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Farm Management Implications of Transitioning from Conventional to Organic Production: An Application of Whole-Farm Linear Programming Model to Examine Transition Period

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Abstract

Over the past decade, organic farming has gained popularity among both consumers and producers. As producers consider the decision to shift from conventional to organic production, the farm management question asks under what price ratios can farmers be enticed to endure transition periods. Current rules require at least three years of organic production before the crop can be marketed as ‘organic’. Using a whole-farm linear programming (LP) model, these ‘non-productive’ transition years were modeled to examine the conditions that entice farmers to convert from conventionally grown corn. Results assist producers in making long term decisions with the objective to maximize returns to their operations. The LP base farm was parameterized using a central Illinois farm including local information on 1) production practices for a corn and soybean rotation, 2) yield penalties for plant and harvest date combinations, and 3) fieldwork probabilities. Preliminary results indicate that given expected price ratios of conventional commodities relative to a $11/bu organic corn price, producers would be willing to begin organic production.

Introduction]

While organic farming has been around for decades, it was not until the past 20-30 years that the organic industry really started to boom. As consumers' wealth started to grow, more consideration was placed on the quality of foods they purchased. This led to an increase in the demand for organically produced food both domestically and internationally. We have seen an increase in the marketing for organically produced foods in grocery stores, farmer's markets, and specialty stores as the organic industry takes up a larger portion of the food market. Consumer's propensity to purchase organically grown food will continue to rise as the number of organic options available for purchase continue to increase.

The percentage of organic farmland in production is still low considering the increase in demand for organically produced food. The 3-year transition period and the additional challenges associated with the transition to organic may make cause hesitation as producers consider the switch to organic production. The price of corn and other commodities continues to dip lower and lower, resulting in producers asking what else they can do to become more profitable. Some of those farmers look to organic production. The price of organic corn is higher than conventional corn, causing many to wonder if switching to organic production will allow them to become more profitable. However, the question still remains, how much does an organic premium have to be in order to entice producers to endure the 3-year transition period, and become certified organic producers? This study analyzes a farm in west central Illinois to determine at what organic price premium it would be logical for the farm to begin switching to organic production.

Literature Review

The profitability of organic farming versus conventional farming has been studied. Delbridge et al. (2011) used the University of Minnesota's Variable Input Crop Management Systems (VICMS) data to analyze the profitability between an organic input rotation versus a chemical input system and analyzed the cumulative distribution functions (CDF's) by stochastic dominance. They found that the per acre net returns for the organic system were significantly higher when the full organic price premium was applied. Delbridge et al. (2013) expanded upon this to examine profits under different machinery complements taking into account overhead costs. They applied stochastic dominance to intermediate optimization results to determine machinery complements and expanded upon the economic procedures in Delbridge et al. (2011) for net returns. They reported that with full organic premiums, the organic input rotation had higher average net returns than the chemical input rotation under all machinery complements. Delbridge (2014) updated these analyses to include the price influx in 2011 and 2012 as well as update the price and yield information and adjusted prices for inflation to 2012 terms.

Delate et al. (2009) reports economic findings from the long-term agroecological research (LTAR) site in Iowa which compared organic and conventional systems. Chavas et al. (2009) used data from the Wisconsin Integrated Cropping Systems Trial (WICST) to report risk analysis on organic and conventional systems. They used an econometric model to find the effect of government programs and organic price premiums and how risk affected net returns. Posner et al.

(2008) also use data from the WICST to report on the productivity of organic to conventional and found that on average, organic corn yielded 90% of conventional yield.

The use of linear programming (LP) to evaluate the profitability and viability of different farming operations has been used numerous times. Griffin and Lowenberg-DeBoer (2017) used a LP model to evaluate integration of mechanical weed control with banded herbicide application to control herbicide resistant weeds. In addition, Rosburg (2017) formulated a LP model to determine the timeliness of field operations from adding additional acreage to an existing farm. While, Wright et al. (2018) used the LP model to evaluate how federal policy impacts farm level production in the Lower Mississippi River Basin.

The need for organic research is greater now than ever as the organic industry has continued to grow and thrive over the past two decades. Total value of U.S. organic products sold in 2016 equaled $7.553 billion, up from $3.53 billion sold in 2011. The number of certified acres increased from 3,648,896 acres in 2011 to 5,019,496 acres in 2016, of which 2,409,869 were in cropland. (USDA, Organic Survey). Hughner et al. (2007) collected various reports surrounding consumer behavior and who purchased organic and reported the reasons why consumers do or do not purchase organic. Their findings found that the main reasons consumers purchase organic is the perceived health benefits from eating these products and the "quality" (taste) of organic is better while the driving factors behind not purchasing organic is high organic premiums and distrust of organic labeling. However, in-depth and extensive study of consumer behavior and the characteristics of the organic industry could be beneficial.

