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Cost Efficiency of International Corn and Soybean Production

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ABSTRACT

The objective of this paper was to examine the cost efficiency of corn and soybean production for typical farms involved in the cash crop *agri benchmark* network using data for the period 2013 to 2017. Average cost efficiency for the typical farms in the network that produced corn, soybeans, and both corn and soybeans was 0.749, 0.774, and 0.939, respectively. Inefficiency was a greater problem for the farms producing corn than for the other farm types examined. Inefficient farms tended to overutilize direct, operating, and overhead inputs.

KEYWORDS

cost efficiency, corn, soybeans, international

INTRODUCTION

Comparative advantage was first introduced by David Ricardo, who argued that a country should specialize in producing commodities in which the country enjoys the greatest comparative advantage, even if one country has an absolute advantage and can more efficiently produce all commodities (Koo & Kennedy, 2005). Absolute advantage refers to the ability to produce an output using fewer inputs than competitors (Hashimzade et al., 2017). Less efficient countries should concentrate on the products for which they have the smallest disadvantage (Koo & Kennedy, 2005).

Individual farms in a particular country may have a comparative advantage due to competitive advantage, effective strategies, and/or exchange rates. Examples of competitive advantage are high-quality soils, educated and experienced operators and employees, access to the latest technologies, and efficient capital markets. Effective strategies involve choosing a direction for the farm that fully utilizes the business's strengths and that fits the external environment.

Competitive advantage is often achieved through innovation (Porter, 1990) which includes new technologies and new methods. Sometimes ideas already exist, but are applied differently or more effectively. Once competitive advantage is achieved, the farm must continuously improve to sustain the advantage. Before trying to exploit a competitive advantage, it is important to know the relative performance of a farm. Efficiency and productivity measures can be used to ascertain the relative performance of a farm (Langemeier et al., 2014; Mugura et al., 2012; Yeager and Langemeier, 2009; Yeager and Langemeier, 2011).

Measuring efficiency and identifying the lowest cost producers of a product can be challenging, and the task is even more complex when comparisons are made across international borders. Differences in production practices and systems are very important when examining global crop production and subsequently must be considered in efficiency measurements. Due to differences in prices, available technologies, capital costs, and credit constraints, the same input mix will likely not represent the lowest cost combination for farms in different countries. It is also important to consistently measure inputs, outputs, revenues, and costs across countries and farms. Part of the effort to ensure consistency of revenue and cost estimates is the conversion of these items to a common currency.

When making farm comparisons among countries, it is imperative that standardized methods pertaining to data collection and aggregation be utilized. The *agri benchmark* concept of typical farms was developed at the von Thunen-Institute (vTI) in Braunschweig, Germany to advance understanding of current production systems and farmers' decision-making. Standardized methods are used within the network to measure inputs, outputs, costs, and revenues. Moreover, costs and revenues for each typical farm are converted to a common currency so that comparisons can be readily made. Activities or profit centers examined by the *agri benchmark* network (www.agribenchmark.org) include beef, cash crops, dairy, pigs and poultry, horticulture, and organic. Cash crops in the network include barley, corn, cotton, palm oil, potato, pulse, rapeseed, rice, soybean, sugar beet, sunflower, and wheat.

The objective of this paper is to examine the cost efficiency of corn and soybean production for typical farms involved in the cash crop *agri benchmark* network using data for the period 2013 to 2017. In addition, the underutilization and overutilization of inputs for inefficient farms and the relationship between cost efficiency and farm characteristics are examined.

METHODS

Cost efficiency was the primary measure of interest in this study. Cost efficiency represents the product of technical and allocative efficiency. A technically efficient farm produces on the production frontier. A farm that is on the production frontier generates the highest output possible given the inputs utilized. Farms that lie below the production frontier are said to be technically inefficient (Coelli et al., 2005). An allocatively efficient farm uses the optimal mix of inputs and produces on the cost frontier. A farm that is using a suboptimal mix of inputs (i.e., underutilizing or overutilizing specific inputs) lies above the cost frontier or on an inefficient portion of the cost frontier (Coelli et al., 2005). In this case, per unit cost could be lowered by using the optimal mix of inputs. Because cost efficiency represents the product of technical and allocative efficiency, a cost efficient farm produces on the production and cost frontiers. Cost efficiency indices, or scores, range from 0 to 1. An index of 1 indicates that a farm is efficient.

