Cost Efficiency Changes and Adoption of Biotechnology Enhanced Soybeans in Kansas

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ABSTRACT

This paper analyzes the cost efficiency impacts of adopting biotechnology-enhanced soybean varieties for a set of Kansas farms from 1993 to 2011 using cost indices estimated from linear programming techniques. The cost efficiency indices are then coupled with survey data about the adoption of biotechnology-enhanced soybean varieties to provide a comparative analysis over time and across different quartiles of the sample. Results indicate that cost efficiency is not likely to decline on average with the adoption of these soybean varieties, but may increase for more efficient farms through a number of different benefits associated with adoption.

Introduction

The adoption of biotechnology-enhanced soybean (BES) seed in the U.S. has happened at a rapid pace. The USDA–National Agricultural Statistics Service (NASS) has estimated the portion of all soybeans planted to herbicide-tolerant varieties has grown from 54 percent in 2000 to 93 percent in 2013 (USDA–NASS, 2001 & 2013). In Kansas, USDA has reported that the percent of all soybeans planted with biotechnology-enhanced seed reached a high of 96 percent in 2011 (USDA–NASS, 2011). The simplicity and flexibility of management practices afforded by herbicide-tolerant soybeans are major benefits that increased the adoption of these crops (Bonny, 2009 & 2011).

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The efficiency in farm performance due to the growth of off-farm income has been referenced as a result of BES seed adoption (Fernandez-Cornejo & Caswell, 2006). Labor savings for on-farm production activities associated with soybeans have been credited with providing more hours to contribute to off-farm work and family income. On the other hand, some studies have found that soybean yields on average decreased with the large-scale adoption of genetically modified varieties (e.g., Xu et al., 2013), but this drag on technical efficiency may be overcome by the potential benefits mentioned above. An examination of the direct impacts of BES adoption over time on-farm from a cost-efficiency perspective has not been highlighted in the literature.

The purpose of this study is to present an analysis of the cost efficiency impacts of adopting BES seed for a set of Kansas farms. The article highlights the impact on farm performance among a sample of 154 farms from adopting genetically modified varieties of soybeans incorporating survey data and other secondary sources. Using linear programming techniques, cost efficiency measures are estimated for each year for each farm and results are presented to examine trends and changes in cost efficiency over the period of 1993 to 2011.

Methods

Cost efficiency indices for each farm were estimated using linear programming methods (Coelli et al., 2005; Cooper, Seiford, and Tone, 2007). For each year in the analysis, data for individual farms were used to estimate their cost efficiency relative to all of the farms in that given year, providing a cost efficiency index for each farm and year from 1993 through 2011. The cost efficiency (CE) index for each farm for a given year represents the ratio of a farm's potential minimum cost of production if they were producing on the cost frontier for the sample of farms (solved for in the LP) relative to that farm's observed cost of production. Thus, the CE index provides a measure of how much a given farm in a given year fell short of achieving the minimum cost of production. The CE index ranges from 0 to 1. A CE index equal to 1 indicates that the farm is cost efficient, producing at the minimum cost possible (on the cost frontier) relative to other farms in the sample being examined. A CE index less than 1 indicates a farm is not producing at their minimum cost and could improve their performance. Cost efficiency, also known as overall efficiency, for a farm is the product of allocative and technical efficiency (Cooper, Seiford, and Tone, 2007). Thus, farms with a CE =1 must also be technically efficient; otherwise they would be able to produce more output with the same level of inputs and lower their costs per-unit of output. Technical efficiency measures how a farm is producing relative to their production possibility frontier or if they are maximizing output production given their current level of inputs. Cost efficiency is estimated with a linear programming model using outputs, inputs and price indices for inputs. For more information pertaining to the estimation of the efficiency measures discussed here, see Coelli et al. (2005) and Cooper, Seiford and Tone (2007).

For analysis of the cost efficiency indices, index estimates are compared over time, between adopters and non-adopters, and across different quartiles in the sample. Adopters of BES seeds were designated as adopters based on survey data collected about the sample. Farms were indicated as adopters every year after they initially indicated they had adopted the use of BES. Year-to-year adoption data was not available for these farms. Thus, it is assumed, given the: (i) benefits of BES outlined above; (ii) the market prevalence of these varieties; and (iii) the change in cropping systems dynamics with these soybean varieties, that once farmers have adopted BES varieties they have continued to use these varieties to the present (Bonny, 2009 & 2011), given data limitations on seed-purchase history.