Model and Methods

In order to calculate the breakeven organic premiums needed, net present value (NPV) calculations were used. Data from a farm in west central Illinois was used for conventional yields and costs and a constant price of $3.26 was used for corn. Organic production was assumed to be 90% of conventional production (Posner et al. 2008). Direct expenses for organic were gathered from The Farm Financial Management Database (FINBIN). The NPV was taken every 5 years for 35 years which represented the length of time a farmer would be producing organic for three different scenarios (best, average, and worst). The best case scenario represented the highest level of profit a producer would receive if they switched to organic, while the worst case scenario represented the lowest level of profit a producer would receive. The average case scenario was somewhere in-between. The NPV was taken of both the net return (price multiplied by yield) and the costs, subtracted and summed over the years. This allowed the determination of what organic price made the sum of the NPV's equal. The organic price is comprised of the conventional corn price and the organic premium. Figure 1 presents these determined organic premiums necessary to break even.

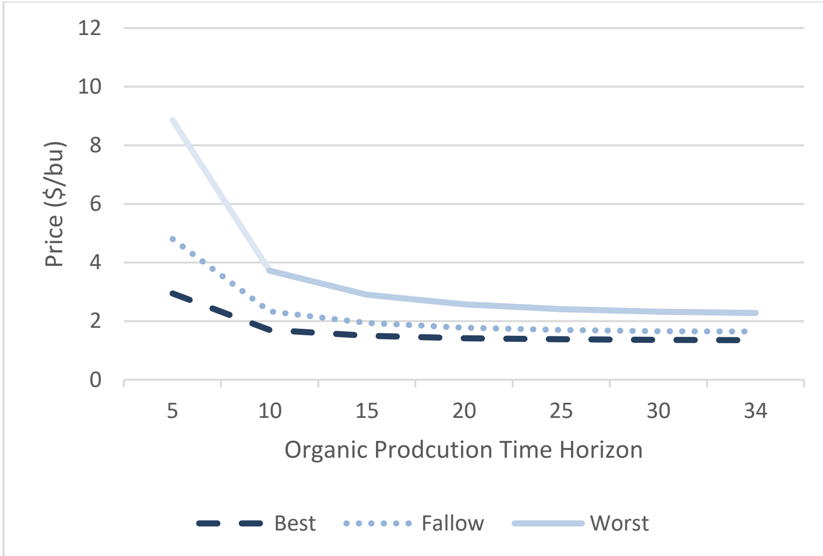

Figure 1 - Breakeven organic premium for three transition scenarios

Figure 1 depicts how the longer the time horizon, the smaller the organic premium would need to be in order for conventional and organic returns to match. If a farmer only produces organic in a given field for 5 years (3-year transition with 2 years certified organic) the organic premium that would be needed in order to recoup any losses (due to yield penalties) taken during those 3 transition years would need to be much higher than if the farmer produced organic for say, 10+ years. Figure 1 presents what the organic premium would need to be in order for the returns from organic production to be the same as conventional production over different time periods for each scenario. At the end of 5 years the organic premiums needed for each scenario vary substantially, from $2.95 for the best case scenario to $8.86 for the worst case scenario. However, as the time horizon is extended out to 30+ years, all scenarios, best, average, and worst, converge to within less than $1.00 of each other, $1.35, $1.64, and $2.28 respectively.

The whole-farm analysis of this research used a linear programming (LP) model to evaluate the potential profitability of systematically switching from a conventional row crop farm to an organic row crop farm. A LP model utilizes mathematics in order to optimize an objective function, often maximizing profit or minimizing costs. This analysis utilizes Purdue Crop/Livestock Linear Programming Model (PCLP) (Dobbins et al., 2001; Dobbins et al., 2006; Preckel et al., 1992) to maximize returns to a producer considering the switch from conventional production to organic production. This analysis uses a series of LP runs to evaluate various scenarios and the viability of switching to organic given different circumstances. Once the base farm had been properly parameterized, a series of LP iterations were run and analyzed.

The LP model can be written in standard summation notation as written in Boehlje and Eidman (1982, pp. 404-405) as:

(1) $$\text{Max} \prod = \sum_{j=1}^{n} c_j X_j$$

Subject to:

(2) $$\sum_{j=1}^{n} a_{ij} X_j \leq b_j \text{ for } i = 1 \ldots m$$

(3) $$X_j \geq 0 \text{ for } j = 1 \ldots n$$

Where:

X_j = the level of the j^{th} production process or activity,
c_j = the per unit return to the unpaid resources (b_i's) for the j^{th} activity,
a_{ij} = the amount of the i_{th} resource required per unit of the j^{th} activity, and
b_i = the amount of the i^{th} resource available.

