Is irrigated farm more efficient than non-irrigated no-tillage farm and non-irrigated conventional farm for a sample of Kansas corn farmer?

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Abstract. The corn farmer has benefited from high corn price. However, the corn price falls from its high price in 2012 to as low as $ 4.46 per bushel in 2013. The drop in corn price and intense competition from the global grain markets make farms that are non-efficient struggle economically. Pure technical, overall, allocative and scale efficiency were measured to analyze the competitiveness of a sample of Kansas corn farmers. Farmers increased their relative efficiency during drought in 2012. Government payment was found to be negatively correlated with efficiency for non-irrigated farms. Interest expenditure might have negative impact on input allocation for irrigated and non-irrigated conventional farms. Irrigated farms should focus on increasing acreage land to increase overall efficiency. On the other hand, non-irrigated conventional farm should focus their effort to enhance overall efficiency by increasing seed inputs.

1. Background
A reversal in profitability for corn farmer occurred when the corn price plunged from its high price in 2012 to $ 4.46 per bushel in 2013. Under the lower price regime, farmers reacted by switching their farm from corn to soybeans [1, 2]. Heavy competition in global markets, net return to excellent growing condition, oil price declines and decreases in ethanol demand are contributors to the corn price decline. The drop in corn price and competition from the global grain markets may make farms that are non-efficient struggle economically. Thus it left to a question of how efficient did corn farmers operate previously.

A sample of Kansas Farm Management Association (KFMA) data for Kansas corn farmers showed that the gross income per acre, variable cost per acre and total expense per acre of irrigated farms were steadily increasing from 2007 to 2012. Moreover, the change in profit per acre over the years was positive for irrigated. There is profit variability among corn farms. Whether the variability is caused by production inefficiency or economies of scale needs further analysis. All corn farmers face exogenous prices for inputs and output, leaving them to make decisions on the quantity of inputs used. Thus, how efficiency compares among farms is an important question.
The objectives of this study are; 1) to examine the differences in efficiency among irrigated farm, 2) to examine the correlation between farm characteristics and efficiency, 3) to analyze the correlation between input use and efficiency.

2. Data and methods

2.1 Data
Enterprise farm level data from the KFMA were used for non-parametric analysis. The enterprise data were constructed by KFMA area field personnel with corn farmer collaboration to ensure the accurateness and completeness of the data. The farms consist of 232 irrigated farms. Eight inputs were defined: land, labour, machinery, seed, fertilizer, fuel/energy, herbicide/insecticide and miscellaneous input. Farm characteristics are defined: percentage of acres owned, percentage of government payment to total income, percentage of insurance payment to total expenditure, and percentage of interest payment to total expenditure. The enterprise farm was assumed to have only one output, corn. Farm level prices were not collected and this study assumes law of one price as suggested [3].

2.2 Methods
This study will use the non-parametric approach for efficiency analysis proposed [4]. The advantage of the non-parametric approach is it can solve for disaggregated inputs [3]. This study will follow [5] assuming cost minimization behaviour in non-parametric efficiency analysis. The non-parametric analysis will measure overall, technical, allocative and scale efficiency.

In the case where costs and input prices are known, DEA based on cost minimization or profit maximization can be used to measure allocative efficiency as well as overall efficiency. This study will use cost minimization DEA in light [6] finding on Kansas farmer behaviour. Found that less evidence against cost-minimization behaviour compared to profit-maximization behaviour in a sample of 289 Kansas farmers.

Overall efficiency (OE) shows the minimum cost $C_f(w, y, T_c)$ of producing a particular output ($y$) under constant return to scale technology, given input prices ($w$). Consider the cost minimization DEA for measure overall efficiency for DMUs at group $N$ as follows:

$$\min_{\lambda_j} C_f(w, y, T_c) = \sum_{m=1}^{M} w_m x_{m,j}^t$$

subject to:

$$\sum_{j=1}^{N} \lambda_j x_{m,j}^t \leq x_{m,j}^t, \quad \text{for } m = 1, \ldots, M$$