The CE indices computed for each farm were used to assign the farms into quartiles for each year analyzed. Quartile 1 represents the top 25 percent of the farms (39 farms in total) with the highest CE index scores. Quartile 2 represents the second best performing group of farms (25–50%, 39 farms in total) using the cost efficiency measures. Quartile 3 represents the second to bottom quarter (50 to 75%) of the sample of farms (38 farms in total) in terms of overall performance. Finally, quartile 4 represents the lowest performing farms for each year (38 farms in total) using the calculated efficiency measures.

Data

The farms used for this study participate in the Kansas Farm Management Association (KFMA) program (see http://kfma.ksu.edu/). KFMA collects detailed financial and production data for the participating farms. All participating farms used produced one or more of the primary crops in Kansas: corn, sorghum, soybeans, and wheat, and had continuous data from 1993 to 2011. This allowed for each farm's cost efficiency relative to their contemporary group in the analysis to be measured prior to the rollout of BES seed in 1996. The fifteen year horizon of the analysis beyond the year of the technology introduction into the market provided an opportunity to include later adopters in the analysis.

A mail survey was administered to 1,487 KFMA farms who produce corn, sorghum, soybean and/or wheat in April and May of 2013. The survey asked questions concerning farm characteristics; farmer demographics; biotechnology-enhanced crop variety adoption; corn and soybean management; and perceptions about crop performance. Potential participants were mailed an eight-page survey questionnaire, followed by a reminder postcard a week and a half after the initial survey mailing. Of the farmers contacted, 422 farmers responded, giving a response rate of 28 percent. Of particular interest in the survey was a question asking farmers in what year they first adopted the use of BES varieties. After matching survey respondents back to the KFMA database, 154 farms were identified as usable for this analysis, as these farms had both survey data and continuous KFMA financial and production data from 1993 to 2011.

A number of financial and production data from KFMA were used for the outputs and inputs in the cost efficiency linear program models. The output used for the estimation of the CE indices for each farm was the total gross value of all crops produced as recorded in KFMA records including crop insurance proceeds and government payments. The inputs represented the total cost of different groupings of inputs, including: (i) direct inputs (seed, fertilizer, and chemicals); (ii) labor (hired and unpaid family labor); (iii) machinery (irrigation repair, building repair, machinery repair, and machinery hire); (iv) energy (fuel use, utilities, irrigation energy consumed, and auto expenses); (v) taxes (property and real estate); and (vi) general (crop marketing, crop insurance, conservation expenses, general farm insurance, depreciation expenses, feed, and organizational fees). The expenses were aggregated to provide fewer inputs for the cost efficiency analysis in order to conserve on the potential number of farms identified by the analysis as being overall efficient.

Relative prices for the different input categories were indexed from 1993 based on USDA–NASS indices (USDA–NASS, 2013). The price index used for direct inputs was a weighted average of the per acre cost of the seed, fertilizer, and chemicals used to grow soybeans, corn, sorghum, and wheat weighted using the number of acres a farm plants to each of these crop. Representative costs were pulled from Kansas State University crop budgets (see agmanager.info; Dumler & Schoup, 2012; O'Brien & Duncan, 2012). A labor price index was developed from survey responses provided by KFMA members (Roehl & Herbel, 2009). Other prices were indexed as 1993 being a base year with a "1" and then multiplied by USDA indices that either correspond to them directly, or that are based on general cost of production indices (see USDA–NASS, 2013). Using the cost indices, quantities of inputs were calculated for use in the cost efficiency linear program by dividing the total input expense for each category by its respective price index.

Results

Table 1 presents the percentage of farms adopting BES varieties overall and by quartile by year for the 154 farms in the sample. By 2006, more than 90 percent of the participants in the survey who would eventually adopt BES by the 2011 planting season had done so. The adoption rates by quartile varied from year to year. This could be representative of farmers who adopted the practice, but may not have seen efficiency gains until after they obtained additional information and experience after a number of years of using the biotechnology-enhanced seed varieties. This may represent the changes during the trial phase of adopting a new technology (Abadi Ghadim & Pannell, 1999).

