MULTIPRODUCT PRODUCTION CHOICES AND PESTICIDE REGULATION IN GEORGIA

Christopher S. McIntosh and Albert A. Williams

Abstract

An increasing emphasis on surface and groundwater quality and food safety may result in some form of pesticide regulations. A restricted profit function model of Georgia agriculture is used to examine the short-run effects of 2 and 5 percent reductions in all pesticides. Point estimates of short-run impacts, along with their 90 percent confidence intervals are presented.

Key words: pesticides, regulation, agricultural production

Agriculture has long been identified as contributing to nonpoint-source pollution of surface and groundwater. Increasing emphasis on environmental problems has intensified concern about agricultural pollution. The Georgia Soil and Water Conservation Commission, the Soil Conservation Service, and the Georgia Association of Conservation District Supervisors concluded in a 1987 statewide assessment that "there is sufficient agricultural pollution (of water) to warrant action" (Georgia DNR 1989, p. 20). The public is also becoming more aware of the real environmental and health risks associated with pesticide use.

Regulatory alternatives to reduce or eliminate pesticide contamination of groundwater are under consideration by the United States Environmental Protection Agency (Taylor et al.). Schaub (p. 25) suggests that the reduction or elimination of chemical use in agriculture "is an issue that has been raised and is not likely to go away in the near future." Many non-agriculturalists view existing water quality problems as mainly problems of policy (Batie). Therefore, it is important to provide economic evidence, based on sound econometric models and procedures, of possible impacts from changing regulations.

Although previous research has examined reducing agricultural chemical use, including a total ban on all herbicides, pesticides, fungicides, and inorganic nitrogen (Knutson et al.;Taylor et al.), these studies provide only point estimates of possible changes. The present study used an econometric model consistent with economic theory and that was capable of providing point estimates of the short-run impacts along with their 90 percent confidence intervals.

The possible impacts of mandatory restrictions on pesticide use are uncertain, but they are likely to differ geographically. Assessing the benefits and costs resulting from a pesticide policy change requires that the analysis be highly disaggregated. The distribution of costs and benefits will also vary among types of producers, such as those producing different combinations of commodities. Thus, the analysis should be as commodity-specific as possible.

The objective of this study was to estimate the short-run impacts of mandated reductions in all pesticide use. A highly disaggregated model of agricultural supply response for the state of Georgia, an important and diverse agricultural state, was used. The model structure was examined, and tests of hypotheses regarding functional structure are presented. The short-run impacts of imposing a tax to reduce pesticide use were examined.

MODEL DESCRIPTION

Several recent studies of agricultural supply response have assumed a behavioral objective of profit maximization and employed duality theory to estimate systems of output supply and input demand equations (e.g., Lopez; Ball; Huffman and Evenson; Shumway and Alexander; Weaver). Some analysts (e.g., Ball; Shumway and Alexander) have reported estimates of supply and demand relationships that are consistent with the neoclassical theory of the profit-maximizing firm, i.e., the estimated supply and demand equations are homogeneous of degree zero in prices and monotonic, and the profit function is, at least locally, convex in prices.

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This study employed a restricted profit function for multiple output supply and input demand estimations. The agricultural sector in the state of Georgia was modeled as a competitive firm assuming (a) the exogeneity of output and variable input prices, and (b) the existence of a twice-continuously-differentiable concave aggregate state-level production function.[1] The indirect restricted profit function was specified using a normalized quadratic functional form (Lau; Shumway). The normalized quadratic form imposes linear homogeneity in prices. It is a locally flexible functional form that does not impose arbitrary restrictions on substitution elasticities or on returns to scale.[2]

Following the "netput" convention (output quantities are positive; variable input quantities are negative), the normalized quadratic profit function can be written as:

$$(1)\quad \bar{\pi} = b_0 + C\bar{P} + .5\bar{P}'D\bar{P}\,,$$

where $\bar{\pi}$ is profit divided by price of netput 1, b_0 is the intercept, C and D are parameter matrices, and $\bar{P} = [\bar{p}_2,\ldots,\bar{p}_m, x_{m+1},\ldots, x_n]$ is the vector of normalized prices ($\bar{p}_i = p_i/p_1$) of the variable netputs, and of quantities of fixed inputs and other exogenous variables ($x_{m+1},\ldots,x_n$). The first derivatives, via Hotelling's lemma (Silberberg), of this function with respect to normalized prices, define output supply and input demand equations that are linear in the vector of normalized prices and other exogenous variables:

$$(2)\quad x_{it} = c_i + \sum_{j=2}^{m} d_{ij}\,\bar{p}_{jt}, + \sum_{j=m+1}^{n} d_{ij}\; x_{jt}\,, \qquad i = 2,\ldots,m,$$

where t is time.

The demand equation of the numeraire (netput 1) is a quadratic form in normalized prices and other exogenous variables:[3]

$$(3)\quad x_{1t} = b_0 + \sum_{i=m+1}^{n} c_i\, x_{it} - .5 \sum_{i=2}^{m}\sum_{j=2}^{m} d_{ij}\,\bar{p}_{it}\,\bar{p}_{jt} + .5\sum_{i=m+1}^{n}\;\sum_{j=m+1}^{n} d_{ij}\, x_{it}\, x_{jt}.$$

The parameters of a system of stacked supply and demand equations, (2) and (3), were estimated as a seemingly unrelated set of equations. Symmetry of cross partial derivatives was maintained, as was homogeneity (through normalization). Monotonicity was not maintained. The parameter estimates were obtained using a constrained nonlinear least squares algorithm which used a Cholesky factorization to maintain convexity (Lau).

