 0.0734 for all the rolling regression periods with a standard deviation of 0.0071, a maximum of 0.0862, and a minimum of 0.0625. The time varying parameter estimates for land reveal fluctuations with each additional year. Results from several rolling regression periods become significant at 10% or less.

Table 4.3. Parameter coefficients for North Dakota agriculture sector land demand equation.

	capital	land	labor	fertilizer	energy	pesticide	material	livestock	crop	other	technology
Roll	**B12**	**B22**	**B23**	**B24**	**B25**	**B26**	**B27**	**LL2**	**LCR2**	**LOF2**	**T2**
1960-1985	-	**0.0862**	-0.0373	**-0.0186**	0.0109	-0.0070	-0.0490	**0.0771**	-0.0275	**0.0548**	0.0005
1960-1986	-	**0.0777**	**-0.0433**	**-0.0154**	0.0022	-0.0096	-0.0454	**0.0702**	-0.0257	**0.0431**	0.0008
1960-1987	-	**0.0759**	**-0.0482**	-0.0064	-0.0007	-0.0099	-0.0521	**0.0802**	-0.0197	**0.0364**	0.0004
1960-1988	-	**0.0770**	**-0.0466**	**-0.0121**	-0.0016	**-0.0131**	-0.0447	**0.0863**	-0.0110	**0.0325**	-0.0002
1960-1989	-	0.0733	**-0.0462**	-0.0103	-0.0016	**-0.0127**	-0.0486	**0.0872**	-0.0117	**0.0271**	-0.0001
1960-1990	-	**0.0796**	**-0.0399**	**-0.0195**	-0.0006	**-0.0131**	-0.0411	**0.0850**	-0.0135	**0.0335**	-0.0003
1960-1991	-	**0.0796**	**-0.0399**	**-0.0195**	-0.0006	**-0.0131**	-0.0411	**0.0850**	-0.0135	**0.0335**	-0.0003
1960-1992	-	**0.0796**	**-0.0399**	**-0.0195**	-0.0006	**-0.0131**	-0.0411	**0.0850**	-0.0135	**0.0335**	-0.0003
1960-1993	-	0.0788	**-0.0426**	**-0.0195**	-0.0012	**-0.0122**	-0.0384	**0.0761**	-0.0136	**0.0272**	-0.0004
1960-1994	-	**0.0782**	**-0.0430**	**-0.0166**	-0.0012	**-0.0120**	-0.0431	**0.0780**	-0.0134	**0.0269**	-0.0004
1960-1995	-	**0.0776**	**-0.0445**	**-0.0160**	-0.0014	**-0.0117**	-0.0417	**0.0741**	-0.0123	**0.0246**	-0.0004
1960-1996	-	**0.0776**	**-0.0445**	**-0.0160**	-0.0014	**-0.0117**	-0.0417	**0.0741**	-0.0123	**0.0246**	-0.0004
1960-1997	-	**0.0639**	**-0.0415**	**-0.0122**	-0.0013	**-0.0099**	-0.0424	**0.0561**	-0.0122	0.0092	0.0005
1960-1998	-	**0.0650**	**-0.0417**	**-0.0135**	0.0007	**-0.0094**	-0.0422	**0.0513**	-0.0117	0.0086	0.0004
1960-1999	-	**0.0625**	**-0.0422**	-0.0113	-0.0004	**-0.0088**	-0.0399	**0.0505**	-0.0103	0.0061	0.0006
1960-2000	-	**0.0634**	**-0.0410**	-0.0123	-0.0005	**-0.0087**	-0.0387	**0.0458**	-0.0121	0.0055	0.0006
1960-2001	-	**0.0640**	**-0.0407**	-0.0126	-0.0001	**-0.0091**	-0.0387	0.0459	-0.0122	0.0062	0.0005
1960-2002	-	**0.0652**	**-0.0395**	-0.0108	-0.0009	**-0.0121**	-0.0398	**0.0468**	-0.0120	0.0077	0.0003
1960-2003	-	**0.0683**	**-0.0352**	-0.0081	0.0001	**-0.0147**	-0.0428	**0.0484**	-0.0133	0.0108	0.0001
1960-2004	-	**0.0737**	**-0.0276**	-0.0100	-0.0007	**-0.0181**	-0.0415	0.0442	-0.0147	**0.0145**	-0.0004
Mean	-	0.0734	-0.0413	-0.0140	-0.0001	-0.0115	-0.0427	0.0674	-0.0143	0.0233	0.0001
St. Dev.	-	0.0071	0.0045	0.0040	0.0027	0.0025	0.0036	0.0165	0.0046	0.0141	0.0004
Max	-	0.0862	-0.0276	-0.0064	0.0109	-0.0070	-0.0384	0.0872	-0.0103	0.0548	0.0008
Min	-	0.0625	-0.0482	-0.0195	-0.0016	-0.0181	-0.0521	0.0442	-0.0275	0.0055	-0.0004

Bold represents the significance level at 10%, 5% and 1%.

During the first period, 1960-1985, the estimate is positively significant and suggests that when capital input is increased by 1 unit, the land cost share will increase by 0.1049. When 1986 is added, the resulting estimate is also significant but decreases to 0.0339 and continues in that trend until 1996 is added to the roll. Thereafter, it follows an increasing trend.

The mean estimate across all rolling regression periods for labor indicates that if labor increases by 1 unit, then the land cost share will increase by an average of 0.0413 for all the rolling regression periods with a standard deviation of 0.0045, a maximum of -0.0276 and a minimum of -0.0482. Time varying estimates for labor reveal that all results are significant at a 10% level or less across the periods except in 1960-1985, and they follow decreasing trend. The fourth input is fertilizer, which has an inverse relationship with the land cost share. If fertilizer usage increases by 1 unit, the land cost share will decrease by an average of 0.0140 with a standard deviation of 0.0040, a maximum of -0.0064, and a minimum of -0.0195. The time varying estimates for fertilizer reveal that most estimates remain significant at the beginning periods and become insignificant in 1960-1999.

