Use of Extraneous Information With an Econometric Model to Evaluate Impacts of Pesticide Withdrawals

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A framework for combining extraneous information with an econometric model to evaluate the economic impacts of pesticide withdrawals is presented in this paper. The extraneous information, which can be a best guess or experimental data, is used to shift an econometrically estimated supply function. The full sectoral econometric model is then simulated through time with and without the supply shift to estimate the relative impacts of withdrawing the pesticide. The theoretical framework is applied to the withdrawal of all insecticides used on cotton.

Economists are increasingly faced with the task of evaluating the aggregate economic impacts of technological changes in agricultural production. These changes may include new advances in technology or reverse technology. New technology would include effective methods of weather modification, higher yielding crop varieties, and new crop production systems. The most prevalent example of "reverse" technology is banning the use of specific chemicals used in agricultural production. Consider the problem of evaluating the effects of withdrawing a pesticide without any historical data for conducting a "positive" evaluation.[1] Under this condition, economists have tended to use experimental or "best guess" data on the yield impact of the technological change and address the aggregate economic effects with either partial budgeting or normative programming approaches (for examples see Casey and Lacewell; Davis, et al.; Delvo, 1973a, 1973b and 1974; Environmental Protection Agency; Fox, et al., Pimental, et al.; Nichol and Heady; and Taylor and Frohberg).

This paper presents and applies a methodological approach that uses extraneous information with an econometric model to evaluate a technology shift. Extraneous information is used as a basis to shift relevant supply curves to reflect the change in technology. Then the relative aggregate economic impacts of the technology-induced shift can be estimated by simulating future values of endogenous variables that may occur with and without the technology. This approach is less subjective than the partial budgeting approach, and less expensive and time consuming than regional or national programming approaches. A multicrop national econometric model is used to illustrate the approach by estimating the aggregate effects of banning the use of insecticides on

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[1]The U.S. Environmental Protection Agency is mandated to make many such evaluations. A recent rebuttable presumption against registration (RPAR) list included 45 pesticides for which an economic evaluation must be done. Typically, these evaluations must occur in three months to one year.

cotton. The methodology presented is applicable to evaluation of many other changes in agricultural production technology.

Theoretical Model

The critical step in using extraneous information with an econometric model to evaluate technology changes is specifying exactly how the technology change will shift the supply curve. In the following theoretical derivation it is assumed that farmers' decision processes and the variables to which farmers respond do not change, but that some technical parameters and levels of variables do change. Under these assumptions, the supply shift can be derived analytically. To illustrate the derivation, consider the following simple four equation model which has the elements common to most econometric models of agricultural sectors:

Acreage response:

$$(1) \qquad A_t = f(A_{t-1}, NR_t^*, G_t)$$

Yield time trend:

$$(2) \qquad Y_t = g(t)$$

Demand (domestic + export):

$$(3) \qquad Q_t^{(d)} = h(P_t, I_t)$$

Market equilibrium conditions: Find P_t such that

$$(4) \qquad A_tY_t = Q_t^{(d)}$$

where A_t = planted acreage in year t; P_t = price in year t; NR_t^* = expected net returns per-acre in year t, which depend on expected price, expected yield, and production costs; Y_t = yield per planted acre in year t; $Q_t^{(d)}$ = quantity demanded in year t; G_t = vector of policy variables; and I_t = vector of exogenous variables influencing demand in year t.

With this model specification, the supply function is given by the product of equations (1) and (2); that is, $Q_t^{(s)} = A_tY_t$. Withdrawal of a pesticide will cause a change in supply, ΔQ_t; and the new supply curve $(Q_t + \Delta Q_t)$ will be:[2]

$$(5) \quad (Q_t + \Delta Q_t) = (A_t + \Delta A_t)(Y_t + \Delta Y_t)$$

Referring to equations (1) and (2), equation (5) can be written as:

$$(6) \qquad (Q_t + \Delta Q_t) = [f(A_{t-1}, NR_t^*, G_t) + \Delta f(A_{t-1}, NR_t^*, G_t)]\,[g(t)+\Delta g(t)].$$

Consider now the incremental change $\Delta g(t)$ in equation (6). This term, which measures the effect of the pesticide withdrawal on expected per-acre yield, will depend on the change in use of alternative pesticides. Let yield, Y_t, be the weighted average of the expected yield obtained with each pesticide:

$$(7) \qquad Y_t = g(t) = \sum_i y_{it}F_{it}$$

where i = pesticide index, with one value of i representing no treatment; y_{it} = average yield obtained with i^{th} pesticide in year t; and F_{it} = fraction of acreage treated with the i^{th} pesticide in year t.