The restricted profit function (1) was not included in the system of equations for estimation. The numeraire equation (3) was included in the estimations, but the interactions between fixed factors were not estimated. Because profit is a linear combination of outputs and inputs and their prices in any time period, it can be determined exactly from equations (2) and (3).

DATA

Annual data for the period 1950-1986 were used for estimating the system of equations derived from the profit function. The exogenous variables in the profit function included output price expectations, observed prices of the variable inputs, quantities of fixed inputs, government policy variables, and time.

Previous studies have examined various market price expectation mechanisms (Shideed and White; Orazem and Miranowski). These studies indicate that no single expectation mechanism dominated the tested alternatives using non-nested hypothesis tests as a measure of information content. Lim, using a series of nonparametric tests, found that a one-year lag of market price was an appropriate specification for price expectations based on secondary data. The one-year lag of state average output price was used as the market price proxy for this study.

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[1] Although the differentiability hypothesis has not been formally tested, Lim found complete nonparametric consistency with the rest of the maintained joint hypothesis for the period 1956 -1982, when measurement errors of less than 1 percent perturbed these data.

[2] Like all second-order Taylor series expansions, the normalized quadratic does not impose cross-effect restrictions on comparative statics at a point, but it does impose other restrictions. For example, the normalized quadratic profit function maintains the joint hypothesis of a quasi-homothetic technology and, except for the numeraire, strongly separable output supplies and input demands; however, the normalized quadratic is more "separability flexible" than is the translog (Pope and Hallam, p. 265).

[3] Because the numeraire demand equation is quadratic, and the other supply and demand equations are linear, a change in numeraire netput changes the model specification. Using 1951-1982 data for each of the ten USDA farm production regions, Gottret found that technology test conclusions did not change, but that own-price elasticities were sensitive to choice of numeraire.

Government policies designed to support incomes and stabilize prices of agricultural commodities were included in the form of effective diversion payments and effective support prices. These were constructed in a manner similar to Houck et al. following McIntosh (1989a). Effective diversion payments appeared in the individual commodity supply equations only; cross-commodity effects of diversion payments were not examined. The data used to construct the effective diversion payment and support price variables were obtained from various *Commodity Fact Sheets* (USDA 1972-1988) and from Cochrane and Ryan.

Supply-inducing prices for program crops were calculated as a weighted average of market expectations and effective support prices using a procedure developed by Romain. This procedure gives some weight to the effective support price in every period (Duffy et al.). Some previous studies incorporated support prices in a "higher of effective support price or expected market price" framework (Shumway; Shumway and Alexander). McIntosh (1990) found that Romain's procedure provided out-of-sample forecasting performance consistently superior to that of the binary weighting scheme used by Shumway, and Shumway and Alexander. The effective support prices were incorporated in the specifications of expected output prices for corn, wheat, soybeans, cotton, tobacco, peanuts, and the milk portion of the dairy-poultry aggregate.

Temperature and precipitation data for critical planting and growing months were included in each of the crop supply equations. The weather data were monthly state averages based on individual weather station observations of precipitation and temperature, weighted by acreage of harvested cropland (Teigen and Singer). Temperature was measured as the average of the month immediately preceding normal planting dates plus those of the following month. Precipitation was included as the total for the first three months of the growing season. Time was included as a proxy for disembodied technological change.

The other fixed factors were family labor, service flows from capital stocks, and land. The service flows from capital stocks were an aggregate dollar measure of depreciation of various capital items including service structures, trucks, tractors, automobiles, and other equipment. Family labor was measured as manhours. Land was included as the number of acres in farms. These data, along with quantity and market price data for the outputs and variable inputs, were obtained from *Agricultural Statistics, Agricultural Prices, The Chicago Board of Trade Statistical Annual, Field Crops Production, Disposition, and Value, Farm Labor, State Farm Income and Balance Sheet Statistics, Meat Animals Production Disposition and Income, Seed Crops, Feed Situation, Wheat Situation* and unpublished USDA sources. They were compiled by Evenson and updated through 1986 by McIntosh (1989b).

The nine output supply equations were: corn, wheat, soybeans, cotton, tobacco, peanuts, an aggregate of other crops including fruits and vegetables, a dairy and poultry aggregate, and a meat animals aggregate. The other crops aggregate included tomatoes, potatoes, lettuce, onions and other vegetables, apples, grapes and other fruits, and miscellaneous field crops not accounted for in the individual supply equations. The meat animals category included cattle and calves, hogs and pigs, and sheep and lambs. The dairy and poultry aggregate included chickens, turkeys, eggs, and milk. All aggregates were constructed using the Tornqvist index (Diewert). All quantities were state totals and were measured in millions of their respective units.