The averages of the CE indices estimated for each year across all the farms; for farms having adopted and those not yet adopting BES varieties; and for each quartile are presented in Table 2. Average cost efficiencies varied by year, likely due to specific climatic, production, and market conditions. The difference between adopters and non-adopters of BES varieties was not consistent over time. From 1996 to 2005, no general pattern seems to arise. In 2005, the greatest difference was observed between adopters and non-adopters, with non-adopters having better performance on-average. After 2005 though, farms adopting BES varieties had higher cost efficiencies on average. This is more interesting, given the rate of adoption for the farms in the sample did not significantly change. Thus, it may be the case that as technology improved for genetically modified soybeans over time and farmers adopted these improved varieties, farmers experienced bigger gains in overall efficiency on their farm.

It should be highlighted though, that the differences on average are relatively small in magnitude for many of the cost efficiency comparisons. These differences may not be statistically different from zero. This is further supported when examining the differences in the average CE index values by quartile (not shown). The differences were not consistent over time and tended not to be large in magnitude. This finding may point to two things occurring on-farm. Historically, BES experienced lower yields than conventional varieties, referred to as a yield drag (Benbrook, 1999). The lower yields when compared to farms using conventional varieties may lower technical efficiency and thereby cost efficiency, as alluded to in the methods section of the paper. This efficiency drop though may be countered by an improvement in other input use and flexibility. Farmers have adopted biotechnology enhanced soybean varieties due to savings on management costs because of their simple usage and by lowering production risk due to the widening of the window for post-emergence spraying (Bullock & Nit Si, 2001). Thus, in these cases, farmers may have experienced a marginal increase in efficiency from these benefits. Depending on the magnitudes of these changes, cost or overall efficiency may rise or fall. From the evidence provided here, it seems that on average farms maintained their cost efficiency and may have gained somewhat over time.

Using additional data from the survey, farms who adopted BES varieties planted 90.4 percent of their soybean acres to these varieties in 2011. For the second, third and fourth quartiles this was 94.9, 84.5, and 68.6 percent on average, respectively. In 2011, only two farms in this analysis planting over 30 acres of soybeans and ranking in the top quartile by cost efficiency measures had not adopted BES. Of the farms in the top quartile for cost efficiency in each of the last five years of the analysis period (2007–2011) that had not yet adopted BES, more than half (on average) did not plant soybeans in that year. Examining the quartiles for the last five years of the analysis period (2007 to 2011), cost efficiency dropped significantly when moving from the top or 1st quartile to the other three. Furthermore, farms that were already in the top quartile as of 2007, tended to remain in that quartile through 2011. With the higher average cost efficiency in these years, it would seem that farmers in the top quartile who had adopted BES varieties became or remained highly cost efficient during this time period.

Summary

The focus of this analysis was on examining if farms that adopted biotechnology-enhanced soybean varieties experienced an increase in cost or overall efficiency. Linear programming models were used to estimate cost efficiency indices for a sample of 154 farms in Kansas. Comparing the farms across years, quartiles and adopters versus non-adopters provides some insight into the cost efficiency gains that may be realized. From 1996 to approximately 2006, efficiency gains are mixed, but on average it seems farms maintained their level of cost efficiency after adopting biotechnology-enhanced soybeans. Starting in 2007, farms, especially in the top quartile, begin to experience gains on average when adopting the genetically modified varieties of soybeans.

Ten years after biotechnology-enhanced soybeans were commercialized, those operations that have adopted biotechnology-enhanced soybeans make up the largest portion of the more cost efficient farms in this analysis. Of the total soybean acres reported being planted by the farms in this sample for 2011, the farms in the top two quartiles of cost efficiency reported planting a greater percentage of their soybeans to biotechnology-enhanced varieties. The percentage of farms in the top quartile of cost efficiency measures for this sample is made up mostly of farms that have previously adopted biotechnology-enhanced soybeans on their operations during the past decade. Given that in 2005 there were 13 farms in Quartile 1 that planted no soybeans at all that year, the relative performance of those actually planting soybeans who have adopted biotechnology-enhanced varieties on their operations is noticeable.