Data envelopment analysis (DEA) was used to measure technical, allocative, and cost efficiency under variable returns to scale in this paper. DEA compares farms in terms of their input use and resulting output level to construct a benchmark or best practice frontier. Information pertaining to the estimation of technical, allocative, and cost efficiency under variable returns to scale can be found in Fare, Grosskopf, and Lovell (1985) and Coelli et al. (2005).

The DEA models utilized output, input, and input price data. For the corn model and the soybean model, one output was used. For the model with both corn and soybeans, two outputs, one for each crop, were used. Input and input prices were categorized using three categories: direct, operating, and overhead. More information pertaining to these variables is discussed in the data section below.

The ratio of actual to optimal input costs was used to examine whether the inputs of inefficient farms were underutilized or overutilized. If the ratio of actual to optimal input costs is greater than 1, a farm is overutilizing the input in question. A farm is underutilizing an input if the ratio of actual to optimal input costs is less than 1. By definition, actual input costs are equal to optimal input costs for efficient farms. The three input cost categories (direct, overhead, and operating) were used to determine whether inputs are under- or overutilized.

Correlation coefficients are used to explore the relationship between cost efficiency and farm characteristics such as percentage of acres planted to corn or soybeans, gross revenue, revenue shares for corn or soybeans, crop price, output, and cost utilization ratios. The relationship between cost efficiency and the three cost utilization ratios is of particular interest. A positive and significant correlation between cost efficiency and a cost utilization ratio indicates that the input is being underutilized. A negative and significant correlation coefficient would indicate that an input is being overutilized and is negatively affecting cost efficiency.

DATA

Table 1 presents the typical farms in the cash crop *agri benchmark* network that had corn and soybean data for the period 2013 to 2017. There were 24 farms with corn data representing 13 countries, 15 farms with soybean data representing 8 countries, and 13 farms with both corn and soybean data representing 6 countries. Typical farms developed by the *agri benchmark* network are defined using

Table 1. Abbreviations for Sample of Typical Farms with Corn, Soybean, or both Corn and Soybean Enterprises.

Farm	Country	Corn Hectares	Soybean Hectares	Both Crops Hectares
AR330ZN	Argentina (north of Buenos Aires)	71.2	258.8	330.0
AR700SBA	Argentina (southeast of Buenos Aires)	39.0	583.0	622.0
AR900WBA	Argentina (west of Buenos Aires)	109.0	659.0	768.0
BG7000PLE	Bulgaria (Pleven)	1122.8	N/A	N/A
BR65PR	Brazil (Parano)	50.9	62.4	113.3
BR1300MT	Brazil (Mato Grosso)	936.0	1300.0	2236.0
CA2000RRV	Canada (Red River Valley)	N/A	548.9	N/A
CZ4000JC	Czech Republic (Jihocesky Kraj)	343.2	N/A	N/A
FR110ALS	France (Alsace)	81.8	N/A	N/A
FR110VGAV	France (Vallee de Garonne Aval)	78.0	N/A	N/A
HU1100TC	Hungary (Tolna Country)	440.0	N/A	N/A
PL730WO	Poland (Wagrowiec Gread)	80.0	N/A	N/A
RO6500IL	Romania (southeastern)	1112.0	480.0	1592.0
UA2600WU	Ukraine (Kremenets region)	N/A	1038.4	N/A
UA7100PO	Ukraine (Poltava region)	1865.2	N/A	N/A
US700IA	United States (Iowa)	360.2	360.2	720.4
US1215INC	United States (Central Indiana)	607.5	607.5	1215.0
US1215INS	United States (Southern Indiana)	580.7	633.3	1214.0
US1300ND	United States (North Dakota)	381.2	592.1	973.3
US2025KS	United States (Kansas)	788.4	N/A	N/A
UY292SW	Uruguay (southwest)	53.4	229.6	283.0
UY360CEN	Uruguay (central)	26.8	276.0	302.8
VN3LM	Vietnam (Lang Minh)	3.0	N/A	N/A
ZA1600EFS	South Africa (Eastern Free State)	647.8	154.0	801.8
ZA1600NFS	South Africa (Northern Free State)	920.6	N/A	N/A
ZA1700WFS	South Africa Western Free State)	927.0	N/A	N/A

N/A = data were not available

country initials, hectares in the farm, and location in the country. For example, US1215INC is a U.S. farm located in central Indiana with 1,215 hectares.