The five variable inputs included capital for machinery and operating inputs, fertilizer, hired labor, pesticides, and miscellaneous inputs. Operating inputs quantities were calculated from the total expenditures for operation and repair of machinery and buildings divided by an index of operating inputs. Fertilizer was an aggregate of all fertilizer use. Pesticide quantities were calculated by dividing pesticide expenditures by an index of pesticide prices. The state-level pesticide expenditure and price data were an aggregate of herbicides, insecticides, and fungicides. These data were obtained from the USDA (unpublished). The miscellaneous inputs category included all inputs not specifically accounted for in the other three variable inputs or in the fixed input categories, e.g., items such as seed, feed, outputs used on farms where produced, short-term interest, electricity and telephone, veterinary supplies, Federal crop insurance, net insurance premiums (fire, wind, and hail), machine hire and custom work, irrigation, and miscellaneous tools and supplies. The price index of hired labor was used as the numeraire.

EMPIRICAL RESULTS

The system of output supply and input demand equations was estimated by nonlinear least squares while maintaining symmetry, convexity, and linear homogeneity of the profit function in prices. Convexity was tested using the approximation test outlined by Talpaz et al. Convexity was not rejected at the .05 level of significance (F statistic of 0.721 with a critical value of $F^{.05}_{182,336} = 1.234$).[4] Monotonicity was not imposed but was not violated at any observation. The empirical estimates are consistent with the theory of profit maximizing behavior and are reported, along with their asymptotic standard errors, in Table 1.

Technology Tests

Much of agricultural production is characterized by firms that produce more than one type of output. If the production of each commodity for a multiproduct firm is independent of the other production activities, then its production is said to be nonjoint in inputs. Input nonjointness implies that the multiproduct profit function is simply the sum of its single product counterparts. Nonjointness is indicated for the normalized profit function if and only if all cross-output-price terms in each supply equation are zero. Nonjointness in inputs was tested subject to homogeneity, symmetry, and convexity and was rejected at the .01 level of significance (Table 2).

Table 1. Parameter Estimates[a]

	Negative of Demand Equations				
Variable[b]	Hired Labor[c]	Capital Operating	Fertilizer	Pesticides	Misc. Inputs
Intercept	-0.0024 (0.4390)	-0.1802 (0.1425)	-0.2663 (0.1384)	-0.0063 (1.5864)	-0.2956 (0.2638)
Normalized Prices					
Cap. Oper. Inputs		0.5200 (0.0025)		Symmetric	
Fertilizer		0.3955 (1.7924)	22.1305 (0.2851)		
Pesticides		0.4211 (0.0049)	0.1282 (0.0005)	0.4749 (0.0350)	
Misc. Inputs		0.8639 (0.1697)	0.2536 (0.0241)	1.3836 (0.0954)	4.9257 (0.0981)
Corn		0.0287 (0.0352)	0.9715 (0.0302)	-0.0306 (0.1912)	-0.2134 (0.1149)
Wheat		0.2309 (0.1065)	0.6959 (0.1504)	0.2246 (0.0692)	0.5683 (0.2513)
Soybeans		-0.0597 (0.0537)	-1.0897 (0.8333)	-0.0921 (0.0241)	-0.3491 (0.1075)
Cotton		-0.3069 (0.2436)	-3.9622 (1.2915)	-0.2587 (0.3156)	-0.6479 (3.5841)
Tobacco		-0.2562 (0.2199)	1.4102 (1.4175)	-0.5966 (0.2110)	-2.4073 (0.5127)
Peanuts		-1.1609 (0.3509)	-7.7209 (0.0489)	-1.1525 (0.1940)	-2.9723 (0.0795)
Other Crops		-0.5902 (0.1386)	0.6576 (0.2115)	0.0319 (0.0008)	1.6354 (0.0038)
Dairy-Poultry		-0.3263 (0.0073)	-1.2582 (0.0016)	-0.2762 (0.0016)	-0.6038 (0.0024)
Meat Animals		0.0558 (0.4928)	-2.1828 (0.0006)	-0.2458 (0.0021)	-1.3921 (0.0005)
Family Labor	94.1673 (0.8128)	179.1490 (0.1872)	-1653.840 (0.0554)	-458.6080 (0.0576)	170.1720 (0.0474)
Land	-0.0811 (4.1285)	4.3672 (0.8564)	12.8851 (0.2746)	-0.9004 (0.1855)	-5.3495 (0.1236)
Capital	0.0193 (0.1687)	-0.5155 (0.4536)	-0.6121 (1.3769)	-0.3076 (0.6100)	-1.721 (0.5133)
Year	-0.00008 (0.5433)	0.0037 (0.2609)	-0.0007 (0.0769)	0.0004 (0.0215)	-0.0004 (0.0181)

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[4] If the null hypothesis of convexity were rejected, the parameter estimates would be biased.