If energy input increases by 1 unit, then the land cost share will decrease by an average of 0.0001 across all the rolling regression periods with a standard deviation of 0.0027, a maximum of 0.0109, and a minimum of -0.0016. The time varying estimates for energy reveal a decreasing trend with each additional year until 1960-1997, after which it increases but is not significant in any period.

The sixth input is pesticide, which has a negative relationship with land cost share. If pesticide usage increases by 1 unit, the farmers will decrease spending on land input by an average of 0.0115 with a standard deviation of 0.0025, a maximum of -0.0070, and a minimum of -0.0181. The time varying estimates for pesticide reveal an increasing trend from 1960-1985 with each additional year until 1960-1987 where it increases dramatically with the addition of 1988 and also becomes significant for the remainder of periods.

The recovered input is material, which has a negative relationship with the capital cost share and is not significant during any of the time-varying estimates. Similarly, all the output variables for crops and technology are not significant in the land input demand function. However, livestock and other farm-related output will increase the capital cost by an average of 0.0674 and 0.0233 respectively. Time-varying estimates for livestock output are significant in most periods while other farm-related output are only significant in 1960-1985 to 1960-1996 and then again in the last period, 1960-2004.

4.4. Empirical results of North Dakota agriculture sector labor input demand equation

Table 4.4 presents parameter coefficients for the labor cost share from the model that includes the net crop insurance variable. Because the symmetry condition is imposed when estimating cost shares, the first two parameter estimates for capital and land input in labor cost share will be equal to labor input in the capital cost share and the land cost share, thus have the same effect on the labor cost share.

Table 4.4. Parameter coefficients for North Dakota agriculture sector labor demand equation.

	capital	land	labor	fertilizer	energy	pesticide	material	livestock	crop	other	technology
Roll	**B13**	**B23**	**B33**	**B34**	**B35**	**B36**	**B37**	**LL3**	**LCR3**	**LOF3**	**T3**
1960-1985	-	-	**0.1484**	0.0044	0.0040	-0.0058	-0.0971	-0.0627	0.0069	0.0287	-0.0018
1960-1986	-	-	**0.1452**	0.0068	-0.0002	-0.0072	-0.0937	-0.0678	0.0081	0.0208	-0.0015
1960-1987	-	-	**0.1379**	0.0099	-0.0028	-0.0078	-0.0860	-0.0690	0.0127	0.0102	-0.0014
1960-1988	-	-	**0.1390**	0.0068	-0.0032	-0.0086	-0.0828	-0.0736	0.0097	0.0129	-0.0014
1960-1989	-	-	0.1408	0.0088	-0.0024	-0.0088	-0.0852	-0.0701	0.0088	0.0131	-0.0014
1960-1990	-	-	**0.1422**	-0.0028	-0.0024	-0.0096	-0.0725	-0.0732	0.0073	0.0166	-0.0018
1960-1991	-	-	**0.1422**	-0.0028	-0.0024	-0.0096	-0.0725	-0.0732	0.0073	0.0166	-0.0018
1960-1992	-	-	**0.1422**	-0.0028	-0.0024	-0.0096	-0.0725	-0.0732	0.0073	0.0166	-0.0018
1960-1993	-	-	**0.1388**	-0.0046	-0.0040	-0.0096	-0.0619	**-0.0866**	0.0075	0.0075	-0.0016
1960-1994	-	-	**0.1324**	-0.0041	-0.0047	-0.0099	-0.0541	**-0.0879**	0.0089	0.0030	-0.0017
1960-1995	-	-	**0.1311**	-0.0043	-0.0055	-0.0100	-0.0486	**-0.0962**	0.0105	-0.0015	-0.0017
1960-1996	-	-	**0.1311**	-0.0043	-0.0055	-0.0100	-0.0486	**-0.0962**	0.0105	-0.0015	-0.0017
1960-1997	-	-	**0.1385**	-0.0046	-0.0079	-0.0096	-0.0449	**-0.1041**	0.0097	0.0004	-0.0018
1960-1998	-	-	**0.1383**	-0.0048	-0.0068	-0.0083	-0.0441	**-0.1020**	0.0089	0.0009	-0.0016
1960-1999	-	-	**0.1465**	-0.0073	-0.0083	-0.0075	-0.0414	**-0.1032**	0.0132	0.0002	-0.0018
1960-2000	-	-	**0.1473**	-0.0080	-0.0082	-0.0078	-0.0426	**-0.1018**	0.0132	0.0017	-0.0019
1960-2001	-	-	**0.1435**	-0.0086	-0.0091	-0.0067	-0.0395	**-0.1067**	0.0134	0.0015	-0.0019
1960-2002	-	-	**0.1424**	-0.0096	-0.0088	-0.0065	-0.0388	**-0.1088**	0.0146	0.0028	-0.0020
1960-2003	-	-	**0.1466**	-0.0084	-0.0082	**-0.0081**	-0.0450	**-0.1056**	0.0117	0.0064	**-0.0024**
1960-2004	-	-	**0.1518**	-0.0108	**-0.0080**	**-0.0115**	-0.0482	**-0.1044**	0.0107	0.0139	**-0.0031**
Mean	-	-	0.1413	-0.0025	-0.0048	-0.0086	-0.0610	-0.0883	0.0100	0.0085	-0.0018
St. Dev.	-	-	0.0056	0.0064	0.0034	0.0014	0.0198	0.0162	0.0024	0.0085	0.0004
Max	-	-	0.1518	0.0099	0.0040	-0.0058	-0.0388	-0.0627	0.0146	0.0287	-0.0014
Min	-	-	0.1311	-0.0108	-0.0091	-0.0115	-0.0971	-0.1088	0.0069	-0.0015	-0.0031

Bold represents the significance level at 10%, 5% and 1%.

The average parameter estimate across all rolling regression periods suggests that when labor increases by 1 unit, then the labor cost share will increase by an average of 0.1413 with a standard deviation of 0.0056, a maximum of 0.1518, and a minimum of 0.1311. The time varying estimates for labor reveal continuous fluctuations with each additional year with all estimates being significant at 10% or less except when 1989 is included.