$$\sum_{j=1}^{N} \lambda_j y_{l,j}^t \geq y_{l,j}^t, \quad \text{for } l = 1, \ldots, L$$

$$\lambda_j \geq 0, \quad \text{for } j = 1, \ldots, N$$

The overall efficiency is calculated as

$$OE = \frac{C_f(w, y, T_c)}{\sum_{m=1}^{M} w_m x_{m,j}^t} = \frac{\sum_{m=1}^{M} w_m x_{m,j}^t}{\sum_{m=1}^{M} w_m x_{m,j}^t}$$
Another measurement is pure technical efficiency (PTE). PTE assesses the amount of all inputs needed to be proportionally reduced to achieve technically efficient production under variable return to scale. Consider DEA for measure pure technical efficiency for DMUs at group N as follows:

\[ D^N(x^t_j, y^t_j) = \min \theta_j \]
\[ s.t \quad \sum_{j=1}^{N} \lambda^t_j x^t_{m,j,} \leq \theta^t_j x^t_{m,j}, \quad \text{for } m = 1, \ldots, M \]
\[ \sum_{j=1}^{N} \lambda^t_j y^t_{l,j} \geq y^t_{l,j}, \quad \text{for } l = 1, \ldots, L \]
\[ \lambda^t_j \geq 0, \quad \text{for } j = 1, \ldots, N \] (6-9)

Allocative efficiency (AE) shows the minimum cost \( C_j(w, y, T_v) \) under variable return to scale technology\((T_v)\), given input prices \( w \). AE sometimes used to assess whether a DMU is using optimal input mix [5]. The programming problem is similar to OE, with an additional constraint of \( \sum_{j=1}^{N} \lambda^t_j = 1 \). The additional constraint, \( \sum_{j=1}^{N} \lambda^t_j = 1 \), allows the technology to exhibit variable returns to scale \((T_v)\) instead of constant return to scale \((T_c)\). The optimization problem for allocative efficiency is to find the minimum cost under variable returns to scale \( C_j(w, y, T_v) = \sum_{m=1}^{M} w^t_m x^t_m \) : Allocative efficiency can be estimated as follows.

\[ AE = \frac{C_j(w, y, T_v)}{\sum_{m=1}^{M} w^t_m x^t_m} = \frac{\sum_{m=1}^{M} w^t_m x^t_m}{\sum_{m=1}^{M} w^t_m x^t_m \theta_j} \] (10)

The final efficiency measurement that we use is scale efficiency (SE) under the cost function. SE measures whether the DMU producing at the most efficient size. The scale efficiency can be estimated as

\[ SE = \frac{C_j(w, y, T_v)}{C_j(w, y, T_v)} \] (11)

2.3. Tobit model

A Tobit model was used to measure the correlation between efficiency measurement with farm characteristics and inputs used. The Tobit model was estimated as follows:

\[ E_j = \sum_{i=1}^{T} \beta_i x_i + \varepsilon_i \quad \text{if} \quad \sum_{i=1}^{T} \beta_i x_i + \varepsilon_i < 1, \quad = 1 \quad \text{otherwise} \] (12)

\( E_j \) is the measure of efficiency (PTE, OE, AE and SE) for each farm and \( \beta_i \) is an estimated parameter. The explanatory variable \( x_i \) for examining the relationship between efficiency and farm characteristics consists of percentage of acres owned, percentage of government payment to total income, percentage of insurance payment to total expense, and percentage of interest payment. The explanatory variable \( x_i \) for
observing the relationship between efficiency and input used comprises land, labour, machine, seed, fertilizer, fuel/energy, herbicide/insecticide and miscellaneous input.

