AGRICULTURAL ECONOMICS

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Cornhusker Economics

Precision Agriculture Adoption and Profitability

Market Report	Year Ago	4 Wks Ago	6-16-17
Livestock and Products, Weekly Average			
Nebraska Slaughter Steers, 35-65% Choice, Live Weight.	119.24	*	128.54
Nebraska Feeder Steers, Med. & Large Frame, 550-600 lb.	161.26	180.95	164.05
Nebraska Feeder Steers, Med. & Large Frame 750-800 lb.	145.42	158.50	153.77
Choice Boxed Beef, 600-750 lb. Carcass.	225.53	248.36	250.86
Western Corn Belt Base Hog Price Carcass, Negotiated	80.48	70.85	86.81
Pork Carcass Cutout, 185 lb. Carcass 51-52% Lean.	86.63	86.27	94.79
Slaughter Lambs, wooled and shorn, 135-165 lb. National.	143.29	159.83	NA
National Carcass Lamb Cutout FOB.	340.95	410.38	425.29
Crops, Daily Spot Prices			
Wheat, No. 1, H.W. Imperial, bu.	3.76	3.12	3.69
Corn, No. 2, Yellow **Columbus**, bu.	4.05	3.42	3.44
Soybeans, No. 1, Yellow **Columbus,** bu.	10.85	8.73	8.59
Grain Sorghum, No.2, Yellow Dorchester, cwt.	6.51	5.77	5.81
Oats, No. 2, Heavy Minneapolis, Mn, bu.	2.60	2.95	2.98
Feed			
Alfalfa, Large Square Bales, Good to Premium, RFV 160-185 Northeast Nebraska, ton.	165.00	128.75	135.00
Alfalfa, Large Rounds, Good Platte Valley, ton.	75.00	65.00	72.50
Grass Hay, Large Rounds, Good Nebraska, ton.	80.00	65.00	70.00
Dried Distillers Grains, 10% Moisture Nebraska Average.	156.00	103.50	100.75
Wet Distillers Grains, 65-70% Moisture Nebraska Average.	50.00	40.00	40.00

*** No Market**

Agricultural producers have increasingly adopted precision agriculture (PA) technologies over the past two decades. Agriculture Risk Management Survey (ARMS) data collected and analyzed by USDA (Schimmelpfennig) showed substantial adoption of various PA technologies, including yield monitoring and mapping, soil sampling and mapping, guidance systems, and variable rate technologies.

However, much of the rapid adoption of PA technologies has happened over the past several years during a period of increased farm profitability. Whether the adoption of PA technology drives increased profitability or whether increased profitability drives adoption is an important question. Recent research by Mike Castle, Brad Lubben, Joe Luck, and Taro Mieno at the University of Nebraska-Lincoln studied this question to assess the economic impact of PA technology adoption in cooperation with Tina Barrett and producer members of Nebraska Farm Business, Inc. (NFBI), a farm recordkeeping and analysis association. The research is encapsulated in Castle's M.S. thesis of December 2016 and provides the background for this discussion.

Castle's assessment of previous work on the impact of PA technology found the majority of studies looked at the returns from PA under hypothetical or simulated conditions, showing the potential or budgeted returns from technology adoption. But, the actual realized impact of PA technology adoption on profitability remained largely unanswered. By tying primary data on PA technology adoption collected through producer surveys with available, secondary financial data over time for a panel of NFBI producers, the research directly analyzed the question of PA technology adoption and farm profitability.

Precision Agriculture Adoption

The survey research provided estimates of adoption rates for various PA technologies for a sample of NFBI produc-

ers going back to the 1990s. PA technologies include those tied to operational efficiency, such as global positioning system (GPS) guidance, automated section control, and telematics. These technologies can improve efficiency through reduced overlap and input usage as well as real-time monitoring and reporting of equipment performance. Other PA technologies address productivity differences and variability within a field and include yield monitors, site-specific soil sampling, variable rate application of inputs, and crop imagery. These technologies can improve productivity and profitability by managing variability and targeting inputs more efficiently within a field.

Figure 1 measures the percent adoption of various PA technologies by the panel of NFBI producers since the mid-1990s. Several PA technologies have seen widespread adoption over time to the point that most producers are using them, including yield monitors (YM) with and without GPS; grid soil sampling (GSS); GPS-based guidance, including light bars (LB), auto-steer (AS); GPS-based automatic section control (ASC); and variable-rate application of fertilizers and seed. The PA technology adoption rates for the panel of NFBI producers are substantially higher than those reported in the USDA ARMS survey summarized by Schimmelpfennig. Producers in the NFBI program are more concentrated in crop production and are likely to be more progressive and management-oriented than average crop producers, so the differences in adoption rates are not necessarily surprising.