From the parameter coefficients for the labor cost share from the model that includes the net crop insurance variable, we can see that when the fertilizer input increases by 1 unit, the labor cost share will decrease by an average of 0.0025 for all the rolling regression periods with a standard deviation of 0.0064, a maximum of 0.0099, and a minimum of -0.0108. The time-varying estimates for fertilizer reveal constant fluctuation with each additional year with only the result of 1960-2002 being significant.

If energy increases by 1 unit, then the labor cost share will decrease by an average of 0.0048 for all the rolling regression periods with a standard deviation of 0.0034, a maximum of 0.0040, and a minimum of -0.0091. The time varying estimates for energy reveal no clear trend throughout the additional years, but results for the last period become significant.

The sixth input is pesticide, which has a negative relationship with the labor cost share. If pesticide usage increases by 1 unit, the farmers will decrease labor usage by an average of 0.0086 with a standard deviation of 0.0014, a maximum of -0.0058, and a minimum of -0.0115. The time varying estimates for pesticide reveal an increasing trend at a decreasing rate from 1960-1985 with each additional year until 1960-1996, where it decreases at a decreasing rate with each additional year until 1985-2003, after which it increases with the addition of the last year where it becomes significant as well.

The recovered input is material which has a negative relationship with the labor cost share. If material usage increases by 1 unit, the farmers will decrease labor usage by an average of 0.0610 with a standard deviation of 0.0198, a maximum of -0.0388, and a minimum of -0.0971. The time varying estimates for material reveal a constant decrease with the addition of each year in the rolling regression periods.

Livestock output has a mean estimate for all rolling regression periods of -0.0883. This means that if livestock output increases by 1 unit, the labor cost share will decrease by 0.0883. Time varying estimates of livestock become significant from the period 1960-1993, while crop output and other farm related output are not significant.

4.5. Empirical results of North Dakota agriculture sector fertilizer input demand equation

Table 4.5 shows the parameter coefficients for the fertilizer cost share from the model that includes the net crop insurance variable. Because the symmetry condition is imposed when estimating cost shares the first three parameter estimates for capital, land and labor input in the fertilizer cost share will be equal to fertilizer input in the capital cost share, the land cost share, and the labor cost share; thus the three components have the same effect on the fertilizer cost share.

The mean parameter estimate across all rolling regression periods for the fertilizer cost share indicate that when fertilizer input increases by 1 unit, the fertilizer cost share will increase by an average of 0.0185 for all the rolling regression periods with a standard

Table 4.5. Parameter coefficients for North Dakota agriculture sector fertilizer demand equation.

	capital	**land**	**labor**	**fertilizer**	**energy**	**pesticide**	**material**	**livestock**	**crop**	**other**	**technology**
Roll	**B14**	**B24**	**B34**	**B44**	**B45**	**B46**	**B47**	**LL4**	**LCR4**	**LOF4**	**T4**
1960-1985	-	-	-	**0.0160**	**-0.0145**	-0.0031	0.0437	**-0.0580**	0.0005	**-0.0156**	**0.0033**
1960-1986	-	-	-	0.0152	**-0.0112**	-0.0020	0.0414	**-0.0549**	-0.0001	-0.0107	**0.0031**
1960-1987	-	-	-	0.0066	-0.0081	-0.0019	0.0490	**-0.0531**	-0.0005	-0.0038	**0.0026**
1960-1988	-	-	-	0.0095	-0.0074	-0.0018	0.0463	**-0.0418**	0.0109	-0.0165	**0.0023**
1960-1989	-	-	-	0.0134	-0.0053	-0.0010	0.0389	**-0.0346**	0.0098	-0.0138	**0.0022**
1960-1990	-	-	-	0.0164	-0.0089	-0.0002	0.0429	**-0.0379**	0.0082	**-0.0335**	**0.0026**
1960-1991	-	-	-	0.0164	-0.0089	-0.0002	0.0429	**-0.0379**	0.0082	**-0.0335**	**0.0026**
1960-1992	-	-	-	0.0164	-0.0089	-0.0002	0.0429	**-0.0379**	0.0082	**-0.0335**	**0.0026**
1960-1993	-	-	-	0.0176	**-0.0102**	0.0028	0.0416	**-0.0360**	0.0088	**-0.0333**	**0.0026**
1960-1994	-	-	-	0.0152	-0.0096	0.0029	0.0444	**-0.0357**	0.0084	**-0.0308**	**0.0025**
1960-1995	-	-	-	0.0201	-0.0079	0.0047	0.0361	-0.0256	0.0069	**-0.0267**	**0.0026**
1960-1996	-	-	-	0.0201	-0.0079	0.0047	0.0361	-0.0256	0.0069	**-0.0267**	**0.0026**
1960-1997	-	-	-	**0.0188**	-0.0081	0.0043	0.0357	-0.0211	0.0068	**-0.0225**	**0.0023**
1960-1998	-	-	-	**0.0200**	**-0.0107**	0.0021	0.0364	-0.0201	0.0073	**-0.0233**	**0.0023**
1960-1999	-	-	-	**0.0175**	**-0.0094**	0.0016	0.0372	-0.0208	0.0045	**-0.0215**	**0.0023**
1960-2000	-	-	-	**0.0183**	**-0.0094**	0.0016	0.0368	-0.0193	0.0051	**-0.0219**	**0.0023**
1960-2001	-	-	-	**0.0202**	**-0.0084**	0.0000	0.0361	-0.0197	0.0050	**-0.0218**	**0.0023**
1960-2002	-	-	-	**0.0300**	**-0.0075**	-0.0026	0.0223	-0.0130	0.0066	-0.0176	**0.0020**
1960-2003	-	-	-	**0.0310**	**-0.0068**	-0.0037	0.0162	-0.0090	0.0052	-0.0145	**0.0017**
1960-2004	-	-	-	**0.0319**	-0.0061	-0.0024	0.0131	-0.0077	0.0056	**-0.0158**	**0.0018**
Mean	-	-	-	0.0185	-0.0088	0.0003	0.037	-0.0305	0.0061	-0.0219	0.0024
St. Dev.	-	-	-	0.0064	0.002	0.0027	0.0095	0.0147	0.0031	0.0085	0.0004
Max	-	-	-	0.0319	-0.0053	0.0047	0.049	-0.0077	0.0109	-0.0038	0.0033
Min	-	-	-	0.0066	-0.01455	-0.0037	0.0131	-0.058	-0.0005	-0.0335	0.0017

Bold estimates represents the significance level at 10%, 5% and 1%.

deviation of 0.0064, a maximum of 0.0319, and a minimum of 0.0066. The time varying estimates for fertilizer reveal no clear trend with each additional year but become significant when 1997 is included and increase dramatically in 1960-1989 and then again in 1960-2002.