Table 1. Parameter Estimates^a (continued)

	Output Supply Equations								
Variable[b]	Corn	Wheat	Soybean	Cotton	Tobacco	Peanuts	Other Crops	Dairy-Poultry	Meat Animals
Intercept	0.3066 (0.1040)	-0.0428 (0.0981)	0.0429 (0.4663)	0.0184 (0.0718)	0.0794 (0.2474)	2.3447 (0.1291)	0.0908 (0.0960)	0.7084 (0.3627)	-0.3213 (0.0709)
Normalized Prices									
Corn	0.2863 0.1043								
Wheat	-0.0304 (0.1043)	0.2373 (0.0168)				Symmetric			
Soybeans	-0.0833 (0.0401)	-0.0575 (0.0133)	0.1257 (0.502)						
Cotton	0.8065 (0.3269)	-0.6659 (0.2404)	0.0855 (0.1127)	8.9737 (3.2612)					
Tobacco	0.1596 (0.1432)	-0.0909 (0.6953)	0.1968 (0.0679)	1.0214 (0.5022)	2.0227 (0.0699)				
Peanuts	1.3041 (0.0421)	-2.2337 (0.0301)	0.9379 (0.2083)	6.8791 (0.0997)	-0.5694 (0.6475)	53.7025 (0.1412)			
Other Crops	-0.4205 (0.0005)	0.1612 (0.0022)	-0.3462 (0.0009)	-0.5002 (0.0005)	-0.9459 (0.0003)	-10.7650 (0.0023)	5.2687 (0.0012)		
Dairy-Poultry	-0.2618 (0.0172)	-0.2009 (0.0003)	0.1489 (0.0012)	-0.5459 (0.0043)	0.0415 (0.0002)	0.9231 (0.0003)	0.2282 (0.0002)	0.5113 (0.0003)	
Meat Animals	-0.1872 (0.0013)	-0.3457 (0.0028)	0.1775 (0.0073)	-0.6964 (0.0006)	-0.0153 (0.0017)	1.9477 (0.0006)	-1.3326 (0.0017)	0.5175 (0.0010)	2.2391 (0.0031)
Family Labor	-24.2087 (0.2303)	- 210.9690 (0.0345)	-59.1103 (0.1144)	1529.810 (0.0399)	269.572 (0.0249)	5297.28 (0.0240)	134.6870 (0.3414)	-1693.55 (1.6101)	216.018 (0.2664)
Land	5.9395 (1.2451)	4.1847 (0.2939)	1.7669 (1.0047)	17.3913 (0.1737)	-1.7347 (0.5296)	31.0402 (0.1438)	14.8309 (0.1159)	2.5897 (0.0720)	-5.6046 (0.4951)
Capital	-0.2073 (0.3147)	-0.0270 (0.9503)	0.2715 (0.7344)	-1.2167 (0.4497)	-0.0056 (0.3794)	0.6553 (0.9866)	-0.3393 (0.1849)	0.0412 (0.3588)	0.5445 (0.1459)
Year	0.0023 (0.0103)	0.0011 (0.7726)	-0.0011 (0.0005)	0.0113 (0.0032)	-0.0009 (0.0108)	0.0290 (0.0069)	0.0071 (0.0009)	0.0072 (0.0014)	-0.0021 (0.0427)
Effect. Div. Pay.	-0.0474 (0.0162)	0.0170 (0.0049)	———	0.7419 (0.1906)	———	———	———	———	———
Precipitation	-0.0011 (0.0102)	-0.0001 (0.0027)	0.0005 (0.0002)	-0.0001 (0.0897)	-0.0004 (0.4874)	0.0041 (0.0964)	-0.0008 (0.0516)	-0.0010 (0.1817)	0.0017 (0.3489)
Temperature	0.0050 (0.0007)	0.0001 (0.0017)	-0.0006 (0.0038)	-0.0046 (0.0019)	0.00009 (0.2021)	-0.0375 (0.0768)	-0.0028 (0.2665)	-0.0060 (0.0025)	0.0065 (0.0029)

[a] Standard errors are in parentheise. MSE = 1.673 with 336 degrees of freedom.

[b] Hired labor price was used to normalize all other prices and profit. Price indexes for 1977 = 1.000, quantity indices are expenditures or receipts (in million dollars) divided by the price indices. Squared and interaction terms for the fixed inputs were not included in the estimation due to collinearity problems.

[c] Hired labor was the numeraire netput. All price parameters estimated for the linear supply and demand equation system are constrained to apply to the quadratic price variables in this equation. Compare text equations (2) and (3).

Global-indirect Hicks-neutral technical change was tested jointly for variable inputs and outputs. Technical change is indirectly Hicks neutral in variable inputs (outputs) if all ratios of variable inputs (output) demands (supplies) are independent of time (Lau). That is,

(4) $d_{i18}x_j - d_{j18}x_i = 0$ for all i, j = 2,..,5 for variable inputs or
all i, j = 6,..,14 for outputs,

where d_{i18} is the coefficient for the interaction of the ith commodity and time (x_{18}).

Global-indirect, Hicks-neutral technical change was rejected jointly for variable inputs and outputs.

Table 2. Chi-Squared Statistics for Hypothesis Tests

Hypothesis	Calculated Value	Degrees of freedom	Critical Value 0.05
Nonjointness	117.30	36	51.00
Global Indirect Hicks-Neutral Technical Change, Variable Inputs and Outputs:	135.70	14	23.68

This test was conducted with symmetry, homogeneity, and convexity imposed (Table 2). Rejection of global-indirect Hicks-neutral technical change indicates that marginal rates of technical substitution (i.e. the rate at which inputs (outputs) are substituted for each other) are changing over time.

Parameter Estimates

The model was estimated subject to theoretical curvature constraints and thus all estimated own-price parameters are positive (Table 1). Therefore, all estimated own-price elasticities of supply (demand) are positive (negative). All input demand and output supply equations had significant (.05 level) own-price parameters. Significant supplementary relationships were evident between service flows from capital stock and miscellaneous inputs, between family labor and fertilizer and pesticides, and between land and pesticides and miscellaneous inputs. Significant complementary relationships were evident between family labor and hired labor, operating inputs, and miscellaneous inputs, and between land and operating inputs and fertilizer.

