Appendix III. Using Whole-Farm Data To Model the Financial Impact of Adoption

The impact of the adoption of GE crops on farm financial performance is assessed by statistically controlling for several other factors that may also affect financial performance. That is, the effect of economic and environmental conditions, management practices, and operator characteristics are accounted for in order to isolate the effect of GE crop adoption on farm financial performance. To control for factors other than GE crop adoption, multiple regression is used in a two-stage econometric model of adoption and the adoption impact. The first stage of the model consists of an adoption-decision model that describes what factors influence the likelihood of adopting GE crops. Results of the first stage provide input for the second stage model that is used to estimate the impact of GE crops on farm financial performance.

In this study, the first stage of Heckman's technique involves the estimation of a GE crop adoption model using the probit analysis. Estimated parameters from the probit model are then used to calculate the predicted probabilities $(\hat{P}_i)$ of adopting GE crop technology. Addressing the simultaneity and self-selectivity concerns when estimating farm net returns is accomplished by appending to the basic regression explaining financial performance the predicted probabilities $(\hat{P}_i)$ of adopting GE crop technology and the inverse Mills ratio $(\hat{\lambda}_i)$ as additional regressors, as in the following:

$$\Pi_i = \beta_0 \Sigma \beta_j X_{ij} + \gamma_1 \hat{P}_{i1} + \varsigma_{i1} \hat{\lambda}_{i1} + \varepsilon_i$$

where Π is a vector denoting net returns (see page 54 for exact measure used); X, a matrix of exogenous variables affecting the farm's financial performance, and ε_i is a vector of errors. This model allows for the estimation of net returns using least squares when the technology adoption decision involves only one choice. In the case when multiple and independent technology choices are involved, it can be extended to reflect these additional choices by appending both the separate predicted probabilities reflecting these choices.

Data. The data used in this study are from phase 3 of USDA's 1998 Agricultural Resource Management Study (ARMS) described in Box 3. The definition of a farm, and thus the target population of the ARMS, is any business that produces at least $1,000 worth of agricultural production during the calendar year. The farm population of interest in this study includes those that grew corn or soybeans during 1998. The ARMS data include information about the financial condition and management of the operation; demographic characteristics; and management and marketing strategies used on the operation. Important to this study is that the 1998 survey included questions about the extent to which GE technologies were used in the farm business. Producers were asked for each crop grown, whether they planted GE seed and, if so, what type of seed was planted and on how many acres it was planted. The adoption of GE crops was defined in cases where herbicide-tolerant soybeans, herbicide-tolerant corn, and Bt corn were used. The analysis of the impact of the adoption of GE corn (soybeans) was conducted on two segments of the farm population: (1) operations that harvested one or more acres of corn (soybeans), and (2) operations that specialized in the production of corn (soybeans). Specialized corn (soybean) farms were defined as those on which corn (soybeans) accounted for more than 50 percent of the total value of farm production. The population of specialized farms was examined in addition to all growers because the impact of GE technologies on farm financial performance is likely to be greatest on operations that specialize in the target commodities.

Spatial variation in the impact of GE crop adoption was examined using the ERS farm resource regions (see box 1). Because pest infestations differ across the U.S., one would expect that the impacts of pest control measures such as GE crops to be greatest where target pest pressures are most severe. Research suggests that the value of Bt corn relative to conventional varieties increases as one moves from east to west in the Corn Belt, because ECB infestations are much more frequent and severe in the western Corn Belt (Hyde et al., 2000). Also, weed pressure tends to be greatest in the Eastern and Southern U.S. because of the hot, moist climate and the longer growing season. Therefore, the expected value of herbicide-tolerant crops would be greater in these areas because of higher conventional weed control costs. The farm resource regions are used to reflect agro-climatic variation across the U.S. and the differences in pest pressures this creates. One change to the regional delineation is that the Heartland is divided along the Mississippi River into the East Heartland and the West Heartland (see box 1). This change better reflects the difference in weed and ECB pressure between these areas.