If energy increases by 1 unit, then fertilizer cost share will decrease by an average of 0.0088 for all the rolling regression periods with a standard deviation of 0.0020, a maximum of -0.0053, and a minimum of -0.0145. The time varying estimates for energy show a decreasing trend throughout the additional years, but when 1998 is added to 1960-1997, there is a sharp increase which is significant at 10% or less.

The sixth input is pesticide, which has a positive relationship with the fertilizer cost share but is not significant in any of the rolling regression periods. The recovered input is material has a positive relationship with the fertilizer cost share. If material usage increases by 1 unit, the farmers will increase fertilizer usage by an average of 0.0370 with a standard deviation of 0.0095, a maximum of 0.0490, and a minimum of 0.0131. The time varying estimates for material reveal an initial increase followed by a decrease with the addition of each year in the rolling regression periods.

Livestock output has a mean estimate for all rolling regression periods of -0.0305 and is significant for the first half of the study period until 1994 is included. This means that if livestock output increases by 1 unit, the fertilizer cost share will decrease by 0.0305, while a 1-unit change in crop and other farm-related output will lead to an increase in the fertilizer cost share of 0.0061 and a decrease of- 0.0219 respectively. New technology has a significant impact on the fertilizer cost share as all estimates are statistically significant at

10% or less. The mean estimate for all the rolling regression periods indicates that an increase in new technology will increase fertilizer cost by an average of 0.0024.

4.6. Empirical results of North Dakota agriculture sector energy input demand equation

Table 4.6 shows parameter coefficients for the energy cost share from the model that includes the net crop insurance variable. Again, due to the symmetry condition, the first four estimated parameters are recurring. When the energy input increases by 1 unit, then the energy cost share will increase by an average of 0.0537 for all the rolling regression periods with a standard deviation of 0.0021, a maximum of -0.0593, and a minimum of 0.0497. The sixth input is pesticide, which has a positive relationship with the energy cost share but is not significant in any of the rolling regression periods. The mean estimate across all rolls that was recovered for material has a negative relationship with the energy cost share. If material usage increases by 1 unit, the farmers will increase energy usage by an average of 0.0102 with a standard deviation of 0.0017, a maximum of -0.0082, and a minimum of -0.0153. The time varying estimates for material experience constant fluctuation with the addition of each year in the rolling regression periods.

Livestock, crop, other farm related output and new technology do not have a significant relationship with the energy cost.

Table 4.6. Parameter coefficients for North Dakota agriculture sector energy demand equation.

	capital	land	labor	fertilizer	energy	pesticide	material	livestock	crop	other	technology
Roll	**B15**	**B25**	**B35**	**B45**	**B55**	**B56**	**B57**	**LL5**	**LCR5**	**LOF5**	**T5**
1960-1985	-	-	-	-	**0.0593**	0.0016	-0.0094	-0.0138	-0.0127	0.0238	0.0003
1960-1986	-	-	-	-	**0.0521**	-0.0007	-0.0084	-0.0207	-0.0109	0.0145	0.0007
1960-1987	-	-	-	-	**0.0497**	-0.0013	-0.0101	-0.0196	-0.0088	0.0095	0.0007
1960-1988	-	-	-	-	**0.0507**	-0.0009	-0.0117	-0.0088	-0.0001	0.0044	0.0002
1960-1989	-	-	-	-	**0.0519**	-0.0009	-0.0153	-0.0064	-0.0005	0.0048	0.0003
1960-1990	-	-	-	-	**0.0539**	0.0001	-0.0119	-0.0074	-0.0029	0.0026	0.0003
1960-1991	-	-	-	-	**0.0539**	0.0001	-0.0119	-0.0074	-0.0029	0.0026	0.0003
1960-1992	-	-	-	-	**0.0539**	0.0001	-0.0119	-0.0074	-0.0029	0.0026	0.0003
1960-1993	-	-	-	-	**0.0529**	0.0003	-0.0082	-0.0138	-0.0028	-0.0016	0.0002
1960-1994	-	-	-	-	**0.0524**	0.0000	-0.0086	-0.0135	-0.0025	-0.0022	0.0002
1960-1995	-	-	-	-	**0.0526**	0.0003	-0.0102	-0.0123	-0.0024	-0.0021	0.0002
1960-1996	-	-	-	-	**0.0526**	0.0003	-0.0102	-0.0123	-0.0024	-0.0021	0.0002
1960-1997	-	-	-	-	**0.0534**	-0.0003	-0.0094	-0.0085	-0.0022	-0.0017	0.0002
1960-1998	-	-	-	-	**0.0555**	0.0007	-0.0088	-0.0083	-0.0031	0.0001	0.0001
1960-1999	-	-	-	-	**0.0550**	0.0008	-0.0088	-0.0082	-0.003	-0.0008	0.0002
1960-2000	-	-	-	-	**0.0558**	0.0018	-0.0091	-0.0086	-0.0034	-0.0011	0.0003
1960-2001	-	-	-	-	**0.0553**	0.0028	-0.0098	-0.0084	-0.0032	-0.0006	0.0002
1960-2002	-	-	-	-	**0.0548**	0.0013	-0.0089	-0.0083	-0.0032	-0.0013	0.0003
1960-2003	-	-	-	-	**0.0546**	0.0017	-0.0101	-0.0075	-0.0034	-0.0003	0.0002
1960-2004	-	-	-	-	**0.0544**	0.0025	-0.0104	-0.0082	-0.0034	-0.0014	0.0003
Mean	-	-	-	-	0.0537	0.0005	-0.0102	-0.0105	-0.0038	0.0025	0.0003
St. Dev.	-	-	-	-	0.0021	0.0011	0.0017	0.0041	0.0032	0.0066	0.0001
Max	-	-	-	-	0.0593	0.0028	-0.0082	-0.0064	-0.0001	0.0238	0.0007
Min	-	-	-	-	0.0497	-0.0013	-0.0153	-0.0207	-0.0127	-0.0022	0.0001

Bold represents the significance level at 10%, 5% and 1%.