Significant complementary relationships were indicated for corn and soybeans, cotton, and peanuts; wheat and other crops; soybeans and tobacco, peanuts, dairy-poultry, and meat animals; cotton and tobacco, and peanuts; tobacco and dairy-poultry; peanuts and diary-poultry, and meat animals; other crops and dairy-poultry; and dairy-poultry and meat animals.

Significant competitive relationships were indicated for corn and soybeans, other crops, dairy-poultry, and meat animals; wheat and soybeans, cotton, peanuts, dairy-poultry, and other crops; soybeans and other crops; cotton and other crops, dairy-poultry, and meat animals; tobacco and other crops, and meat animals; peanuts and other crops; and other crops and meat animals. Evidence of both competitive and complementary input demand and output supply relationships is consistent with earlier findings of Antle, Lopez, and Shumway and Alexander.

Table 3 presents the elasticities of supply and demand obtained from the parameter estimates along with their standard errors. The standard errors were calculated using a Taylor's series approach. A Monte Carlo study by Dorfman, Kling, and Sexton showed the Taylor's series approach to be accurate for calculating the variances for ratios of normally distributed random variables. The input demand functions are generally price inelastic. Estimated own-price elasticities of demand ranged from -0.574 for hired labor to -0.073 for capital for machinery and operating inputs. All estimated own-price elasticities of supply were inelastic. The own-price elasticities of supply ranged from 0.867 for wheat to 0.010 for the dairy-poultry aggregate.

Short-Run Impacts of Pesticide Reduction

Agricultural pollution of groundwater and food safety issues appear to dominate the current debate over agricultural chemical use. Increasing public concern over groundwater contamination will likely lead to more forms of governmental restrictions on pesticide use. Taylor et al. suggest that agricultural economists can contribute to the policy debate by examining alternative forms of regulation that fall between the status quo and a complete ban on all pesticides. This analysis examines 2 and 5 percent reductions in the use of all herbicides, insecticides and fungicides.

The econometric model of Georgia agriculture was used to estimate the short-run impacts of a mandated across-the-board reduction in pesticide applications. Since the model describes a short-run situation, impacts resulting from increased research and development or changes in agricultural imports are not addressed. Producers are assumed to be risk-neutral profit-maximizers, thus the risk-bias effects resulting from a decrease in pesticide use cannot be examined explicitly. While this may appear to be a serious abstraction of reality, recent empirical results suggest that Georgia data do not contradict the risk-neutral profit maximizing hypothesis (Lim).

Shortle and Dunn found that management practice incentives in the form of a tax (either positive or negative) provided the best method for pollution abatement of the methods they examined. In the present analysis, a tax was added to the price of pesticides in order to decrease the quantity demanded. In order to cause a 2 percent reduction in pesticide demand, a tax of 17.86 percent would be needed; for a 5 percent reduction, a tax of 44.64 percent would be needed.

The impact of these taxes on competing inputs and all outputs were examined. The predicted impacts, along with their 90 percent confidence intervals, are presented in Table 4. The confidence intervals were calculated using the Taylor's series approach. The