Variable Specification and Estimation. The adoption-decision model was estimated by a probit analysis of GE crop adoption for each of the corn and soybean farm populations (i.e. all growers and specialized operations). Separate models were estimated for (1) herbicide-tolerant corn, (2) Bt corn, and (3) herbicide-tolerant soybeans. The models were specified using variables that have shown to be related to technology choice in the previous literature (Feder, Just, and Zilberman 1985; Feder and Umali, 1993). Variables regressed against the decision to adopt each technology included operator education, age, primary occupation, risk preference, management level, farm size, specialization in the target commodity, and land tenure (appendix table 3.1). Operator preference toward risk was specified using a risk index constructed according to farmers' answers to a series of survey questions about how they react toward risk, including the use of risk management tools (Bard and Barry, 1998). The operator's management level was specified as higher if the operator reported the use of budgeting or other recordkeeping methods to manage cash flows or control costs. Variables for geographic location were also included in the model to account for the impact that differences in soil, climate, production practices, and pest pressures would have on adoption.

The adoption-impact model was next estimated for each of the farm populations by regressing the same set of explanatory variables, plus other information obtained from the decision model, on alternative measures of farm financial performance. Several measures of farm financial performance were examined, but results are reported for only two measures, modified net farm income (MNFI) per tillable acre, and crop operating margin (RACS) per tillable acre. MNFI and RACS were measured as:

MNFI = Net Farm Income (NFI) + Interest Expense, where:

NFI = Gross Farm Income - Total Farm Operating Expenses (excluding marketing expenses),

Gross Farm Income = Gross Cash Farm Income + Net Change in Inventory Values + Value of Farm Consumption + Imputed Rental Value of Operators Dwelling,

Total Farm Operating Expenses = Total Cash Operating Expenses + Estimated Non-Cash Expense for Paid Labor + Depreciation on Farm Assets; and:

RACS = Gross Value of Crop production – Total Farm Chemical and Seed Expenses,

where gross value of crop production is the production of each crop commodity produced on the farm operation valued at the State-average price received by farmers (USDA, NASS, 1999a). To ascertain the impact of GE crop adoption on financial performance, the predicted probabilities of adoption estimated from the adoption-decision model were also included in the adoption-impact model. Because technology adoption and farm financial performance are jointly determined, the predicted probability of adoption for each technology provided an instrument for the adoption decision that mitigates bias due to simultaneity concerns (Zepeda, 1994). The predicted probabilities were also specified as interaction terms with the geographic location variables. These interaction terms provided a means by which regional differences in the financial impact of adoption could be evaluated. A hypothesis is that regions with greater pest pressures would benefit more from GE crops than other regions. Selectivity variables for each technology were also estimated and added to the adoption-impact model to allow for unbiased and consistent parameter estimates (Lee, 1983). Heckman's two-step procedure (1976) was used to estimate the two-equation model, using weighted regression procedures and a jackknife variance estimator (Dubman, 2000).

Results. Probit parameter estimates for the herbicide-tolerant and the Bt corn adoption-decision models are presented in appendix table 3.2, while parameter estimates for the herbicide-tolerant soybean adoption-decision models are shown in appendix table 3.3. The overall fit of the models was better, as indicated by the higher log-likelihood values (less negative), for the population of specialized corn and soybean producers than it was for all producers of each crop.

The adoption of herbicide-tolerant corn among all corn growers was significantly influenced by many operator characteristics, including age, education, and farm occupation (appendix table 3.2). Greater education, higher age, and having farming as a major occupation were associated with a higher likelihood of adopting herbicide-tolerant corn. These results are consistent with adoption literature, except that older farm operators generally have a lower likelihood of adopting new technologies. The adoption of herbicide-tolerant corn was also more likely among growers in the Western Heartland region relative to those in the Eastern Heartland (the deleted group). However, when the population was restricted to specialized corn operations, the only significant factor was a higher probability of adopting herbicide-tolerant corn in the Northern Crescent region.