4.7. Empirical results of North Dakota agriculture sector pesticide input demand equation

Table 4.7 shows the mean estimate across all rolling regression periods for the pesticide cost share from the model that includes the net crop insurance variable. Again, due to the symmetry condition, the first five estimated parameter are recurring. As expected, the mean estimate across all rolling regression periods for pesticide input has a positive relationship with the pesticide cost share but is not significant.

The mean estimate across all rolls that were recovered for material input has a positive relationship with the pesticide cost share. If material usage increases by 1 unit, the farmers will increase pesticide usage by an average of 0.0033 with a standard deviation of 0.0041, with a maximum of 0.0088 and a minimum of -0.0022.

Livestock output has a mean estimate of -0.0122, this means that, if livestock output increases by 1 unit, energy cost share will decrease by 0.0122. The only estimate that is statistically significant corresponds to 1960-1987. On the other hand, several time-varying estimates from crop output are significant, starting in 1960-1989 and ending in 1960-1994.

The mean estimate across the rolling regression periods suggests that a 1 unit change in crop output will lead to an increase in the pesticide cost share of 0.007. Time-varying estimates for other farm-related outputs are statistically significant, beginning from 1960-1990 and ending in 1960-1996. The mean estimate for the 20 regressions indicates that, when other farm-related outputs increase by 1 unit, the farmers' expenditure on pesticide will decrease by 0.0112.

Table 4.7. Parameter coefficients for North Dakota agriculture sector pesticide cost share.

	capital	land	labor	fertilizer	energy	pesticide	material	livestock	crop	other	technology
Roll	**B16**	**B26**	**B36**	**B46**	**B56**	**B66**	**B67**	**LL6**	**LCR6**	**LOF6**	**T6**
1960-1985	-	-	-	-	-	0.0029	0.0056	-0.0205	0.0033	-0.0071	**0.0018**
1960-1986	-	-	-	-	-	0.0022	0.0061	-0.0225	0.0040	-0.0097	**0.0019**
1960-1987	-	-	-	-	-	0.0027	0.0066	**-0.0233**	0.0039	-0.0098	**0.0020**
1960-1988	-	-	-	-	-	0.0012	0.0073	-0.0207	0.0083	-0.0162	**0.0019**
1960-1989	-	-	-	-	-	0.0010	0.0070	-0.0201	**0.0085**	-0.0153	**0.0019**
1960-1990	-	-	-	-	-	0.0013	0.0060	-0.0195	**0.0080**	**-0.0163**	**0.0019**
1960-1991	-	-	-	-	-	0.0013	0.0060	-0.0195	**0.0080**	**-0.0163**	**0.0019**
1960-1992	-	-	-	-	-	0.0013	0.0060	-0.0195	**0.0080**	**-0.0163**	**0.0019**
1960-1993	-	-	-	-	-	0.0034	0.0008	-0.0126	**0.0083**	**-0.0124**	**0.0019**
1960-1994	-	-	-	-	-	0.0035	0.0012	-0.0124	**0.0084**	**-0.0122**	**0.0019**
1960-1995	-	-	-	-	-	0.0044	-0.0020	-0.0085	0.0079	**-0.0106**	**0.0020**
1960-1996	-	-	-	-	-	0.0044	-0.0020	-0.0085	0.0079	**-0.0106**	**0.0020**
1960-1997	-	-	-	-	-	0.0045	-0.0022	-0.0074	0.0079	-0.0087	**0.0018**
1960-1998	-	-	-	-	-	0.0040	-0.0004	-0.0041	0.0065	-0.0070	**0.0019**
1960-1999	-	-	-	-	-	0.0042	-0.0011	-0.0038	0.0066	-0.0064	**0.0019**
1960-2000	-	-	-	-	-	0.0049	-0.0021	-0.0011	0.0072	-0.0056	**0.0019**
1960-2001	-	-	-	-	-	0.0040	-0.0010	-0.0016	0.0069	-0.0062	**0.0019**
1960-2002	-	-	-	-	-	0.0023	0.0055	-0.0049	0.0069	-0.0098	**0.0021**
1960-2003	-	-	-	-	-	0.0024	0.0087	-0.0072	0.0076	-0.0125	**0.0023**
1960-2004	-	-	-	-	-	0.0030	0.0088	-0.0055	0.0082	-0.0151	**0.0026**
Mean	-	-	-	-	-	0.0029	0.0033	-0.0122	0.0071	-0.0112	0.0020
St. Dev.	-	-	-	-	-	0.0013	0.0041	0.0077	0.0016	0.0037	0.0002
Max	-	-	-	-	-	0.0049	0.0088	-0.0011	0.0085	-0.0056	0.0026
Min	-	-	-	-	-	0.0010	-0.0022	-0.0233	0.0033	-0.0163	0.0018

Bold represents the significance level at 10%, 5% and 1%.

New technology has a very significant relationship with the pesticide cost share since all time-varying estimates are statistically significant, and the mean across all regressions indicates that an increase in technology will increase pesticide use by an average of 0.0020.