The average acreage, revenue, output, and costs for the sample of typical farms is presented in Table 2. All dollar figures are expressed in U.S. dollars. For farms with both corn and soybeans, these crops represent approximately 73 percent of planted acreage.

The DEA models use information on outputs, inputs, and input prices. Outputs were computed using gross revenue and crop price for each crop. Specifically, each crop's gross revenue was divided by crop price to obtain the implicit output for each crop. Gross revenue for each crop included crop revenue, crop insurance indemnity payments, and government payments. The crop price used was the farm gate price. This study assumes variations in location of farms, specifically the proximity to grain buyers or ports, is captured by using the farm gate price. Our procedures for computing output ensure that crop insurance indemnity payments and government payments are included in the analysis.

Though output is not divided by hectares in the DEA analysis, for illustrative purposes it is

Table 2. Average Acreage, Revenue, Output, and Cost for Sample of Typical Farms.

Variable	Units	Corn	Soybeans	Both Crops
Planted Acres	Percentage of Total	33.6%	42.7%	73.1%
Gross Revenue for Corn	USD/ha	1231.77	N/A	1105.54
Gross Revenue for Soybeans	USD/ha	N/A	944.19	963.08
Corn Price	USD/ton	149.56	N/A	136.61
Soybean Price	USD/ton	N/A	333.23	329.60
Implicit Output for Corn	tons/ha	8.31	N/A	8.11
Implicit Output for Soybeans	tons/ha	N/A	2.86	2.95
Direct Cost	USD/ha	559.65	284.62	403.32
Direct Cost Share	Percentage of Total	43.3%	32.5%	38.8%
Operating Cost	USD/ha	440.14	290.02	316.77
Operating Cost Share	Percentage of Total	32.6%	33.7%	30.4%
Overhead Cost	USD/ha	318.76	305.53	334.03
Overhead Cost Share	Percentage of Total	24.1%	33.8%	30.9%

convenient to examine revenue and output on a per hectare basis in Table 2. The average implicit output for corn was 8.31, but varied from 4.50 for the South African farm in the Northern Free State region (ZA1600NFS) to 13.30 for the French farm in the Vallèe de Garonne Aval region (FR110VGAV). The implicit output for soybeans ranged from 1.68 for the South African farm in the Eastern Free State region (ZA1600EFS) to 3.94 for the central Indiana farm (US1215INC), and averaged 2.86. Average gross revenue on a per hectare basis was approximately $1,231 for corn and $944 for soybeans. The farms with both corn and soybeans had a relatively lower average corn yield and gross revenue per hectare, but a relatively higher average soybean yield and gross revenue per hectare.

Inputs included direct, operating, and overhead inputs. Direct inputs included seed, nitrogen, phosphorus, potash, lime, other fertilizer, pesticides, energy, irrigation, crop insurance, other direct, and interest. Operating inputs included hired labor, family labor, contractor expense, machinery (depreciation and interest), diesel, and other energy. Overhead inputs included buildings (depreciation and interest), land, and miscellaneous. Inputs were computed by dividing input cost by weighted average input prices. Cost shares for the individual inputs (e.g., seed cost share for direct inputs) were used to obtain the weights used in the computations of direct, operating, and overhead inputs.

Total input levels for direct, operating, and overhead inputs were used along with input prices in the DEA analysis. Again, it is convenient to illustrate and discuss input information on a per hectare basis. Average cost shares for corn, soybeans, and

Table 3. Average Input Costs (USD/ha) for Sample of Typical Farms.

Variable	Corn	Soybeans	Both Crops
Direct Cost			
Seed	163.56	103.29	145.00
Nitrogen	137.07	5.55	66.73
Phosphorus	51.78	34.65	44.29
Potash	29.37	27.92	25.91
Lime	0.98	0.41	1.33
Other Fertilizer	2.77	0	0.69
Pesticides	80.32	83.92	82.60
Energy	35.17	0.61	2.95
Irrigation	21.16	3.23	2.89
Crop Insurance	13.65	14.27	14.91
Interest	5.66	3.12	5.06
Other Direct	18.17	7.66	10.95
Operating Cost			
Hired Labor	74.17	41.22	38.60
Family Labor	73.38	29.19	34.57
Contractor	72.17	67.37	77.88
Machinery	155.88	120.78	124.98
Diesel	56.70	28.85	38.20
Other Energy	7.84	2.62	2.54
Overhead Cost			
Buildings	31.42	13.56	14.35
Land	232.47	256.31	278.80
Miscellaneous	54.87	35.66	40.88

corn and soybeans are presented in Table 2. Direct cost per hectare and in proportion to total cost (i.e., direct cost share) was substantially higher for corn than for soybeans. Operating cost per hectare was similar for the two crops. However, because of the relatively lower direct and operating cost per hectare for soybeans, overhead cost in proportion to total cost (i.e., overhead cost share) was higher for soybeans.