The objective function (Equation 1) maximizes per unit net returns (c_j) from all activities (X_j). Equation 2 defines the constraints on how many units of each activity that can be in the optimal solution. The *j* activities include production of two crops, corn and soybean, grown in rotation. The *i* resources include 1) land available for crop production, 2) available labor expressed as combination of number of people, number of hours per day, and number of days suitable for fieldwork per period, and 3) the availability of machinery based on number of machines of each type, number of hours per day that the machine is available, and working rates expressed as acres per hour for each crop production task. The remaining variables *a* and *b* are the production process or activity resource requirements, and resource availability constraints, respectively. In all, there were nearly 1,000 constraints. The production season was segmented into 20 time period constraints; the most active planting and harvesting times were in one week increments and longer periods otherwise. Labor constraints were divided into unpaid and hourly wage earners. Equation 3 prevents negative production. (for addition details see Griffin and Lownberg-DeBoer, 2017.)

Base Farm for Whole Farm LP

The base farm was parameterized for a typical corn-soybean farm in west central Illinois. The 3,000 acre farm has four full time employees working 14 hours/day. All grain produced is stored and dried on farm. Weather constraints were modeled using days suitable for fieldwork (DSFW) (USDA NASS) for Illinois at the 20^{th} and the 40^{th} percentile best years in the spring and the fall, respectively as suggested in Dobbins et al. (2010). Expected long run prices for each crop were determined given local cash prices. Machinery resources are presented in Table A1 which are supplemented by 3 tractors, two of which are considered “large” and one is considered “small”.

The use of the implements depended on crop rotation and soil texture, but in general followed the sequence: chisel, field cultivate, plant, pre-emerge spray, and post-emerge spray. All conventional acres are fall chiseled and spring field cultivated with the addition of a vertical tillage tool brought through in the fall for conventional corn. Organic corn is field cultivated in the spring and then a rotary hoe is pulled through 3-5 weeks after planting to control any early blooming weeds. All yields, costs, and yield penalties were determined given historical data from the farms records.

Table A2 gives a description of field operations for all crops represented in the model. The list of machinery available is on the left, the different crops are along the top, and the values represent the time period that the respective field operations take place. For example, conventional corn is chisel plowed between the 18^{th} and 19^{th} time periods associated with the model. A description of the time periods can be found in Table A3.

Three different LP scenarios were run, collected, and analyzed after the base farm had been properly parameterized. Research indicates that long-term (3-5 years) organic yields can match up to 90-95% of conventional yields (Posner et al. 2008)). Therefore, Scenario 1 was a best case scenario in which the producer had 90% of conventional yield in all three years of transition and the first year organic. The price in the three transition years was the same as conventional prices and then the first year organic was assigned an organic premium. Scenario 2 was considered "average" in which they were not producing for a profit but would use the crop produced for something other than sale, i.e. livestock feed. Scenario 3 was a worst case scenario in which there was virtually no revenue from the three-year transition period meaning the producer would be operating at a net loss.

Results and Discussion

The base case resulted in a profit from operations of $1,113,344. Profit from operations decreased in each best, average, and worse cases by $69,297.04, $88,119.76, and $88,119.84 respectively. Table 1, presents the acres of each crop produced in each scenario. The best case scenario resulted in organic production of 727.4 acres while both the worst case and average case resulted in 0 acres of organic production. The average and worst cases resulted in the same crop mix and the same profit from operations.

Table 1 - Acre and profit results of LP model

	Acres Produced of each Crop				**Profit From Operations**
Scenario	Conventional Corn	Conventional Seed Corn	Conventional Soybeans	Organic Corn	
Best	186.2	1136.2	836.2	727.4	$1,044,046.96
Average	1286	950	650	0	$1,025,224.24
Worst	1286	950	650	0	$1,025,224.16

Table 2 depicts the organic corn price premiums needed to make organic production as profitable as conventional given a 10-year time horizon. A 10-year time horizon was selected based on Figure 1 above. A 5-year time horizon would not allow enough time to recoup losses (due to yield loss) while a time horizon of 20+ years would result in organic premiums nearing $0. A 10-year planning horizon allowed for enough time to begin to see profit from organic production while still seeing substantial organic premiums.