4.8. Allen elasticity of substitution

Elasticities play a significant role in characterizing farmers' economic behavior. Estimates from the Allen elasticity of substitution (AES) for the model that includes net crop insurance reveals that the mean own elasticity of substitution across all the rolling regression periods for all the inputs does have expected signs, as presented in Table 4.8. The mean own AES for capital across all the rolling regression periods suggests that a 1% increase in the price of capital will lead to a decrease in capital use by 2.3433% with a standard deviation of 0.3046, a maximum of -1.3850, and a minimum of -2.8305. The time-varying estimates all conform to curvature conditions. The mean Allen own elasticity of substitution for land across all the rolling regression periods indicates that a 1% increase in price of land will lead to a decrease in land use by 1.7867% with a standard deviation of 0.7929, a maximum of 0.1267, and a minimum of -2.8852.

The sign of the estimates for each rolling regression period does have an expected sign, except for the first period, 1960-1985. The mean own elasticity of substitution for labor across all the rolling regression periods suggests that a 1% increase in the price of labor will lead to a decrease in labor use by 0.7365 % with a standard deviation of 0.0857, a maximum of -0.5865, and a minimum of -0.8977.

Table 4.8. Own Allen elasticity of substitution for model with NCI.

	Cap.	Land	Labor	Fert.	Energy	Pest.
Roll	**AES11**	**AES22**	**AES33**	**AES44**	**AES55**	**AES66**
1960-1985	-1.3850	0.1267	-0.6256	-13.8116	0.2851	-47.1027
1960-1986	-2.3905	-1.0378	-0.6720	-14.2059	-1.5871	-47.3992
1960-1987	-2.7085	-1.3491	-0.7901	-18.9858	-2.1912	-44.2066
1960-1988	-2.6908	-1.3266	-0.7699	-17.1437	-1.9205	-47.0003
1960-1989	-2.8305	-1.7599	-0.7332	-14.9073	-1.5919	-45.4951
1960-1990	-2.4269	-1.197	-0.7117	-13.2551	-1.0449	-43.5555
1960-1991	-2.4231	-1.2459	-0.7071	-13.1707	-1.0341	-41.9322
1960-1992	-2.4235	-1.2777	-0.7065	-13.1289	-0.9963	-40.4243
1960-1993	-2.4376	-1.3729	-0.7648	-12.4882	-1.2006	-35.3758
1960-1994	-2.4832	-1.4493	-0.8741	-13.6232	-1.2530	-34.4338
1960-1995	-2.5225	-1.5180	-0.8977	-11.2311	-1.1189	-32.0243
1960-1996	-2.5291	-1.5401	-0.8977	-11.1750	-1.0691	-31.1991
1960-1997	-2.4308	-2.7495	-0.7795	-11.6983	-0.7582	-30.5380
1960-1998	-2.2327	-2.6580	-0.7859	-11.1473	-0.0423	-30.5216
1960-1999	-2.1411	-2.8852	-0.6612	-12.1865	-0.0527	-29.5536
1960-2000	-2.1388	-2.8142	-0.6509	-11.8115	0.2388	-27.9526
1960-2001	-2.1363	-2.7554	-0.7135	-10.9629	0.1376	-28.4036
1960-2002	-2.2340	-2.6545	-0.7335	-6.9550	0.0706	-29.3799
1960-2003	-2.1973	-2.3777	-0.6684	-6.5631	0.0206	-28.3335
1960-2004	-2.1049	-1.8928	-0.5865	-6.2882	-0.0800	-26.6484
Mean	-2.3433	-1.7867	-0.7365	-12.237	-0.7594	-36.074
St. Dev.	0.3046	0.7929	0.0857	3.1515	0.7718	7.6057
Max	-1.3850	0.1267	-0.5865	-6.2882	0.2851	-26.6484
Min	-2.8305	-2.8852	-0.8977	-18.9858	-2.1912	-47.3992

The time-varying estimates show elasticities increasing steadily until 1998 is added to the rolling regression periods, 1960-1997, after which they follows a decreasing trend. The mean own elasticity of substitution for fertilizer across all the rolling regression periods indicates that a 1% increase in the price of fertilizer will decrease fertilizer use by 12.2370% with a standard deviation of 3.1515, a maximum of -6.2882, and a minimum of -

18.9858. Estimated elasticity for fertilizer had an initial increasing trend with the addition of the first three years after which it declined slowly. The mean own elasticity of substitution for energy across all the rolling regression periods indicates that a 1% increase in the price of energy will decrease energy use by 0.7594% with a standard deviation of 0.7718,a maximum of 0.285,1 and a minimum of -2.1912. Curvature conditions were violated in the first period, 1960-1985, and then again in 1960-2000 and for the three subsequent years. The mean own elasticity of substitution for pesticide across all the rolling regression periods indicates that when the price of pesticide increases by 1%, farmers will decrease pesticide use by 36.0740% with a standard deviation of 7.6057, a maximum of -26.6484, and a minimum of -47.3992. The time-varying estimates show a decreasing trend.

Looking at the cross AES in Table 4.9, we can gather the economic relationship between inputs. Capital and land; capital and labor; capital and pesticide; land and energy; labor and fertilizer; labor and energy; fertilizer and pesticide and energy and pesticide cross AES has a positive relationship, which indicates that they are Allen substitutes. The mean AES across all the rolling regression periods for capital and land indicates that a 1% increase in the price of capital will lead to an increase in land use by 2.7365% with a standard deviation of 0.3145 a maximum of 3.2202 and a minimum of 1.7932.

Capital and labor mean AES across all the rolling regression periods indicates that a 1% increase in the price of capital will lead to an increase in labor by 0.5366% with a standard deviation of 0.2798, a maximum of 0.9399, and a minimum of 0.0743. The mean AES across all the rolling regression periods for capital and pesticide indicates that a 1%

Table 4.9. Cross AES for model with NCI for North Dakota agriculture sector.

