Production Cost and the Sequential Adoption of Precision Technology

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Motivation:

Precision Agriculture (PA) refers to a suite of technologies advertising decreased input costs by providing the farm operator detailed production information that can be used to more nearly optimize management practices. In spite of potential cost-savings from the use of yield-monitoring harvesters, tractor guidance systems, GPS soil mapping, and variable rate input application, adoption has been far from universal. As the demand for high-yielding, high-profit agricultural production continues to surge, why has adoption been fairly low, especially for Variable Rate Technology (VRT)? Do farmers perceive the costs of precision technology to outweigh the benefits or are there other technical barriers to adoption? Some of these technologies are more widespread, so does this imply a hierarchy of adoption?

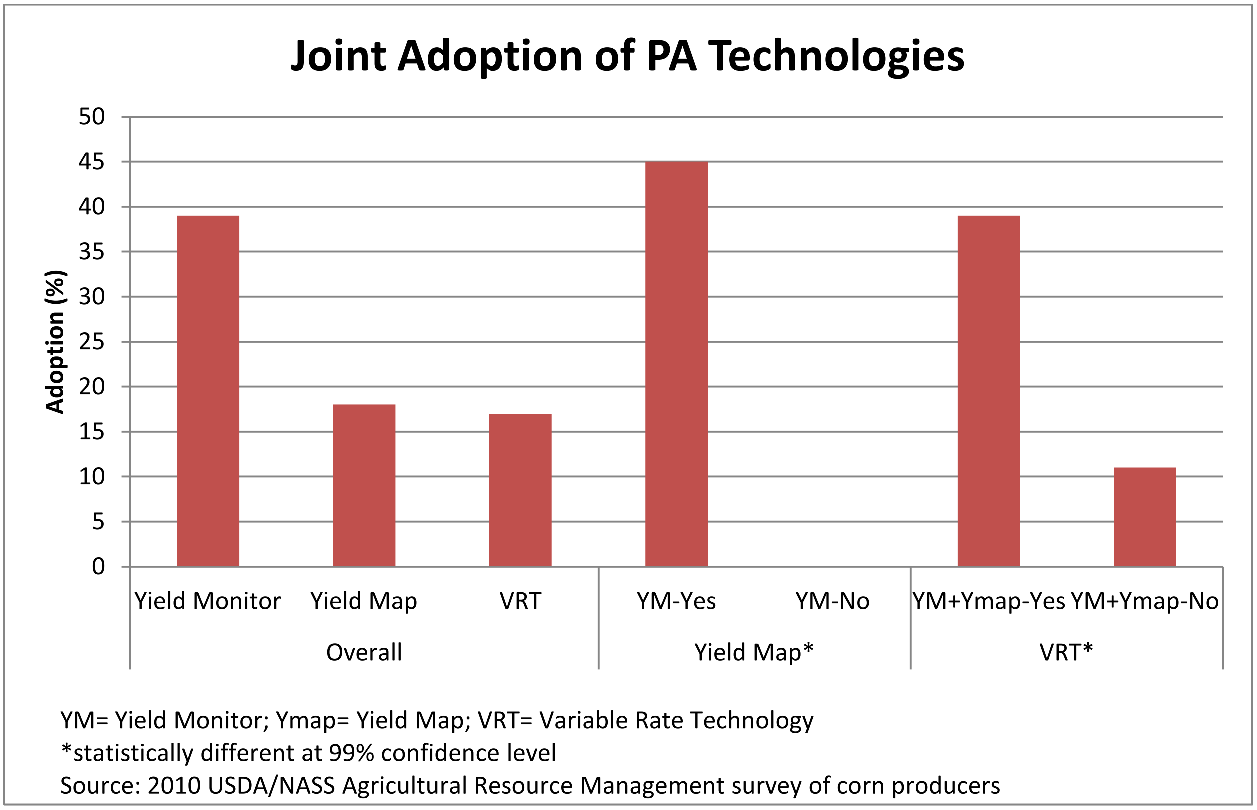
We consider PA technologies both independently and as a suite of complementary goods that each creates information that might be used with another precision technology (Bullock, et al., 2009). The implication of this approach is that while each technology may have value itself, it may be possible to multiply that value several times by combining it with other precision technologies. We explore different combinations of technologies and attempt to discern the characteristics of producers that adopt them and which technologies appear to increase the value of the information the most. These results are used to try to understand the observed lower VRT adoption rates.

Research Questions:

- Is adoption of PA sequential?
- What are the characteristics of different PA adopters?
- Does adoption of PA have an effect on costs?

ARMS Data:

We utilize the 2010 Agricultural Resource Management Survey (ARMS) of corn producers, which collected data on field-level production practices and farm finances. The ARMS collects crucial data on resources required for agricultural production—including seeds, fertilizer, pesticides, machinery, labor, and the use of information technologies, along with yields obtained (Phase II questionnaire) — and expenditures on inputs, as well as farm operator characteristics, such as educational attainment, age, and off-farm income (Phase III questionnaire). 1445 observations from the 2010 corn survey were available for this analysis. ARMS is conducted annually, surveying producers of a rotating set of commodity crops, and descriptive PA data for other years and crops can be found in Schimmelpfennig and Ebel (2011). The 2010 corn survey used in this analysis provides a comprehensive dataset with information on each corn farm's use of precision technologies, costs of production, and demographic profile.