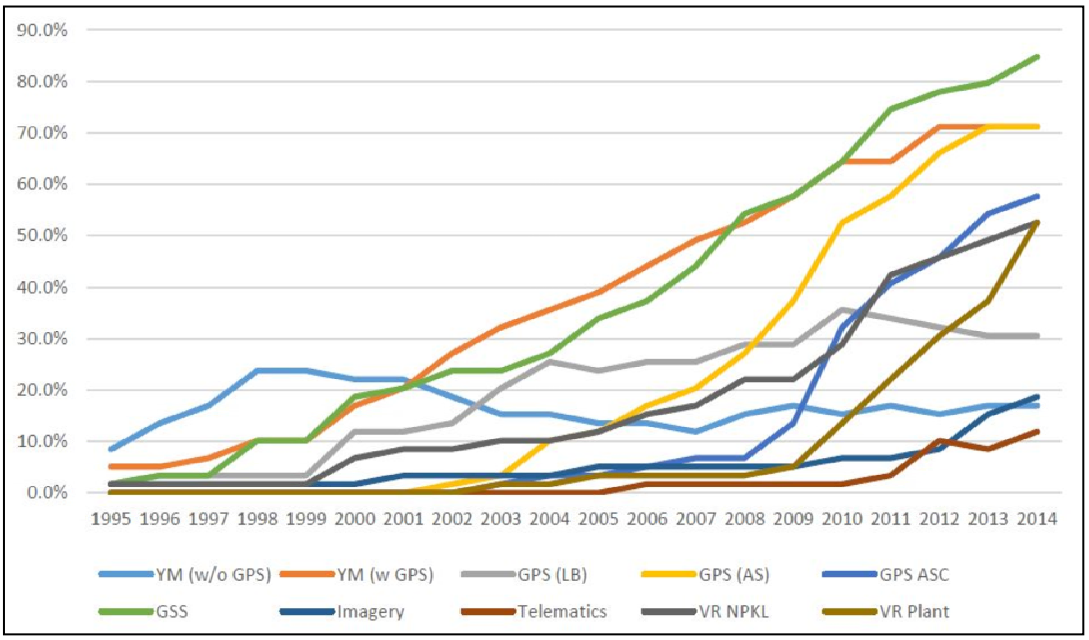

Figure 1. Percent Adoption of Precision Agriculture Technologies (from Castle)

With the widespread adoption of PA technologies over the past 20 years, the analysis can compare pre- and post-adoption factors and profitability across producers to assess the question of the economic impact of PA technology. The research utilized a fixed-effects panel data model to examine the effect of PA technology adoption on profitability while accounting for trends in the data over time and endogenous producer-specific effects.

Precision Agriculture Impacts on Profitability

Initial analysis focused on differences in profitability between adopters and non-adopters of PA technology by analyzing profitability against the number of PA technologies adopted. Several different measures of profitability or efficiency were analyzed, including net farm income (NFI), net farm income ratio (NFIR), and operating expense ratio (OER). Both ratios are financial ratios calculated as net farm income and operating expense respectively over gross farm income. While the interpretation of NFI is straightforward, NFIR is a measure of efficiency, specifically the ability to turn gross income into net income, with a higher ratio indicating increased efficiency. Similarly OER is an efficiency measure of the ability to turn operating inputs or expenses (less interest and depreciation) into gross income, with a lower ratio indicating increased efficiency. The initial regression analysis measuring the impact of adopting PA technology is shown in Table 1.

The parameter reported in Table 1 for NFI suggests that each additional technology adopted is associated with increased net farm income of more than $43,000, a measure that is statistically highly significant. The parameter estimates for NFIR and OER show expected results as well, with each additional technology associated with a 1.04 percentage point increase in NFIR or a 1.04 percentage point decrease in OER. However, the parameter estimates are less statistically significant, with neither achieving the standard measure of significance of α=0.05 (P-values of less than 0.0500).

In sum, the initial regression results suggest higher levels of PA technology adoption are associated with increased profitability. However, this initial analysis only shows a strong relationship between the two. Whether PA technology adoption drives profitability or whether profitability drives PA technology adoption (or whether they endogenously drive each other) remains a significant question.

To directly address the hypothesis that PA technology adoption drives profitability, the analysis looked at pre- versus post-adoption NFI within the panel data. An initial linear regression of technologies used by years used suggested a statistically significant and positive relationship, providing supporting evidence for the hypothesis. The analysis of technologies used and years used was taken further to study a polynomial regression model, recognizing that the impact of years used may not be linear, but may instead be sigmoid, or S-shaped, reflecting a learning curve associated with PA technology adoption. The learning curve can be representative of many different skills and certainly could describe PA technology, where the impact of adoption is initially small as knowledge or skill is gained or data is collected. Then, once sufficient data and skill are present, the gains from PA technology adoption could grow quickly to a point where the benefits are largely realized and further gains are limited.

Analyzing the pre- and post-adoption data with a polynomial regression model allows for the estimation of a learning curve in the economic impact of PA technology adoption. The results of the polynomial regression analysis are shown in Table 2.

The polynomial model shows increased statistical significance for the various explanatory terms as compared to the simple linear model, but the parameter estimates and significance of the interaction terms don't directly provide an interpretation. The real measure of significance is the marginal effect of an additional year of technology use on NFI calculated from the equation as a whole. The value of the marginal effect of PA technology adoption is demonstrated in Figure 2.