Operator characteristics were less important in explaining the adoption of Bt corn, but farm size, specialization, operator risk perception, and region were significant (appendix table 3.2). The likelihood of adopting Bt corn increased (at a decreasing rate) as farm acreage increased. This relationship between farm size and technology adoption is consistent with most adoption literature. Also, increasing a farm's specialization in corn production increased its likelihood of adopting Bt corn. Coefficients on the risk perception variable indicate that more risk-adverse producers were more likely to adopt the Bt technology. While this result is counter to the common profile of technology adopters as more risk taking, the more risk-adverse producers may be attracted to the Bt corn technology because of the insurance it offers against the threat of ECB infestations. Producers in the Western Heartland region were also found to be more likely to adopt Bt corn than were producers in the Eastern Heartland. This result was expected due to higher rates of ECB infestations in portions of the Western Heartland.

In contrast to corn, very few of the variables in either the model for all soybean growers or the model for specialized soybean growers were significant (appendix table 3.3). A possible reason for this lack of explanatory power is the significant diffusion of this technology across the population. Farm adoption rates for herbicide-tolerant soybeans in this study, 37 percent of all soybean farms and 35 percent of specialized soybean farms, were significantly greater than for the other technologies. Thus, the adoption of herbicide-tolerant soybeans has progressed past innovator and early adopter stages into the realm where adopting farmers are much more like the majority of farmers (Rogers, 1995).

Parameter estimates for the adoption-impact models for corn are presented in appendix table 3.2, while those for soybeans are shown in appendix table 3.3. The overall model fit was very poor for both corn and soybean populations that included all producers, with an R-squared ranging from 0.03 to 0.10 among these models. Goodness of fit improved among the specialized corn and soybean populations, but was substantially lower for MNFI than for RACS. This result was not surprising since MNFI accounted for the costs and returns of all farm enterprises, while RACS included only crop returns and the costs that would be most impacted by the adoption of GE crops. Overall, the model fit was best for the RACS model estimated on the populations of specialized corn farms and specialized soybean farms (R-squared of 0.36 and 0.33, respectively).

Nearly all of the explanatory variables were insignificant in both adoption-impact models estimated on the population of all corn producers, and on the model using MNFI among specialized corn producers (appendix table 3.2). The impact of GE crop adoption was not significantly different from zero in any of these models. However, several factors, including GE crop adoption, were found to affect RACS on specialized corn farms. RACS increased with size of operation (at a decreasing rate), increased with operator age, and was higher for producers who more actively managed risk. Farm location was significant, and indicated that the RACS was lower among specialized corn farms in regions outside of the Heartland.

The impact of GE crops on the RACS of specialized corn farms varied by region. To illustrate the impacts, elasticities were estimated to show the percentage change in RACS from a change in the probability of adoption. The elasticity of 0.27 for the adoption of herbicide-tolerant corn on all specialized corn farms indicates that as the probability of adoption increases by 10 percent, RACS increases 2.7 percent. The greatest impact of the adoption of herbicide-tolerant corn was in the Eastern Heartland, where a 10-percent increase in the probability adoption increases RACS by 4.1 percent, significantly greater than in most other regions. This result was not unexpected due to relatively high weed pressures in the East. In contrast to herbicide-tolerant corn, the adoption of Bt corn resulted in a decrease in RACS among the specialized corn farms. The overall elasticity of -0.34 suggests that as the probability of adoption increases 10 percent, RACS declines by 3.4 percent. The negative impact of adoption was significantly less in the Western Heartland compared with the Eastern Heartland (-0.46 versus -0.27), as expected, because of greater pressure by the ECB in portions of the Western Heartland.

Very few explanatory variables were significant in the adoption-impact models for soybeans (appendix table 3.3). The most notable result for soybeans was that the adoption of herbicide-tolerant soybeans had a significant and negative impact on MNFI. This result varied little by region, except that among specialized soybean farms, adoption resulted in a lower MNFI in the Mississippi Portal region than in the Eastern Heartland.