The adoption of genetically modified soybean varieties may provide labor savings; an opportunity to obtain off-farm income; allow labor resources to be devoted to other farm enterprises; provide additional flexibility with crop management; lower risk of the timing of operations; and provide a needed foundation for adopting no-tillage (Bonny, 2009 & 2011; Bullock & Nit Si, 2001). These spillover effects may enhance the farm's economic performance and in turn overall efficiency, offsetting any potential yield drags or other effects that may lower overall efficiency. The benefits of biotechnology-enhanced crops accruing to other farm enterprise performance may indeed contribute to the gains in cost efficiency that are found in this analysis and deserve further examination.

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Table 1. Number of sample Kansas farms with experience using biotechnology-enhanced soybeans, 1993-2011[a]

		Percent of Farms Adopting by Quartile			
Year	**Percent Farms Adopting** (*N* = 154)	**1st Quartile** (Top 25%)	**2nd Quartile** (25 to 50%)	**3rd Quartile** (51 to 75%)	**4th Quartile** (Bottom 25%)
1993	---	---	---	---	---
1994	---	---	---	---	---
1995	---	---	---	---	---
1996	6%	10%	8%	0%	5%
1997	19%	23%	23%	16%	16%
1998	25%	15%	23%	42%	18%
1999	31%	21%	38%	29%	37%
2000	34%	36%	28%	32%	42%
2001	53%	67%	51%	47%	47%
2002	55%	54%	51%	63%	50%
2003	60%	56%	64%	66%	53%
2004	60%	64%	69%	50%	55%
2005	62%	41%	67%	74%	66%
2006	63%	59%	74%	61%	58%
2007	63%	59%	69%	66%	58%
2008	63%	64%	64%	63%	61%
2009	65%	64%	74%	61%	61%
2010	68%	74%	74%	68%	55%
2011	69%	82%	72%	66%	58%

[a] Varieties of genetically modified soybean where not available in the market until 1996.

Table 2. Average cost efficiency measures of sample Kansas farms with and without adopting genetically modified soybean varieties

Year	All Farms	Farm Previously Adopting[a]	Farms Not Yet Adopting	Difference in Adoption Rates	1st Quartile (Top 25%)	2nd Quartile (25 to 50%)	3rd Quartile (51 to 75%)	4th Quartile (Bottom 25%)
1993	0.571	---	0.571	---	0.812	0.625	0.494	0.345
1994	0.630	---	0.630	---	0.877	0.669	0.555	0.411
1995	0.567	---	0.567	---	0.812	0.600	0.490	0.358
1996	0.543	0.578	0.535	8%	0.787	0.567	0.471	0.341
1997	0.627	0.640	0.622	3%	0.865	0.658	0.544	0.432
1998	0.563	0.541	0.573	- 6%	0.792	0.587	0.499	0.368
1999	0.443	0.408	0.461	- 11%	0.679	0.459	0.372	0.254
2000	0.456	0.453	0.459	- 1%	0.649	0.477	0.397	0.293
2001	0.527	0.549	0.499	10%	0.736	0.551	0.469	0.345
2002	0.531	0.530	0.531	0%	0.792	0.545	0.448	0.330
2003	0.556	0.554	0.560	- 1%	0.774	0.588	0.498	0.359
2004	0.471	0.488	0.443	10%	0.723	0.518	0.376	0.257
2005	0.218	0.190	0.267	- 29%	0.416	0.207	0.145	0.100
2006	0.560	0.563	0.554	2%	0.759	0.596	0.504	0.373
2007	0.373	0.374	0.371	1%	0.577	0.391	0.304	0.215
2008	0.496	0.500	0.489	2%	0.748	0.503	0.422	0.304
2009	0.537	0.549	0.513	7%	0.802	0.559	0.454	0.326
2010	0.397	0.413	0.359	15%	0.613	0.397	0.326	0.245
2011	0.457	0.478	0.409	17%	0.702	0.483	0.382	0.252

[a] Varieties of genetically modified soybean where not available in the market until 1996.