	Cap/Land	**Labor**	**Fert.**	**Energy**	**Pest.**	**Land/Labor**	**Fert.**	**Energy**	**Pest.**
Roll	**AES12**	**AES13**	**AES14**	**AES15**	**AES16**	**AES23**	**AES24**	**AES25**	**AES26**
1960-1985	1.7932	0.6683	-2.3769	-3.1809	2.6614	-0.5920	-3.8025	2.8744	-3.2981
1960-1986	2.7443	0.8483	-3.1456	-1.7006	4.0453	-0.8034	-2.7893	1.3626	-4.4554
1960-1987	3.0817	0.9399	-4.7698	-1.1417	4.0451	-0.9693	-0.5235	0.8780	-4.2673
1960-1988	3.0303	0.9083	-3.7644	-1.0731	5.0111	-0.8841	-1.8243	0.7439	-5.6612
1960-1989	3.2202	0.8576	-4.0268	-1.1031	4.6835	-0.8571	-1.3079	0.7412	-5.0597
1960-1990	2.6597	0.6987	-2.1270	-1.4055	4.6340	-0.5868	-3.3224	0.9001	-5.0665
1960-1991	2.6411	0.6973	-2.0757	-1.4030	4.4859	-0.5826	-3.2202	0.9010	-4.7765
1960-1992	2.6311	0.6969	-2.0546	-1.4109	4.3563	-0.5740	-3.1642	0.9013	-4.5258
1960-1993	2.6412	0.6743	-2.0221	-1.3831	4.0518	-0.6670	-3.1043	0.8131	-3.9355
1960-1994	2.7677	0.6634	-2.4818	-1.2884	3.9238	-0.6704	-2.4444	0.8093	-3.7167
1960-1995	2.7640	0.6323	-2.4852	-1.2862	3.8279	-0.7180	-2.2645	0.7812	-3.4391
1960-1996	2.7607	0.6311	-2.4326	-1.3027	3.7471	-0.7095	-2.1888	0.7814	-3.2769
1960-1997	3.0331	0.3966	-2.5341	-1.2102	3.5038	-0.5778	-1.3942	0.7975	-2.5282
1960-1998	2.9448	0.3433	-2.0633	-1.5965	3.0969	-0.5725	-1.6328	1.1095	-2.2531
1960-1999	2.8995	0.2021	-1.9609	-1.5068	2.9434	-0.5698	-1.1839	0.9417	-1.9706
1960-2000	2.7905	0.2047	-1.8029	-1.6414	2.8389	-0.5098	-1.3454	0.9193	-1.8423
1960-2001	2.7751	0.2181	-1.7720	-1.6762	2.7373	-0.4901	-1.3948	0.9773	-1.9001
1960-2002	2.8150	0.2172	-1.2479	-1.6575	3.0310	-0.4414	-1.0499	0.8541	-2.7043
1960-2003	2.5592	0.1592	-1.0966	-1.7862	3.2359	-0.2865	-0.5219	1.0218	-3.3659
1960-2004	2.1779	0.0743	-0.6124	-1.8199	3.7776	-0.0165	-0.8565	0.8913	-4.1962
Mean	2.7365	0.5366	-2.3426	-1.5287	3.7319	-0.6039	-1.9668	1.000	-3.6120
St. Dev.	0.3145	0.2798	0.9832	0.4496	0.7037	0.2111	1.0003	0.4637	1.1494
Max	3.2202	0.9399	-0.6124	-1.0731	5.0111	-0.0165	-0.5219	2.8744	-1.8423
Min	1.7932	0.0743	-4.7698	-3.1809	2.6614	-0.9693	-3.8025	0.7412	-5.6612

Table 4.9. (Continued)

	Labor/Fert.	**Energy**	**Pest**	**Fert./Energy**	**Pest**	**Eng/Pest**
Roll	**AES34**	**AES35**	**AES36**	**AES45**	**AES46**	**AES56**
1960-1985	1.4249	1.2571	-0.3299	-4.6502	-3.2754	2.4680
1960-1986	1.6544	0.9849	-0.5970	-3.3203	-1.5774	0.3622
1960-1987	1.9494	0.8204	-0.6657	-2.0815	-1.3877	-0.1257
1960-1988	1.6457	0.7920	-0.7740	-1.7942	-1.1969	0.2774
1960-1989	1.8323	0.8433	-0.7556	-0.9612	-0.1313	0.2754
1960-1990	0.7418	0.8434	-0.8602	-2.3028	0.7395	1.0509
1960-1991	0.7438	0.8422	-0.8000	-2.2578	0.7533	1.0490
1960-1992	0.7454	0.8415	-0.7341	-2.2449	0.7642	1.0473
1960-1993	0.5853	0.7322	-0.6872	-2.6897	3.6001	1.2006
1960-1994	0.6354	0.6807	-0.6768	-2.4698	3.6500	0.9937
1960-1995	0.6219	0.6293	-0.6481	-1.8134	5.1078	1.1793
1960-1996	0.6288	0.6277	-0.5961	-1.7732	4.9053	1.1743
1960-1997	0.6088	0.4653	-0.4833	-1.8209	4.4395	0.8326
1960-1998	0.6020	0.5381	-0.2237	-2.7479	2.6184	1.4180
1960-1999	0.4016	0.4414	-0.0728	-2.2923	2.2127	1.5154
1960-2000	0.3510	0.4436	-0.0827	-2.2785	2.1177	2.0886
1960-2001	0.3152	0.3842	0.1120	-1.9338	1.0108	2.6082
1960-2002	0.2380	0.4059	0.1585	-1.6237	-0.7473	1.7594
1960-2003	0.3413	0.4467	-0.0004	-1.3611	-1.3530	1.9446
1960-2004	0.1611	0.4564	-0.3701	-1.0879	-0.4325	2.3183
Mean	0.8114	0.6738	-0.4544	-2.1753	1.0909	1.2719
St. Dev.	0.5605	0.2314	0.3280	0.8086	2.4113	0.7593
Max	1.9494	1.2571	0.1585	-0.9612	5.1078	2.6082
Min	0.1611	0.3842	-0.8602	-4.6502	-3.2754	-0.1257

increase in the price of capital will lead to an increase in pesticide by 3.7319% with a standard deviation of 0.7037, a maximum of 5.0111, and a minimum of 2.6614.