Table 1. Precision Agriculture Adoption Impact on Profitability Regression Results (from Castle)

Dependent Variable	Parameter Estimate	Standard Error	t-Value	P-Value
NFI	43,616***	10,495	4.1557	<0.0001
NFIR	1.0399	0.6964	1.4932	0.1359
OER	-1.0404*	0.4736	-1.8140	0.0701

Note: Each row represents the results of each respective regression. Parameter estimates indicate the estimated change in the given dependent variable from the use of an additional precision agriculture technology. Year dummy variables were also included in each regression to control for the time trend. ***indicates statistical significance at the α=1% level and * indicates significance at the 10% level.

Table 2. Precision Agriculture Adoption Impact on Net Farm Income Polynomial Regression Results (from Castle)

Variable	Parameter Estimate	Standard Error	t-Value	P-Value
Tech Use	70,697	45,394	1.5573	0.1199
Tech Use * Years Used	-11,855	13,427	-0.8830	0.3776
(Tech Use * Years Used)^2	2.635*	1,372	1.9199	0.0553
(Tech Use * Years Used)^3	-67.91	42.48	-1.5985	0.1104

Note: Year dummy variables were also included to control for the time trend. * indicates statistical significance at the α=10% level.

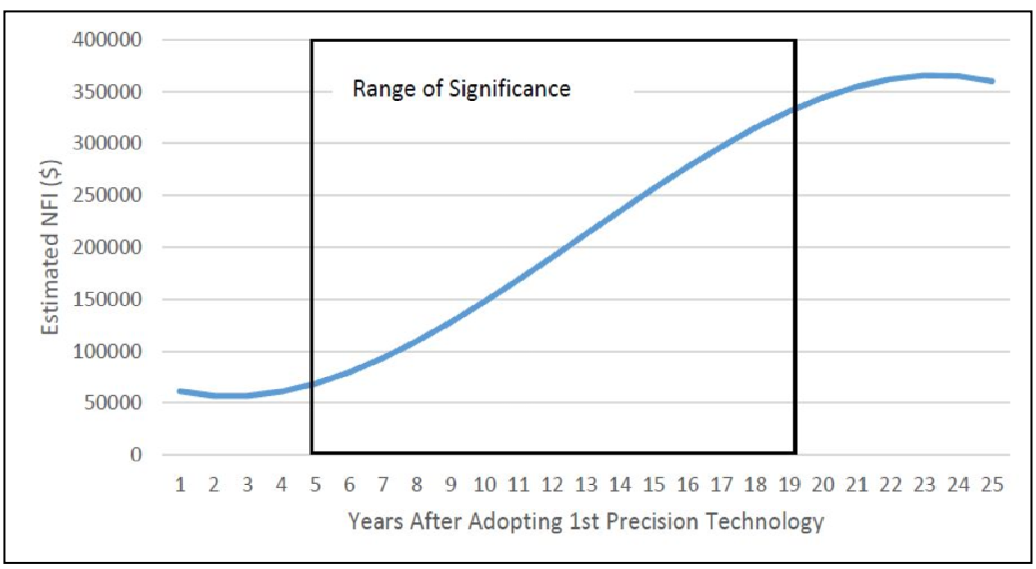

Figure 2. Estimated Change in Net Farm Income from Precision Agriculture Technology Use (from Castle)

The graph demonstrates the combined marginal effect and interaction of PA technology use and years used. It implies an initial period of time when the effect of PA technology adoption on NFI is statistically insignificant and could, in fact, be negative. While some technologies such as guidance and section control could improve efficiencies immediately upon adoption, others such as yield mapping would likely not provide sufficient information for management decision-making until a number of years of data are available. Considering the up-front cost of investing in PA technology (particularly if costs are expensed immediately for tax purposes as opposed to depreciated over time), it is not surprising to see a negligible or even negative impact on NFI from PA technology adoption. However, in time, the increased operational efficiency, data, and ability to make management changes may substantially improve NFI, with the model suggesting significant improvements in NFI from 5 to 19 years after adoption of initial PA technology before the impact levels off.

Conclusion

The overall economic impact of PA technology adoption remains unclear. The simple analysis of adoption versus non-adoption shows PA technology adoption is positively and significantly associated with higher profitability. However, the relationship alone does not prove causation nor indicate which drives which. Further analysis of pre- versus post-adoption shows positive estimated effects on NFI from PA technology adoption, although the results are not statistically significant. The polynomial regression analysis does demonstrate that the profitability of PA technology adoption increases with time (experience) as shown in Figure 2, but the overall impact on profitability remains statistically uncertain.

Further analysis with additional data or refined analysis of specific technologies or families of technologies (such as section controls or variable-rate applications) over time could provide more insight into the realized economic impacts of adoption. In general, prospective or ex ante analysis of technologies and practices can continue to provide insight and estimates of the potential economic impacts of adoption. To go beyond the potential returns, the more complex pre- and post-adoption analysis as used in this work can provide a better picture and a more complete perspective of the real economic impacts of adoption.

References

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Schimmelpfennig, D. "Farm Profits and Adoption of Precision Agriculture." ERR-217, U.S. Department of Agriculture, Economic Research Service, October 2016. Available at: https://www.ers.usda.gov/publications/pub-details/?pubid=80325.

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