Table 3. Output Supply and Input Demand Elasticities for Georgia

Output or Input	Elasticity with respect to the price of													
	Hired Labor	Capital Operating Inputs	Fertilizer	Pesticides	Misc. Inputs	Corn	Wheat	Soybeans	Cotton	Tobacco	Peanuts	Other Crops	Dairy-Poultry	Meat Animals
Hired Labor	-0.574 (0.684)	0.143 (0.008)	0.078 (0.007)	0.141 (0.003)	0.372 (0.411)	0.022 (0.002)	0.154 (0.002)	-0.098 (0.001)	0.122 (0.005)	-0.013 (0.002)	-0.096 (0.071)	0.042 (0.012)	-0.103 (0.158)	-0.181 (0.002)
Capital Operating Inputs	0.099 (0.127)	-0.073 (0.061)	-0.012 (0.025)	-0.053 (0.021)	-0.098 (0.043)	-0.007 (0.023)	-0.075 (0.031)	0.028 (0.023)	0.013 (0.015)	0.040 (0.046)	0.028 (0.033)	0.077 (0.047)	0.038 (0.022)	-0.007 (0.024)
Fertilizer	0.089 (0.170)	-0.020 (0.041)	-0.240 (0.045)	-0.005 (0.024)	-0.010 (0.064)	-0.084 (0.041)	-0.081 (0.042)	0.185 (0.039)	0.061 (0.025)	-0.080 (0.057)	0.067 (0.053)	-0.031 (0.068)	0.052 (0.035)	0.097 (0.040)
Pesticides	0.205 (0.153)	-0.111 (0.044)	-0.007 (0.309)	-0.112 (0.034)	-0.294 (0.056)	0.014 (0.033)	-0.137 (0.043)	0.082 (0.031)	0.021 (0.022)	0.177 (0.016)	0.052 (0.014)	-0.008 (0.019)	0.060 (0.009)	0.057 (0.011)
Misc. Inputs	0.059 (0.048)	-0.022 (0.001)	-0.001 (0.009)	-0.032 (0.006)	-0.104 (0.023)	0.010 (0.011)	-0.034 (0.011)	0.031 (0.010)	0.005 (0.007)	0.071 (0.016)	0.013 (0.014)	-0.040 (0.019)	0.013 (0.009)	0.032 (0.011)
Corn	-0.035 (0.324)	0.016 (0.056)	0.120 (0.058)	-0.016 (0.037)	-0.098 (0.114)	0.284 (0.128)	-0.040 (0.074)	-0.162 (0.077)	0.142 (0.049)	0.103 (0.093)	0.129 (0.094)	-0.224 (0.115)	-0.124 (0.077)	-0.095 (0.103)
Wheat	-0.516 (0.638)	0.363 (0.151)	0.237 (0.123)	0.317 (0.100)	0.721 (0.237)	-0.083 (0.151)	0.867 (0.211)	-0.307 (0.133)	-0.323 (0.090)	-0.161 (0.205)	-0.606 (0.199)	0.236 (0.265)	-0.262 (0.134)	-0.482 (0.135)
Soybeans	0.248 (0.441)	-0.104 (0.082)	-0.409 (0.865)	-0.144 (0.054)	-0.489 (0.160)	-0.251 (0.120)	-0.232 (0.100)	0.741 (0.141)	0.046 (0.066)	0.385 (0.141)	0.281 (0.135)	-0.560 (0.166)	0.214 (0.099)	0.274 (0.118)
Cotton	-0.490 (0.494)	-0.084 (0.093)	-0.234 (0.095)	-0.063 (0.065)	-0.142 (0.188)	0.381 (0.130)	-0.422 (0.118)	0.079 (0.114)	0.756 (0.105)	0.314 (0.152)	0.324 (0.156)	-0.127 (0.196)	-0.123 (0.112)	-0.169 (0.125)
Tobacco	0.021 (0.415)	-0.091 (0.105)	0.109 (0.077)	-0.191 (0.056)	-0.692 (0.152)	0.099 (0.089)	-0.075 (0.096)	0.238 (0.087)	0.113 (0.055)	0.813 (0.182)	-0.035 (0.122)	-0.314 (0.175)	0.013 (0.081)	-0.005 (0.084)
Peanuts	0.041 (0.107)	-0.017 (0.020)	-0.025 (0.020)	-0.015 (0.014)	-0.036 (0.038)	0.034 (0.024)	-0.077 (0.025)	0.047 (0.023)	0.032 (0.015)	-0.010 (0.033)	0.137 (0.047)	-0.148 (0.045)	0.011 (0.021)	0.026 (0.024)
Other Crops	-0.014 (0.113)	-0.037 (0.023)	0.009 (0.020)	0.002 (0.015)	0.083 (0.039)	-0.046 (0.024)	0.024 (0.026)	-0.074 (0.022)	-0.010 (0.015)	-0.067 (0.037)	-0.116 (0.036)	0.309 (0.064)	0.012 (0.021)	-0.074 (0.021)
Dairy-Poultry	0.014 (0.022)	-0.007 (0.004)	-0.006 (0.004)	-0.006 (0.003)	-0.011 (0.008)	-0.010 (0.006)	-0.010 (0.005)	0.011 (0.005)	-0.004 (0.003)	0.001 (0.007)	0.004 (0.007)	0.005 (0.008)	0.010 (0.007)	0.010 (0.007)
Meat Animals	0.084 (0.098)	0.005 (0.016)	-0.039 (0.016)	-0.018 (0.010)	-0.094 (0.033)	-0.027 (0.029)	-0.067 (0.019)	0.050 (0.022)	-0.018 (0.013)	-0.001 (0.025)	0.028 (0.026)	-0.104 (0.029)	0.036 (0.024)	0.166 (0.051)

Note: Standard errors in parenthesis were calculated using the Taylor series method.

predicted impacts of a 5 percent reduction (44.64 percent tax) are proportionately larger than those from a 2 percent reduction (17.86 percent tax) and are shown for contrast. They will not be discussed in this section.

The predicted impacts of reduced pesticide use were found to be significantly different from zero for hired labor, machinery, operating inputs, pesticides, miscellaneous inputs, wheat, soybeans, tobacco, the other crops aggregate, dairy-poultry, and the meat animals aggregate. Impacts not significantly different from zero were indicated for fertilizer, corn, cotton, and peanuts. A reduction in all inputs demanded except hired labor was indicated. All output supplies decreased except wheat and the other crops aggregate. The inelasticity of all own- and cross-price effects with respect to pesticides are evident in that the relative impacts of a tax on pesticides were quite small. The greatest expected impacts from a 2 percent reduction in pesticide use were a 5.666 percent increase in wheat supplied and a 3.414 percent reduction in tobacco supplied. The smallest impacts were a 0.036 percent supply increase in other crops, a 0.089 percent decrease in fertilizer demand, and a 0.107 percent decrease in dairy-poultry supply. For all inputs and outputs, a 2 percent reduction in pesticide use would cause four quantities to change by more than 2 percent, while eight would change by less than 1 percent.