Detailed information pertaining to average input costs per hectare are presented in Table 3. The five largest cost items for corn were land, seed, machinery (depreciation and interest), nitrogen, and pesticides. For soybeans, the five largest cost items were land, machinery (depreciation and interest), seed, pesticides, and contractor expense.

RESULTS

Average cost efficiency indices for corn, soybeans, and both corn and soybeans are presented in Table 4 along with their distributions. In general, it was more difficult for a farm with corn to be cost efficient than it was for a farm with soybeans, or both corn and soybeans.

The average technical, allocative, and cost efficiency indices for corn were 0.802, 0.929, and 0.749, respectively. The AR330ZN, AR700SBA,

Table 4. Cost Efficiency Indices for Sample of Typical Farms.

	Corn	Soybeans	Both Crops
Summary Statistics			
Average	0.749	0.774	0.939
Standard Deviation	0.219	0.202	0.078
Distribution (# of Farms)			
Less than 0.5	4	2	0
0.5 to 0.6	5	1	0
0.6 to 0.7	3	3	0
0.7 to 0.8	0	2	0
0.8 to 0.9	1	2	4
0.9 to 1.0	6	0	2
1.0	5	5	7

UA7100PO, US1215INC, and VN3LM farms were cost efficient. The two French farms, the Polish farm, and the Romanian farm had cost efficiency indices that were under 0.50 or 50%.

For soybeans, the average technical, allocative, and cost efficiency indices were 0.861, 0.888, and 0.774, respectively. The AR330ZN, AR900WBA, BR1300MT, BR65PR, and US1215INC farms were cost efficient. It is important to note that two of these farms (i.e., AR330ZN and US1215INC) were also cost efficient for corn. The farms from Romania and Ukraine had cost efficiency indices below 0.50 or 50%.

For farms with both corn and soybeans, 7 of 13 farms were cost efficient (i.e., AR330ZN, AR900WBA, BR1300MT, BR65PR, RO6500IL, US700IA, and US1215INC). Two of these farms, the smallest Argentine farm and the farm in central Indiana, were also cost efficient for corn in the single output analysis and for soybeans in the single output analysis. The lowest cost efficiency index was 0.803 for the AR700SBA farm.

Table 5 presents the cost utilization ratios for corn, soybeans, and both corn and soybeans. A utilization ratio below 1 indicates that a farm is underutilizing an input while a ratio above 1 indicates that the farm is overutilizing an input. Farms that are cost efficient have an input utilization ratio of 1.

It was more common for farms to overutilize inputs than it was for farms to underutilize inputs. Because they tended to be more cost efficient, inefficient input utilization was less of a problem for farms with both corn and soybeans. For corn, overutilization of direct inputs was particularly problematic. The average direct cost utilization ratio for corn (i.e., 2.35) indicates that, on average, actual direct costs were more than double optimal costs. Inefficient corn farms need to focus on adjusting their use of direct inputs. In addition to input levels, the cost utilization ratios could also be suboptimal if relative input prices for a particular typical farm are large compared to other farms in the sample. For soybeans, operating cost had the highest cost utilization ratio. Also, the standard deviation of the cost utilization ratio for this cost category was substantially higher than it was for the direct and overhead costs.

The relationship between cost efficiency and farm characteristics for the sample of farms is presented in Table 6. In Table 6, *r* represents the correlation coefficient and *Sig* represents the

Table 5. Cost Utilization Ratios for Sample of Typical Farms.

