THE USE OF BAYES' THEOREM TO EXPLORE THE ADOPTION OF HERBICIDE-TOLERANT COTTON SEED AND NO-TILLAGE PRODUCTION PRACTICES

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ABSTRACT

This paper examines the relationships between the adoption of no-tillage production practices in cotton and the adoption of herbicide-tolerant seed. Using Bayes' theorem, time series data on cotton tillage practices are compared to the planting of herbicide-tolerant cotton seed. Farmers who have already adopted no-tillage production practices have a higher probability of adopting herbicide-tolerant seed and farmers who have already adopted herbicide-tolerant seed have a higher probability of adopting no-tillage production practices. This result suggests that adoption of no-tillage production practices facilitates the adoption of herbicide-tolerant seed and that adoption of herbicide-tolerant seed facilitates the adoption of no-tillage production practices.

INTRODUCTION

The area under no-tillage production practices in the United States experienced steady growth and increased from 5.4 million acres in 1973 to 11 million acres in 1983 to almost 55 million acres in 2002 (International Soil Tillage Research Organization). In 1989, 5.1 million acres of corn and 4.8 million acres of soybean were planted using no-tillage production practices. By 2002, 15 million acres of corn and 26 million acres of soybean were planted using no-tillage technology. Adoption rates of no-tillage corn and soybean increased to 19.1% and 34.9%, respectively, in 2002 from around 7% in 1989. In Tennessee, diffusion of no-tillage increased to 61% of cropland acreage from 1983 to 2002, and rose more rapidly during the 1997-2002 period.

Weed control is a vital step for no-till adoption. Failure to control weeds when using no-tillage production systems will result in decreased output and lower quality and may even impact crop harvest. Herbicide-tolerant cotton varieties have been developed using genetic engineering techniques. Crops that carry herbicide-tolerant genes were developed to survive certain herbicides that previously would have destroyed the crop along with the targeted weeds. With herbicide-tolerant crops, farmers have a wider range of chemical herbicides from which to select (Fernandez-Corne and Mcbride, 2002).

Herbicide-tolerant cotton varieties provide farmers with effective weed control programs that eliminate some of the problems associated with conventional programs. Until 1995, cotton farmers did not have any broadleaf herbicides that could be used over a growing cotton crop without causing crop injury. With the introduction of herbicide-tolerant cotton, farmers could use a broad-spectrum herbicide over the growing cotton with minimal cotton injury. The introduction of herbicide-tolerant cotton varieties has led to a reduction in the number of herbicide applications made by cotton farmers (Janet E. Carpenter, 2001). Thus, farmers who use no-tillage production practices may benefit if adopting herbicide-tolerant crops allows them to use a more effective herbicide treatment system (Robbin Shoemaker, 2001).

Jaffe et al (2000) pointed out that diffusion is the process by which a successful innovation gradually becomes broadly used through adoption by firms or individuals. This process generally results in an S-shaped diffusion curve (Griliches 1957). After a slow start in which only a few farmers adopt the innovation, adoption expands at an increasing rate. Eventually, the rate of adoption tapers off as the number of adopters begins to exceed the number of potential adopters who have not yet adopted the innovation. Finally, the adoption rate approaches its asymptotic maximum and the process ends. No-tillage production practices and herbicide-tolerant cotton seed adoption both follow the well-known diffusion process. However, compared with the diffusion curve for herbicide-tolerant (HT) cotton seed, diffusion curve for no-tillage cotton is flatter and the rate of diffusion was slower (Figure 1).

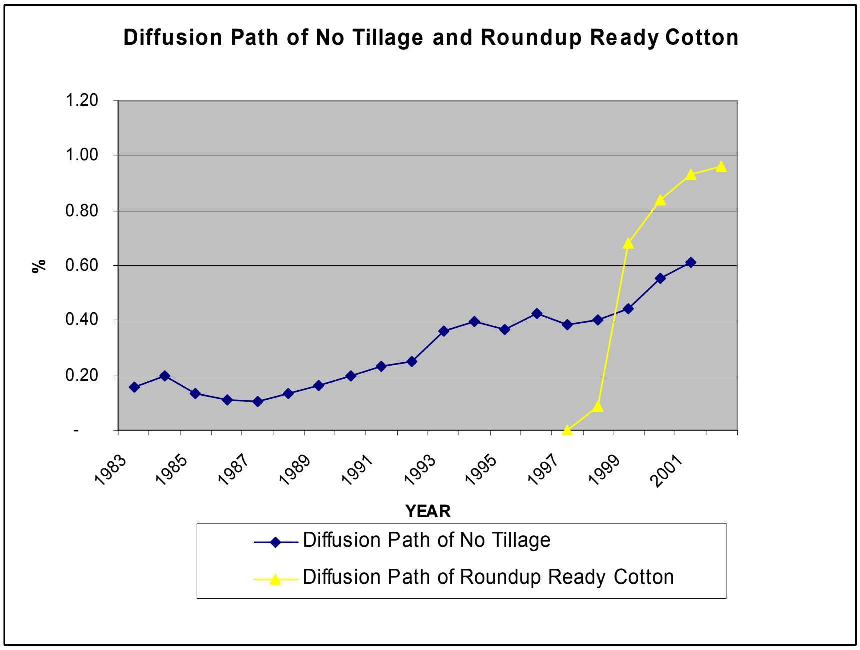

Figure 1. No-tillage and herbicide-tolerant crop technology adoption by cotton farmers