Although the model used is highly disaggregated in terms of output supplies and input demands, it is still very general. Because of that generality, it is capable of examining only the very broad implications of a mandated reduction in pesticide use. Nevertheless, this analysis indicates that a policy reducing pesticide use by even a small amount (e.g. 2 percent) would have substantial impacts on production patterns. The potential reallocations of inputs among various outputs suggests new uncertainties could arise for agricultural producers and agribusiness firms.

SUMMARY AND CONCLUSIONS

Increasing public concern about safe (i.e. pesticide-free) food and drinking water may lead to further government regulation of chemical use in agriculture. The non-agricultural public is likely to view existing water quality problems as mainly problems of policy (Batie). The public is likely to argue that the "polluter pays" principle applies to agriculture as well as to industrial polluters. In the present political environment, it is important that scientists, including economists, provide information about alternative forms of regulation.

The possible impacts of pesticide regulations will be geographically and commodity specific. This analysis has presented a highly disaggregated econometric model of agriculture for the state of

Table 4. Short-Run Impacts of Reducing Pesticide Use on Georgia Agriculture

	Predicted Quantitiy Change From:			
Output or Input	2 Percent Reduction	90 Percent Confidence Limits[a]	5 Percent Reduction	90 Percent Confidence Limits[a]
		Percent		
Hired Labor	+2.518	+2.481, +2.555	+6.295	+6.109, +6.480
Machinery Operating Inputs	-0.946	-1.570, -0.322	-2.366	-3.924, -0.808
Fertilizers	-0.089	-0.630, +0.808	-0.223	-2.018, +1.572
Pesticides	-2.000	-2.989, -1.010	-5.000	-7.472, -2.528
Miscellaneous Inputs	-0.571	-0.752, 0.390	-1.429	-1.881, -0.977
Corn	-0.286	-1.369, +0.797	-0.714	-3.419, +1.991
Wheat	+5.666	+2.724, +8.607	+14.152	+6.805, +21.49
Soybeans	-2.574	-4.153, -0.995	-6.429	-10.374, -2.484
Cotton	-1.126	-3.042, +0.790	-2.812	-7.598, +1.974
Tobacco	-3.414	-5.048, -1.780	-8.527	-12.608, -4.446
Peanuts	-0.268	-0.678, +0.142	-0.670	-1.693, +0.353
Other Crops	+0.036	-0.397, +0.469	+0.089	-0.992, +1.170
Dairy-Poultry	-0.107	-0.188, -0.026	-0.286	-0.471, -0.65
Meat Animals	-0.321	-0.602, -0.040	-0.804	-1.506, -0.102

[a] Confidence limits were calculated using the Taylor series method.

Georgia. This model provides a basis, consistent with economic theory, for examining restrictions on pesticide use. Point estimates of impacts from pesticide reductions along with their 90 percent confidence intervals are presented.

All agricultural inputs and outputs in Georgia would be affected by restricting pesticide use. Supplies of all outputs would decrease except for wheat and the aggregate of other crops. All input demands would decrease except hired labor. Of the significant decreases in outputs, tobacco and soybeans were expected to change the most.

Previous studies have documented the geographical diversity of supply response. These geographic differences have important implications for formulating agricultural policies. In order to measure impacts of policy changes on individual crops, it is important to estimate individual supply equations rather than aggregate categories. Further research should be directed at additional and improved state-level models to accurately reflect the geographic differences and provide more detailed information regarding other forms of economic incentives/disincentives for improving surface and groundwater quality and food safety.

REFERENCES

Antle, J. M. "The Structure of U.S. Agricultural Technology, 1910-78." *Am. J. Agr. Econ.*, 66(1984):414-421.

Ball, V. E. "Modeling Supply Response in a Multiproduct Framework." *Am. J. Agr. Econ.*, 70(1988):813-825.

Batie, S. S. "Agriculture as the Problem, The Case of Groundwater Contamination." *Choices,* Third Quarter, 1988:4-7.

Chicago Board of Trade. *Statistical Annual: Chicago Board of Trade*, annual series, 1939-1982.

Cochrane, W. W. and M. E. Ryan. *Am. Farm Policy 1948-1973,* Minneapolis, Minnesota: University of Minnesota Press, 1976.

Diewert, W. E. "Exact and Superlative Index Numbers." *J. Econometrics,* 4(1976):115-145.

Dorfman, J. H., C. L. Kling and R. J. Sexton. "Confidence Intervals for Elasticities and Flexibilities: Re-Evaluating the Ratio of Normals." *Am. J. Agr. Econ., 72(1990):1006-1017.*

Duffy, P. A., J. W. Richardson, and M. K. Wohlgenant. "Regional CottonAcreage Response." *So. J. Agr. Econ.,* 19(1987):99-109.

Evenson, R. State-Level Data Set for U.S. Agriculture 1949-1982, Economic Growth Center, Yale University, New Haven, CN, 1986.

Georgia Department of Natural Resources. *Georgia Nonpoint Source Assessment Report*, 1988.

Gottret, P. E. "A Regional Approach to the Estimation of Multiproduct Input Demand and Output Supply Functions in the U.S." Ph.D. thesis, Texas A&M University, 1987.