	Corn	Soybeans	Both Crops
Direct Costs			
Average	2.35	1.48	1.11
Standard Deviation	1.41	0.45	0.20
# of Farms with Ratio < 1	0	0	1
# of Farms with Ratio = 1	5	5	7
# of Farms with Ratio > 1	19	10	5
Operating Costs			
Average	1.42	1.62	1.05
Standard Deviation	1.14	0.94	0.26
# of Farms with Ratio < 1	7	1	3
# of Farms with Ratio = 1	5	5	7
# of Farms with Ratio > 1	12	9	3
Overhead Costs			
Average	1.28	1.18	1.08
Standard Deviation	0.33	0.22	0.13
# of Farms with Ratio < 1	2	1	1
# of Farms with Ratio = 1	5	5	7
# of Farms with Ratio > 1	17	9	5

significance level. We will start with a discussion of the cost utilization ratios. The correlation coefficients for all three cost utilization ratios for corn and for soybeans were significant and negative, indicating that all three inputs tended to be overutilized. For the farms with both corn and soybeans, direct and overhead cost utilization ratios were significant and negatively related to cost efficiency. The correlation coefficient for operating cost for these farms was negative, but not significant. The results with respect to the cost utilization ratios in Table 6 are consistent with the results in Table 5. Overutilization of inputs is a problem on inefficient farms.

The correlation coefficient results for the percentage of total acres planted to corn, the percentage of total acres planted to soybeans, and revenue share for soybeans can be explained by exploring the relative profitability of corn and soybeans over the study period. The economic profit for soybeans was substantially higher than the economic profit for corn during the study period. Thus, it was not surprising to find a significant and negative relationship between cost efficiency for corn

Table 6. Correlation Coefficients between Cost Efficiency and Farm Characteristics for Sample of Typical Farms.

	Corn		Soybeans		Both Crops	
Variable	r	Sig	r	Sig	r	Sig
Percentage of Total Acres Planted to Corn	-0.404	*	N/A		-0.181	
Percentage of Total Acres Planted to Soybeans	N/A		0.745	***	0.195	
Gross Revenue (USD/ha)	0.028		0.409		0.196	
Revenue Share for Corn (%)	0.120		N/A		0.223	
Revenue Share for Soybeans (%)	N/A		0.770	***	0.545	*
Crop Price (USD/ton)	-0.362	*	-0.390		N/A	
Implicit Output (tons/ha)	0.258		0.776	***	N/A	
Direct Cost Utilization Ratio	-0.529	***	-0.861	***	-0.536	*
Operating Cost Utilization Ratio	-0.583	***	-0.800	***	-0.436	
Overhead Cost Utilization Ratio	-0.738	***	-0.675	***	-0.629	**

and the percentage of acres planted to corn, and a significant and positive relationship between cost efficiency for soybeans, and the percentage of acres planted to soybeans, and the revenue share for soybeans. The significant and positive correlation coefficient between cost efficiency and the implicit output for soybeans indicates that soybean farms with higher yields were relatively more cost efficient. The correlation coefficient between cost efficiency and the implicit output for corn was positive, but insignificant.

CONCLUSIONS AND IMPLICATIONS

The objective of this paper was to examine the cost efficiency of corn and soybean production for typical farms involved in the cash crop *agri benchmark* network using data for the period 2013 to 2017. Average cost efficiency for the typical farms in the network that produced corn, soybeans, and both corn and soybeans was 0.749, 0.774, and 0.939, respectively. Inputs and costs were categorized into three categories: direct, operating, and overhead. The ratios of actual to optimal input costs were used to examine whether the inputs of inefficient farms were underutilized or overutilized. Utilization ratios for direct, operating, and overhead costs were negatively correlated to cost efficiency for farms with corn, soybean, and both corn and soybean production, indicating that inputs tended to be overutilized on inefficient farms.

Measuring efficiency and productivity among countries is a difficult task. When making farm comparisons among countries, it is extremely important to use standardized methods pertaining to data collection and aggregation. By using standardized methods, this study contributes to our understanding of comparative advantage for world corn and soybean production. As noted above, there was a substantial difference in efficiency between the typical farms examined in this study. Many of the farms were overutilizing inputs, suggesting that there is room for improvement in input utilization. It is important to note that government payments were included in the output computation for each typical farm. Even with these government payments, some of the farms (e.g., typical farms in the European Union) were inefficient. Input allocation decisions were made knowing that these payments were forthcoming or at least highly likely. It is beyond the scope of this study to determine how the suboptimal use of inputs is related to government policies and/or regulations.

This study was limited by data availability. Future research could incorporate China and African countries into the analysis. Additional countries would create more robust conclusions on a global level. Special attention could also be paid to farms that are double-cropping. Although the second crop may have relatively lower yields and lower competitiveness compared to single-cropped counterparts, the efficiency of such crops in the whole farm system would be interesting to explore. As such, a whole farm approach may be of particular interest going forward. A whole farm approach would also incorporate other crops in the rotation such as sorghum, sunflowers, or rapeseed, which this study omits.

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