Methods

A conditional probability is defined as the probability of an event given that another event has occurred, the probability that event B occurs, given that event A has already occurred is stated mathematically in equation (1),

$$P(B|A) = P(A \text{ and } B)/P(A) \quad (1)$$

where P(B|A) is the probability of event B occurring given the fact that event A has already occurred, P(A and B) is the probability of events A and B occurring together, and P(A) is the probability of event A occurring. Bayes' Rule allows the order of conditional probabilities to be reversed. Many (but not all) conditional probability problems are of this type. Bayes' Rule states that

$$P(B|A) = \frac{P(B)P(A|B)}{P(B)P(A|B) + P(\bar{B})P(A|\bar{B})} \quad (2)$$

where $P(\bar{B})$ is the probability of the complement to event B occurring. And according to Bayes' Rule, a posterior probability exists,

$$P(A|B) = \frac{P(A)P(B \mid A)}{P(A)P(B \mid A) + P(\bar{A})P(B \mid \bar{A})} \quad (3)$$

In this analysis, attention is given to two events, the adoption of no-tillage production practices and the adoption of herbicide-tolerant seed. A conditional probability of P (H|N) is the probability that a farmer adopts herbicide-tolerant seed (H), given that the farmer has already adopted no-tillage practices (N). Another conditional probability exists (P (H|$\overline{N}$) and is defined as the probability that a farmer adopts herbicide-tolerant seed, given that the farmer has not adopted no-tillage practices. Thus, the two conditional probabilities can be written as,

$$P(H|N) = \frac{P(H)P(N \mid H)}{P(H)P(N \mid H) + P(\bar{H})P(N \mid \bar{H})} \quad (4)$$

and

$$P(H|\overline{N}) = \frac{P(H)P(\overline{N} \mid H)}{P(H)P(\overline{N} \mid H) + P(\bar{H})P(\overline{N} \mid \bar{H})} \quad (5)$$

If the two conditional probabilities are the same, the adoption of no-tillage practices did not influence the adoption of herbicide-tolerant seed. If the first conditional probability is greater than the second, the farmer who adopts no-tillage practices is more likely to adopt herbicide-tolerant seed than a farmer who does not adopt no-tillage practices.

According to Bayes' Rule, the posterior probabilities, P (N|H) and P (N|$\overline{H}$) can be calculated as,

$$P(N|H) = \frac{P(N)P(H \mid N)}{P(N)P(H \mid N) + P(\bar{N})P(H \mid \bar{N})}, \quad (6)$$

and

$$P(N|\overline{H}) = \frac{P(N)P(\overline{H} \mid N)}{P(N)P(\overline{H} \mid N) + P(\bar{N})P(\overline{H} \mid \bar{N})}, \quad (7)$$

where P (N|H) is the probability of adopting no-tillage practices given adoption of herbicide-tolerant seed and P (N|$\overline{H}$) is the probability of adopting no-tillage practices given non-adoption of herbicide-tolerant seed. The Bayes' posteriors will be used to evaluate whether adoption of herbicide-tolerant seed has an influence on adoption of no-tillage production practices.

Data used in the analysis were taken from Doane AgroTrak for 1998 through 2002. The Doane AgroTrak data contain information about the number of Tennessee cotton acres in no-tillage production practices and herbicide-tolerant seed, as well as the number of cotton acres in both no-tillage production practices and herbicide-tolerant seed.

RESULTS

The results show that over the years the percentage of cotton acres in herbicide-tolerant seed that was also no-tilled (P (H|N)) is greater than the percentage of cotton acres in herbicide-tolerant seed that was not no-tilled (P (H|$\overline{N}$). This result suggests that farmers who have adopted no-tillage practices have a higher probability (.96 < .71 in 2000) of adopting herbicide-tolerant cotton seed, which further suggests that the diffusion of herbicide-tolerant cotton seed has been faster with farmers who have adopted no-tillage practices that farmers who have not

Table 2. Comparison between herbicide-tolerant cotton adoptions given no tillage and given non-no-tillage practice

	1998	1999	2000	2001	2002
RR Pct ---P(H)	0.09	0.68	0.84	0.93	0.96
No-tll Pct---P(N)	0.10	0.47	0.51	0.72	0.67
RR No-till Pct--P(HN)	0.05	0.38	0.49	0.71	0.66
Non-RR No-till Pct	0.05	0.09	0.02	0.01	0.01
P(H|N)	**0.50**	**0.81**	**0.96**	**0.99**	**0.99**
P(H| $\overline{N}$)	**0.04**	**0.56**	**0.71**	**0.78**	**0.90**

adopted no-tillage practices.

The posterior probability P (H|N) suggests that farmers who have adopted herbicide-tolerant seed have a higher probability of adopting no-tillage practices than do farmers who have not

Table 3 Comparison between No-tillage adoption given herbicide-tolerant cotton seed and given non- herbicide-tolerant cotton seed adoption

	1998	1999	2000	2001	2002
RR Pct ---P(H)	0.09	0.68	0.84	0.93	0.96
No-till Pct---P(N)	0.10	0.47	0.51	0.72	0.67
RR No-till Pct--P(HN)	0.05	0.38	0.49	0.71	0.66
Non-RR No-till Pct	0.05	0.09	0.02	0.01	0.01
P(N|H)	**0.56**	**0.56**	**0.58**	**0.76**	**0.69**
P(N| $\overline{H}$)	**0.05**	**0.28**	**0.12**	**0.14**	**0.25**

adopted no-tillage practice (.58 > .12 in 2000).

CONCLUSIONS

In general, the probability analysis explores the relationship between adoption of herbicide-tolerant seed and adoption of no-tillage production practices. The data indicate that farmers who have already adopted no-tillage production practices have a higher probability of adopting herbicide-tolerant seed and farmers who have already adopted herbicide-tolerant seed have a higher possibility of adopting no-tillage production practices. The results suggest that no-tillage production practices encourage farmers to adopt herbicide-tolerant seed and herbicide-tolerant seed technology facilitates the adoption of no-tillage production practices.

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