Houck, J. P., M. E. Abel, M. E. Ryan, P. W. Gallagher, R. G. Hoffman, and J. B. Penn. *Analyzing the Impact of Government Programs on Crop Acreage. Washington, D. C.: USDA ERS, Tech. Bull. No. 1548, 1976.*

Huffman, W. E., and R. E. Evenson. "Supply and Demand Functions for Multiproduct U.S. Cash Grain Farms: Biases Caused by Research and Other Policies." *Am. J. Agr. Econ., 71(1989):761-773.*

Knutson, R. D., C. R. Taylor, J. B. Penson, and Jr., E. G. Smith. *Economic Impacts of Reduced Chemical Use.* College Station, TX: Knutson and Associates, 1990.

Lau, L. J. "Applications of Profit Functions," *Production Economics: A Dual Approach to Theory and Applications,* Vol. 1, M. Fuss and D. McFadden, eds. Amsterdam: North Holland, 1978.

Lim, H. "Profit Maximization, Returns to Scale, Separability, and Measurement Error in State-Level Agricultural Technology." Ph.D. thesis, Texas A&M University, 1989.

Lopez, R. E. "Estimating Substitution and Expansion Effects Using a Profit Function Framework." *Am. J. Agr. Econ.,* 66(1984):358-367.

McIntosh, C. S. "Specification of Government Policy Variable for Feed Grains, Wheat, Soybeans, Rice, Cotton, Peanuts, Tobacco, Sugar Beets and Milk, 1950-1986." Dept. Agr. Econ., Faculty Series FS89-61, University of Georgia, 1989(a).

_______"State Level Data Set for Selected States, 1982-1986." Dept. Agr. Econ., University of Georgia, unpublished, 1989(b).

_______"Choosing Among Alternative Methods of Including Government Policy Information for State-Level Multiproduct Agricultural Supply Analysis." Dept. Agr. Econ., Faculty Series FS90-22, University of Georgia, 1990.

Orazem, P. and J. Miranowski. "An Indirect Test for the Specification of Expectation Regimes." *Rev. of Econ. and Stat.,* 68(1986):603-609.

Pope, R. D. and A. Hallam. "Testing the Separability of Production Using Flexible Functional Form Profit Functions." *Econ. Letters,* 26(1988):265-270.

Romain, R. F. J. "A Commodity Specific Policy Simulation Model for US Agriculture." Ph.D. thesis, Texas A&M University, 1983.

Schaub, J. R. "Economic Impacts of Chemical Use Reduction on the South: Discussion." *So. J. Agr. Econ.,* 23(1991):25-26.

Shideed, K. H. and F. C. White. "Alternative Forms of Price Expectations in Supply Analysis for U.S. Corn and Soybean Acreages." *West. J. Agr. Econ.,* 14(1989):281-293.

Shortle, J., and J. Dunn. "The Relative Efficiency of Agricultural Source and Water Pollution Control Policies." *Am. J. Agr. Econ., 68(1986):668-677.*

Shumway, C. R. "Supply, Demand, and Technology in a Multiproduct Industry: Texas Field Crops." *Am. J. Agr. Econ.,* 65(1983):748-760.

Shumway, C. R., and W. P. Alexander. "Agricultural Product Supplies and Input Demands: Regional Comparisons." *Am. J. Agr. Econ.,* 70(1988):154-161.

Silberberg, E. "A Revision of Comparative Statics Methodology in Economics, or How to do Comparative Statics on the Back of an Envelope." *J.Econ.Theory* 7(1974):159-172.

Talpaz, H., W. P. Alexander, and C. R. Shumway. "Estimation of Systems of Equations Subject to Curvature Constraints." *J. Stat. Comp. and Sim.,* 32(1989):201-214.

Taylor, C. R., J. B. Penson, Jr., E. G. Smith, and R. Knutson. "Economic Impacts of Chemical Use Reduction on the South." *So. J. Agr. Econ.,* 23(1991):15-23.

Teigen, L. D., and F. Singer. Weather in U.S. *Agriculture: Monthly Temperature and Precipitation by State and Farm Production Region, 1950-1986.* Washington, D. C.:USDA ERS Stat. Bull. No. 765, February 1988.

U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service, *Commodity Fact Sheets.* Washington, D. C., 1972-1988.

U.S. Department of Agriculture, *Agricultural Prices,* annual series. Wahsington, D. C.: 1949-1984a.

_______. *Agricultural Statistics*, annual series. Wahsington, D. C.: 1949-1988b.

_______. *Feed Situation,* ERS annual series. Wahsington, D. C.: 1949-1988c.

_______. *Wheat Situation,* ERS annual series Wahsington, D. C.: 1949-1988d.

_______. *State Farm Income and Balance Sheet Statistics,* ERS annual series. Wahsington, D. C.: 1949-1988e.

_______. *Meat Animals, Production, Disposition and Income,* Crop Reporting Board annual series. Wahsington, D. C.: 1949-1984f.

_______. *Seed Crops,* Crop Reporting Board, annual series. Wahsington, D. C.:1949-1984g.

_______. *Farm Labor,* Crop Reporting Board, annual series. Wahsington, D. C.: 1949-1984h.

U.S. Economics, Statistics and Cooperatives Service. F*ield Crop Production, Disposition, and Value,* annual series. Wahsington, D. C.: 1949-1984i.

Weaver, R. D. "Multiple Input, Multiple Output Production Choices and Technology in the U.S. Wheat Region." *Am. J. Agr. Econ.,* 65(1983):45-56.