3. Results and discussion
There were four non-parametric linear program solved for 232 irrigated farms. This study was estimating the measures of pure technical efficiency, overall efficiency, allocative efficiency and scale efficiency for all enterprise farms. The statistics of efficiency measure results are presented in Table 1.

| Farm Type | Efficiency estimation | Distribution | Distribution | Distribution | Mean  | Stdev  | Min  | Max  |
|-----------|-----------------------|--------------|--------------|--------------|-------|--------|------|------|
|           |                       | 0.4 0.41-0.60 | 0.61-0.80    | 0.81-0.90    | 0.91-1.00 |       |       |      |      |
| Irrigated | TECHNICAL             | 4            | 17           | 63           | 41     | 107    | 0.843| 0.167| 0.196| 1    |
|           | ALLOCATIVE            | 101          | 61           | 45           | 10     | 15     | 0.446| 0.273| 0.065| 1    |
|           | OVERALL               | 152          | 46           | 27           | 0      | 7      | 0.308| 0.259| 0.011| 1    |
|           | SCALE                 | 35           | 28           | 43           | 26     | 100    | 0.746| 0.271| 0.102| 1    |

Technical efficiency for irrigated farms ranges from 0.167 to 1, with average measures of 0.843. Thus, the output for irrigated farms can be potentially increased by 15.6% if all farms were purely technical efficient. Allocative efficiency was lower than technical efficiency for all farm types. Allocative efficiency for irrigated farms ranged from 0.065 to 1 with standard deviation of 0.273. The overall efficiency varied across irrigated farm from 0.011 to 1. The average overall efficiency for irrigated farms, 0.308, shows that irrigated farms were not efficient on average. Irrigated farms could produce similar output with 69.2% less expenditure.

The average of scale efficiency is higher than average of allocative efficiency for each farm type. The scale efficiency for irrigated farms had an average of 0.746 and standard deviation of 0.271. The comparison between average of scale efficiency and average of allocative efficiency for each farms shows that the greater proportion of lower overall efficiency is because farms producing above the cost frontier rather than farms were producing at inefficient scale.

A Tobit model was estimated using a set of farm characteristics and inputs used to explain efficiency. The dependent variables are the efficiency measures comprise pure technical efficiency, overall efficiency, allocative efficiency and scale efficiency. The explanatory variables for farm characteristics are percentage of own acreage of total planted acreage (OwnAcre), percentage of government payment to total income (GovPay), percentage of insurance expense to total expenditure (InsExp) and percentage of interest payments to total expenditure (InterExpe).

The estimation of Tobit model for efficiency analysis is applied for each farm type. Chow test analysis and pooled/un-pooled sample t-test had been conducted to identify the possibility of pooling all the enterprises farm data for Tobit model estimation. The Chow test analysis showed that the parameter of one farm type were not equal to those of other farm types. Thus, the data cannot be pooled for Tobit model estimation. The pooled/un-pooled sample t-test shows that most input and efficiency measures for different farm type have statistically different means.

The results in Table 2 indicated that most farm characteristics were not associated with efficiency measures for irrigated farms. Interest expenditure has significant negative impact to allocative efficiency. Thus, allocative efficiency can be improved if irrigated farmer has less interest expenditure. High interest
expenditure may induce farmer to make less efficient input allocation which result to produce above the cost frontier. The overall efficiency of irrigated farm is the highest during severe drought weather in 2012. The start of drought in 2011 causes farmer to have the lowest overall efficiency. Irrigated farmers might not anticipate the drought impact in 2011 on their inputs allocation.

Table 2. Relationship between efficiency measures and farm characteristic for irrigated farms

| Farm type | Efficiency | Own Acreage | Government Payment (%) | Insurance Expenditure (%) | Interest Expenditure (%) | y2012 | y2013 | Intercept |
|-----------|------------|-------------|------------------------|--------------------------|-------------------------|-------|-------|-----------|
| Irrigated | Technical  | -0.063      | -0.392                 | 0.320                    | -0.304                  | 0.078 | 0.090 | -0.126** |
|           | Allocative | 0.041       | -0.198                 | -0.838                   | -2.066**                | 1.317*** | 1.198*** | -1.642*** |
|           | Overall    | 0.017       | -0.426                 | 0.556                    | -0.934                  | 2.081*** | 1.877*** | -2.730*** |
|           | Scale      | 0.060       | -0.045                 | 1.174                    | 0.993                   | 0.810*** | 0.637*** | -0.888*** |

*** 1% significance, ** 5% significance, * 10% significance

There is no significant relationship between all efficiency measures and insurance expenditure. Thus, it implies that there is no moral hazard effect from insurance payment to input allocation. Crop insurance payment is used only to protect farmers from losing crop yield due to natural disaster or the loss of revenue due to drop in corn price.