Table 2 - Breakeven organic corn premium

	Organic Corn Premium
Best	$4.95
Average	$5.57
Worst	$6.97

In order to remain timely and efficient, it's important that a producer is not under or over utilized when it comes to machinery. The limiting resource in all three of the LP scenarios were small tractors and the planter. Small tractors were especially limiting in the best case scenario due to the production of organic acres and the addition of the rotary hoe for the land preparations for organic acres. A shadow value, or marginal value, is defined as the amount of money one would pay for an additional unit of a resource. Table 3 presents the shadow values of the limiting resources. In this case, the shadow value of a piece of machinery would be the amount of money a producer would be willing to pay for an additional hour of use for the respective machinery. Therefore, the producer would be willing to pay $8,379.47 for an extra hour in a small tractor from April 26 to May 2.

Table 3 - Shadow values for machinery

	Small Tractors		Planter	
	Apr 22 – Apr 25	Apr 26 – May 2	Apr 22 – Apr 25	Apr 26 – May2
Best	$0	$8379.47	$8563.31	$0
Average	$4442.55	$4258.71	$0	$0
Worst	$4442.56	$0	$0	$4258.71

Conclusion

Organic production can be a viable option for producers wanting to be more profitable. The optimal decision depends on which scenario the producer is facing. It was profitable for the producer to transition to organic production under the best case scenario however, a higher organic premium or higher yields would be needed in order to make the average and worst cases feasible options. In addition, the results indicate that if the producer decided to transition to organic production, they would need to change their machinery inventory in order to remain timely and efficient.

This analysis has several limitations. First, it only considers transitioning to organic corn. Certified organic guidelines state that you must have sustainable rotations in place, therefore planting continuous organic corn is not feasible. Future analysis could include two or more organic crops to the rotation. Second, the analysis considers fairly simple land preparations for organic corn (only field cultivated and rotary hoe). An analysis including more extensive land preparations for organic production could be more representative. Lastly, this analysis only takes into account information from a single a farm in west central Illinois. Results may differ if different regions were included.

The organic industry continues to grow as consumers become more aware of how their food is grown. In addition, producers desire to be more sustainable with their production practices. These facets, coupled with decreasing commodity prices and low NFI could entice farmers to transition to organic production to become more sustainable while still increasing profits.

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Appendix

Table A1: Catalog of machinery implements

Machine	Width/Row	Number of Machines	Labor Hours per Machine Hour	Working Rate (acres/hour)
Dry fertilizer applicator*		1	1	66
Rotary Hoe*	30”	1	1	30.2
Chisel	17’	1	1	10
Chisel	15’	1	1	10
Anhydrous applicator	30”	1	1.5	20
Disc	40’	1	1	20
Field Cultivator	60’	1	1	40
Sprayer	80’	1	2	110
Vertical Tillage Tool	40’	1	1	10
Planter (corn)	30”/16 row	1	1.8	20.5
Planter (soybeans)	30”/16 row	1	1.8	25
Harvester (corn)	8 row	1	1.9	10.5
Harvester (soybeans)	30’	1	1.9	13.7

*Were not included in original machinery set but later added to supplement organic production

Table A2: Description of field operations

	Conventional Corn		Conventional Seed Corn		Conventional Soybeans		Organic Corn	
	Beginning Time Period	Ending Time Period	Beginning Time Period	Ending Time Period	Beginning Time Period	Ending Time Period	Beginning Time Period	Ending Time Period
Dry Fertilizer Applicator	-	-	-	-	-	-	1	2
Chisel Plow	18	19	16	17	19	20	-	-
Anhydrous	19	20	19	20	-	-	-	-
Disc	17	18	-	-	-	-	-	-
Field Cultivator	1	4	2	5	3	5	2	3
Sprayer	1	7	-	-	3	9	-	-
Rotary Hoe	-	-	-	-	-	-	6	11
Vertical Tillage	17	18	17	18	-	-	-	-

Table A3: Description of time periods (Dobbins et al. 2006)

Time Period	Associated Weeks
1	Dec. 6 – Apr. 21
2	Apr. 22 – Apr. 25
3	Apr. 26 – May 2
4	May 3 – May 9
5	May 10 – May 16
6	May 17 – May 23
7	May 24 – May 30
8	May 31 – Jun. 6
9	Jun. 7 – Jun. 13
10	Jun. 14 – Jun. 20
11	Jun. 21 – Jun. 27
12	Jun. 28 – Jul. 4
13	Jul. 5 – Jul. 11
14	Jul. 12 – Aug. 29
15	Aug. 30 – Sep. 19
16	Sep. 20 – Sep. 26
17	Sep. 27 – Oct. 10
18	Oct. 11 – Oct. 31
19	Nov. 1 – Nov, 14
20	Nov. 15 – Dec. 5