Appendix table 3.1—Means and definitions of variables, financial impact model, 1998

Variables	Definition	Corn (at least one harvested acre)	Corn (specialized operations)	Soybean (at least one harvested acre)	Soybean (specialized operations)
EDYEARS	Education of farm operator (years)	12.99	13.42	13.03	12.77
OPAGE	Age of farm operator (years)	51	50	50	50
OCCUPF	Occupation of farm operator (1= farming; 0 otherwise)	0.68	0.55	0.65	0.42
SIZE	Farm size, measured as total harvested acres (100 acres)	4.44	4.47	4.82	2.94
SIZESQ	Farm size, squared	59.25	54.06	65.64	31.08
SPECIALIZ	Value of sales of relevant commodity / Total value of sales	0.30	—	0.40	—
RISKPERCP	Operator's risk perception (index:10=least, 50=most risk taking)	28.37	27.83	28.62	30.79
BUDGET	Operator's management level (`= use budgeting or other record keeping to manage cash flow and/or control cost; 0 otherwise)	0.74	0.76	0.72	0.55
TENURE	Rented acres / Total operated acres	0.61	0.61	0.55	0.61
HRTLNDW	Farm location (1= West Heartland; 0 otherwise)	0.30	0.42	0.31	0.23
NCRESCNT	Farm location (1= Northern crescent; 0 otherwise)	0.24	0.12	0.15	0.14
PRGATEWY	Farm location (1= Prairie Gateway; 0 otherwise)	0.07	0.06	—	—
MISSPORT	Farm location (1= Mississippi Portal; 0 otherwise)	—	—	0.04	0.06
OTHREGN[1]	Farm location (1= other crop producing region; 0 otherwise)	0.15	0.06	0.15	0.08
MNFI	Modified net farm income per tillable acre ($)	101.47	82.23	99.07	65.40
RACS	Crop value less cost of chemicals and seed per tillable acre ($)	163.87	206.48	170.38	162.71
ADOPT_HT	Herbicide-tolerant seed (1= adoption; 0 otherwise)	0.05	0.06	0.37	0.35
ADOPT_Bt	Bt seed (1= adoption; 0 otherwise)	0.20	0.30	—	—
Sample size		2,719	535	2,321	395
Population		460,210	118,158	400,542	112,975

Note: *ADOPT_HT*=1 and *ADOPT_Bt*=1 include a small fraction of farms that used stacked=trait seeds.

[1] *OTHREGN* in the case of corn includes Northern Great Plains, Eastern Upland, Southern Seaboard, Fruitful Rim, and Basin and Range regions, and in the case of soybeans includes Northern Great Plains, Prairie Gateway, Eastern Upland, Southern Seaboard, Fruitful Rim, and Basin and Range regions.

— = Not applicable

Appendix table 3.2—Regression estimates of the financial impact model in corn production, 1998