Table 3. Relationship between efficiency measures and farm inputs for irrigated farms

| Efficiency estimation | Technical | Allocative | Overall | Scale |
|-----------------------|-----------|------------|---------|-------|
| lland                 | 0.3535*** | 0.6677***  | 0.7137*** | -0.0994 |
| llabor                | -0.0536*** | 0.0338 | -0.0489*** | -0.0505** |
| lmachine              | -0.0805** | -0.079 | -0.0516 | 0.0545 |
| lseed                 | 0.051 | -0.0248 | -0.0225 | -0.0683 |
| lferti                | -0.0354 | -0.1424* | -0.1675*** | 0.0135 |
| lfuel                 | -0.024 | -0.0197 | -0.1308*** | -0.062 |
| lherbi                | -0.0377 | -0.2689*** | -0.1126*** | 0.1615*** |
| lother                | -0.1037*** | -0.0303 | -0.0810*** | -0.0059 |
| y2012                 | -0.0327 | 1.4694*** | 2.1394*** | 0.7656*** |
| y2013                 | -0.1290* | 1.2821*** | 1.7665*** | 0.5561*** |
| Intercept             | 0.5186 | -0.3847 | -0.8358** | -0.6009 |

The importance of each input in explaining efficiency is reported in Table 3. The logged efficiency index was regressed using Tobit model on the log of input cost. The explanatory variable for input costs
are logged land cost (lland), logged labour cost (llabor), logged machinery fee (lmach), logged seed expense (lseed), logged fertilizer cost (lferti), logged fuel expense (lfuel), logged herbicide cost (lherbi) and logged miscellaneous expense (lother). The coefficients estimated from Tobit model shows the relative importance of each input costs in explaining efficiency index. The direct interpretation of Tobit coefficient on this study is because the dependent and independent variables are in log [7].

From Table 3, we can observe that there are more inputs that have significant correlation with efficiency for irrigated farm compared to other type of farm. Inputs that have significant correlation with technical efficiency for irrigated farms comprise land, labour, machine and other miscellaneous inputs. The output of irrigated farms can be potentially increase if farm increase land acreage. Furthermore, the decrease in labour, machinery and other miscellaneous inputs will also increase technical efficiency. Significant inputs related to allocative efficiency consists of land, fertilizer and herbicide. Results in Table 3 indicated that land is underutilized but fertilizer and herbicide being underutilized. The most important input to increase allocative efficiency in irrigated farms is land.

There are more inputs that have significant correlation with overall efficiency for irrigated farms. The overall efficiency can be increase if irrigated farmers increase land but reduce other inputs comprises labour, fertilizer, fuel, herbicide and other miscellaneous inputs. Irrigated farmers should focus on land to increase overall efficiency. The only inputs that are related with scale efficiency are labour and herbicide. Farmer may reduce herbicide to become more scale efficient.

4. Conclusion
The group efficiency comparisons were estimated to analyze the efficiency comparison between farms. Pure technical, overall, allocative and scale efficiency were measured to analyze the competitiveness of a sample of Kansas corn farmers. The efficiency measures are estimated using non-parametric analysis of a sample of Kansas corn farms. Farmers increased their relative efficiency during severe drought condition in 2012. The output of all farm types can be potentially increased by high magnitude if all farms were pure technical efficient. The greater proportion of lower overall efficiency for all farm types is because farms producing above the cost frontier rather than farms were producing at inefficient scale.

Tobit models were estimated to analyze the source of lower efficiency. Interest expenditure may have negative impact on input allocation for irrigated. Irrigated farms should focus on increasing acreage land to increase overall efficiency. The increase of acreage land has positive impact to increase technical efficiency for irrigated farms but has negative impact to technical efficiency for non-irrigated conventional farms. Irrigated and non-irrigated no-tillage farms should focus their effort to increase allocative efficiency by increasing land acreage. Non-irrigated conventional farm might overuse machinery inputs that result to lower input allocation.

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