The mean AES across the rolling regression for land and energy unitary elastic indicates that a 1% increase in the price of land will lead to an increase in energy by 1% with a standard deviation of 0.4637, a maximum of 2.8744, and a minimum of 0.7412. The mean AES across all the rolling regression periods for labor and fertilizer indicates that a 1% increase in the price of labor will lead to an increase in fertilizer by 0.8114% with a standard deviation of 0.5605, a maximum of 1.9494, and a minimum of 0.1611. Labor and energy have a mean AES across all the rolling regression periods, which signify that a 1% increase in the price of labor will cause energy use to increase by an average of 0.6738% with a standard deviation of 0.2314, a maximum of 1.2571, and a minimum of 0.3842.

Fertilizer and pesticide have a mean AES across all the rolling regression periods which signify that a 1% increase in the price of fertilizer will cause pesticide use to increase by an average of 1.0909 with a standard deviation of 2.4113, a maximum of 5.1078, and a minimum of -3.2754. The mean AES across all the rolling regression periods for energy and pesticide is 1.2719, which signifies that a 1% increase in the price of energy will cause pesticide use to increase by an average of 1.2719% with a standard deviation of 0.7593, a maximum of 2.6082, and a minimum of -0.1257.

Capital and fertilizer; capital and energy; land and labor; land and fertilizer; land and pesticide; labor and pesticide; fertilizer and energy; and inputs are complements. Capital and fertilizer have a mean AES across all the rolling regression periods, signifying that a 1% increase in the price of capital will cause fertilizer use to decrease by 2.3426% with a standard deviation of 0.9832, a maximum of -0.6124, and a minimum of -4.7698.

Capital and energy have a mean AES across all the rolling regression periods, which signify that a 1% increase in the price of capital will decrease energy use by 1.5287% with a standard deviation of 0.4496, a maximum of -1.0731, and a minimum of -3.1809.

Land and labor inputs have a mean AES across all the rolling regression periods of -0.6039, which signifies that a 1% increase in the price of land will decrease labor by 0.6039% with a standard deviation of 0.2111, a maximum of -0.0165, and a minimum of -0.9693. Land and fertilizer have a mean AES across all the rolling regression periods of -1.9668, which signifies that a 1% increase in the price of land will decrease fertilizer by 1.9668% with a standard deviation of 1.003, a maximum of -0.5219, and a minimum of -3.8025. Land and pesticide have a mean AES across all the rolling regression periods of -3.6120, which signify that a 1% increase in the price of land will decrease pesticide by 3.6120% with a standard deviation of 1.1494, a maximum of -1.8423, and a minimum of -5.6612. Labor and pesticide have a mean AES across all the rolling regression periods of -0.4544, which signifies that a 1% increase in the price of labor will decrease pesticide by 0.4544% with a standard deviation of 0.3280, a maximum of 0.1585, and a minimum of -0.8602. Fertilizer and energy have a mean AES across all the rolling regression periods of -2.1753, which signify that a 1% increase in the price of fertilizer will decrease energy by 2.1753% with a standard deviation of 0.8086, a maximum of -0.9612, and a minimum of -4.6502.

Conclusions

Given the changes in input use and output production, interest has grown in understanding how technology and/or federal farm policies like crop insurance have affected or altered the farm economic structure. Research in crop insurance has focused more on the impact of specific input or crop. This line of research is valid due to the current setting of insurance programs that is crop specific. In general, the effects of crop insurance encompass a simultaneous impact on the farm economic structure -resource use and output production mix rather than in isolation to individual output or input. Second, in the context of farm economic structure, the input and output relationships are assumed to be constant. However the constant nature of the relationship is questionable due to changes in the industry induced by the advancements in structure of agriculture and policies. Literature in the area of farm economic structure seldom examines the importance of the time-varying effect of technology or farm programs like crop insurance on input and output farm economic structure.

This research closed this gap by empirically analyzing the impact of crop insurance on farm economic structure and also the importance of the time-varying impact of crop insurance on the changes in farm economic structure with an empirical application to the North Dakota agriculture sector for the period1960-2004. Specifically, this study estimated the input demand functions, including the net crop insurance variable to quantify farmers' changes in inputs use when they purchase crop insurance.

Empirical results of the system of input demand functions for the state of North Dakota agriculture sector suggest that crop insurance will significantly increase fertilizer and pesticide usage but decrease land use signifying no moral hazard. This implies that crop insurance does not influence farms to become larger in size. Technology, not crop insurance, led to increase in land use over time. Technology also influence increases in fertilizer and pesticide use over time. Crop insurance and technology led to decreases in labor use over time. Technology led to decrease in capital use but Crop insurance led to increase in capital use.

Results also provide evidence that the input-output relationship is non-constant and changes dramatically over time. The cumulative rolling regression indicate some estimates are not statistically different from zero in some periods, but in certain periods, the addition of additional years of data does cause the estimate to become statistically significant. For example, the crop insurance variable becomes significant in the fertilizer cost share when the years 1993, 1994, 1995, 1996, 1997 and 1998 are added to the period; this can be the lagged effect of the crop insurance reform act that was instituted in 1994.

Both one-price-one-factor elasticity of substitution (AES) and the two- price-one-factor elasticity of substitution (MES) are estimated to identify the differences in the economic relationship of inputs. Estimates of the Allen elasticity of substitution reveal that farmers that participate in the Federal Crop Insurance Program use capital and fertilizer; capital and energy; land and labor; land and fertilizer; land and pesticide; and fertilizer and energy as complements. On the other hand, the Morishima elasticity of substitution identifies capital and energy; fertilizer and land; fertilizer and energy; and pesticide and land as complements. The Morishima elasticity estimates also have clear policy implications because changes in the two-input combination can cause different changes when the input combination use is changed, and thus, that same policy will have unintended effects.

This research utilized aggregate state data to perform the empirical analysis. This is not a limitation but does present limitations on the interpretation of the results since results will be general without specific regard to differences across farms such as size. In the future, we would like to perform similar analyses utilizing farm-level data and also including variables to account for changes in farmers' insurance coverage level and risk aversion.

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