Variables	Corn (at least 1 harvested acre)		Corn (specialized operations)	
	MNFI[1]	*RACS*[2]	*MNFI*[1]	*RACS*[2]
INTERCEPT	285.87	146.07	47.04	372.58***
EDYEARS	5.17	-21.55	10.50	0.10
OPAGE	-1.25	1.56	2.31	1.05***
OCCUPF	52.38*	-4.40	-14.15	-21.29
SIZE	-1.53	-12.23	6.01	4.76***
SIZESQ	0.06	0.18	-0.07	-0.05***
SPECIALIZ	-33.90	56.42	—	—
RISKPERCP	-5.77	1.87	-6.49	-7.69***
BUDGET	8.90	51.55	8.91	26.46
HRTLNDW	117.63	-62.78	49.73	17.69
NCRESCNT	18.27	97.42	31.21	-99.97***
PRGATEWY	138.03	-25.51	-18.59	-108.72***
OTHREGN[3]	25.53	24.21	216.55	-96.97***
PHT[4]	-655.40	961.73	126.73	1402.03***
PBt[5]	-309.58	840.17	-345.66	-319.70***
*PHT*HRTLNDW*	100.67	-504.50	-114.24	-731.63***
*PHT*NCRESCNT*	-1215.14	1660.49	-1144.22	-812.51**
*PHT*PRGATEWY*	128.54	-1413.79	352.02	-325.27
*PHT*OTHRREGN*	-1425.66	30.13	-212.97	-746.41*
*PBt*HRTLNDW*	-50.94	-290.62	36.53	131.65*
*PBt*NCRESCNT*	436.13	-1265.58	402.22	155.08
*PBt*PRGATEWY*	-361.46	120.11	-27.54	97.76
*PBt*OTHREGN*	375.03	-135.87	-900.09*	-15.29
LAMBDAHT	-9.59	0.19	-3.99	3.47
LAMBDABt	6.09	3.92	-0.98	16.31***
R^2	0.02	0.003	0.07	0.36
Sample size	2,719		535	
Population	460,210		118,158	

[1] *MNFI* denotes modified net farm income per tillable acre.
[2] *RACS* denotes returns above cost of chemicals and seed per tillable acre.
[3] *OTHREGN* includes Northern Great Plains, Eastern Uplands, Southern Seaboard, Fruitful Rim, and Basin and Range regions.
[4] *PHT* is the predicted probability of adopting herbicide-tolerant corn estimated from the adoption-decision model.
[5] *PBt* is the predicted probability of adopting Bt corn estimated from the adoption-decision model.
* Significant at 10 percent. ** Significant at 5 percent. *** Significant at 1 percent.
— = Not applicable.

Appendix table 3.3— Regression estimates of the financial impact model in soybean production, 1998

Variables	Soybean (at least 1 harvested acre)		Soybean (specialized operations)	
	MNFI[1]	*RACS*[2]	*MNFI*[1]	*RACS*[2]
INTERCEPT	789.19***	158.26**	506.15***	302.85**
EDYEARS	20.14	3.82	-3.58	-1.64
OPAGE	-0.88	-0.13	-0.08	-1.09**
OCCUPF	35.30	-8.85	60.79**	31.24
SIZE	0.72	3.31	-3.98	-1.66
SIZESQ	-0.02	-0.04	0.08	0.04
SPECIALIZ	-61.01	38.20	—	—
RISKPERCP	-17.37**	*2.88	-9.78***	-2.45
BUDGET	-17.10	6.07	-44.19*	-16.04
HRTLNDW	135.76	25.40	-31.26	4.28
NCRESCNT	-142.56	-34.10	53.07	18.72
MISSPORT	302.94	67.21	100.30	-82.94***
OTHREGN[3]	-145.95	48.41	-156.67	-59.34*
PHT[4]	-1029.13**	118.60	-237.00***	67.54
*PHT*HRTLNDW*	-203.92	-108.73	100.10	-27.15
*PHT*NCRESCNT*	158.07	-31.68	-68.15	-64.77
*PHT*MISSPORT*	-687.93	-214.74	-410.68**	7.25
*PHT*OTHRREGN*	93.24	-263.77	226.29	-35.52
LAMBDAHT	2.59	2.73	-15.76	8.83
R^2	0.02	0.003	0.07	0.36
Sample size	2,321		395	
Population	400,542		112,975	

[1] *MNFI* denotes modified net farm income per tillable acre.
[2] *RACS* denotes returns above cost of chemicals and seed per tillable acre.
[3] *OTHREGN* includes Northern Great Plains, Prairie Gateway, Eastern Upland, Southern Seaboard, Fruitful Rim, and Basin and Range regions.
[4] *PHT* is the predicted probability of adopting herbicide-tolerant soybeans estimated from the adoption-decision model.
* Significant at 10 percent. ** Significant at 5 percent. *** Significant at 1 percent.
— = Not applicable.