Joint Technology Adoption Data Description:

The "overall" columns of the adoption percent bar graph show that yield monitor adoption is over twice as prevalent as either yield mapping or VRT. The "yield map" columns show that for those that have adopted yield monitoring, they are far more likely to have also created a yield map that relies on the collection and organization of their yield data. For those producers that take both of these steps, almost 40 percent also make use of VRT. Significant paired t-tests for differences in these mean adoption percentages argues for sequential adoption and an affirmative answer to the first research question posed in the motivation section.

Model:

Based on the adoption percentages presented in the previous section, we develop a treatment-effects model designed to exploit this information to reveal the effect of precision agriculture on production costs (Fernandez-Cornejo, 02). This approach allows us to construct profiles of precision technology adopters unlike previous analyses. The treatment-effects approach is necessary because some of the factors hypothesized to cause selection bias between groups of precision agriculture adopters and non-adopters include adoption of other technologies (including herbicide-resistant seed, soil nutrient testing and no-till), operator age and education, and farm size (Ebel and Schimmelpfennig, 2011). Implementing a series of treatment-effects models starting with yield monitoring, then for joint yield monitoring and yield mapping, and finally for these two technologies jointly with VRT allows us to control omitted variable bias from both endogenous and exogenous variables, as well as self-selection (Greene, 2007).

Results:

	Entry adoption (Yield Monitor)			**Intermediate adoption (Yield Monitor + Yield Map)**			**Advanced adoption (Yield Monitor + Yield Map + VRT)**	
AIC/N:	13.084			12.663			12.384	
Observations:	1445			1445			1445	
	Coefficient estimate	Std. Err.		Coefficient estimate	Std. Err.		Coefficient estimate	Std. Err.
Wald Treatment Effect Test	**-38.7163*** **	6.49794		**-33.535*** **	6.52272		**-1.83398**	14.59099
Selection (probit) equation:								
Constant	-0.40919***	0.12887		-.92368***	0.14974		-1.62687***	0.3843
Soil test	0.21258***	0.04978		.19070***	0.06092		.31556***	0.10881
GMO seed use	0.17157**	0.08005		0.16619	0.1061		.63214***	0.23371
Off-farm income	0.01711	0.02306		-0.00674	0.02761		-0.05666	0.05459
Operator age	-0.00441**	0.00178		-0.00366	0.00235		-.00908**	0.00462
Corrected (OLS) equation:								
Constant	159.776***	11.06396		192.740***	10.47725		248.871***	10.9073
Operation acreage	-0.00261**	0.00106		-.00268***	0.00085		-.00475***	0.00119
Irrigated	0.18476***	0.04706		.17899***	0.04205		.27232***	0.06034
Education	-9.41891***	2.61552		-8.40274***	2.45757		-12.6072***	2.73456
Yield Goal	0.60984***	0.05565		.56459***	0.05273		.47339***	0.05834
No-till	-23.8372***	5.50859		-22.5517***	5.53923		-31.5262***	6.60231
Based on analysis of data from the 2010 USDA/NASS Agricultural Resource Management survey of corn producers.								

This section focuses on discussion of three nested models of precision technology adoption (see “model” section), but models substituting soil testing based on global positioning systems (GPS) and guidance systems for yield mapping each gave very similar results. Yield mapping was chosen for presentation because of our intention to show that mapping capability could not have been ruled-out by farmers because of a lack of appropriate data – the farmers in these models had already adopted the yield monitoring technology that collects the necessary data. We present the case when VRT is added to yield monitoring and mapping but any of the three intermediate technology adoption formulations also gave very similar results.

The three treatment effects models that we discuss are estimated using full-information maximum likelihood and the same variables are used in each of the models. The models are identical formulations in that each of the sub-sections – sample selection probit and the corrected regression (Regime 1 in Bill Greene's vernacular) also each have the same variables in each of the nested models. The variables selected for the probit section of the maximum likelihood estimation of all three nested models presented in the table are soiltest, GMO, off-farm income, and farmer age:

- Soil testing is positive and significant in all three models as would be expected. GMO is positive in all three but not significant in the second model.
- Income is never significant which seems to indicate that affordability is less of a constraint on adoption than might be suspected.
- Older farmers are less likely to adopt but the effect is small.

The corrected regressions section of the maximum likelihood estimation of all three nested models give the main results of this analysis. The variables used in this section of the model and presented in the table are acres, irrigated, educational attainment, yield growth, and use of no-till:

- Yield monitoring and joint yield monitoring/mapping models show significant cost savings from the adoption of PA technologies.
- VRT when added to the joint formulation creating a three-tier adoption model is not significant. This may explain some of the lack of VRT adoption. When coupled with existing information technologies that are cost-saving, VRT does not show overall savings.
- In contrast, No-till has a strong negative impact on cost, meaning that farmers have found yield monitoring and joint yield monitoring/mapping to be complementary to No-till in reducing costs of corn production
- Larger farms also have reduced costs but the effects are small

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