Based on equation (7) the change $\Delta g(t)$ is:

$$(8) \qquad \Delta g(t) = \sum_i y_{it}\Delta F_{it}.$$

Now the critical step, and in most applications the most subjective step, is determining y_{it} and ΔF_{it}. Hence, one must rely on information obtained from experts who are familiar with pesticide use patterns and farmers' pesticide decision processes.

The other change in equation (6) that needs to be specified is $\Delta f(A_{t-1}, NR_t^*, G_t)$, which is the change in acreage that results from the pesticide withdrawal. This change will obviously depend on the exact specification of the acreage response function in equation (1). For illustration, suppose that

[2]The derivation is specified in terms of discrete changes, represented by Δ, since the withdrawal of a pesticide does not represent an infinitesimally small change.

expected net returns, NR^*_t, is an explanatory variable in the function:

$$(9) \qquad NR^*_t = P^*_t\hat{Y}_t - C_t$$

where P^*_t = expected per-unit price in year t; C_t = per-acre variable production cost in year t; and $\hat{Y}_t$ = farmers' expectation of per-acre yield in year t. Then

$$(10) \qquad \Delta f(A_{t-1}, NR^*_t, G_t) = \frac{\Delta f(A_{t-1}, NR^*_t, G_t)}{\Delta NR^*_t} \cdot \Delta NR^*_t \cdot$$

The first term on the right hand side of (10), $\Delta f/\Delta NR^*_t$, is the incremental slope (with respect to NR^*_t) of the originally estimated acreage response equation. For a linear acreage response function, this term will of course be a constant. The second term of (10) gives the incremental change in expected net returns.

Substituting the incremental change of equation (9) into (10) gives:

$$(11) \qquad \Delta f(A_{t-1}, NR^*_t, G_t) = \frac{\Delta f(A_{t-1}, NR^*_t, G_t)}{\Delta NR^*_t} \cdot (P^*_t\Delta\hat{Y}_t - \Delta C_t).$$

The two remaining terms that must be specified are: (a) the change in expected per-acre average cost, ΔC_t; and (b) the change in farmers' expectations of per-acre average yield, $\Delta\hat{Y}_t$. If farmers have full information and act rationally, equation (8) will give the change in expected yield $\Delta\hat{Y}_t$; otherwise, other extraneous information must be obtained to specify $\Delta\hat{Y}_t$. Letting

$$C_t = \sum_i c_{it}F_{it}$$

where c_{it} = per-acre variable production cost using pesticide i in year t, the last term in (11), ΔC_t, can be measured as:

$$(12) \qquad \Delta C_t = \sum_i c_{it}\Delta F_{it}$$

Thus by obtaining extraneous information on c_{it}, y_{it}, F_{it}, ΔF_{it}, and $\Delta\hat{Y}_t$, the supply function that occurs in the absence of the pesticide can be derived. If the above set of assumptions is not appropriate for the issue in question, the appropriate set can be specified and a supply shift derived using similar logic. Then, sensitivity analyses can be easily performed either with respect to the shift parameters or the set of assumptions underlying the shift.

An Application

As a methodological test, this conceptual framework was used to estimate the economic impacts of withdrawing use of all insecticides on cotton. A multicommodity model was used because cotton competes with other crops. Besides cotton, crops included are wheat, soybeans, corn, grain sorghum, barley and oats. Econometric models for these crops, developed by personnel of the Commodity Economic Division (CED) of the U.S. Department of Agriculture (USDA), were used in developing the simulation model.[3] The USDA/CED econometric models were linked in the simulation model to provide a price vector that simultaneously clears all markets in each year of the simulation period, given the predetermined production for each crop in that year. Brown's derivative-free method was used to solve 16 simultaneous non-linear equations for the market clearing price vector [International Mathematical and Statistical Libraries]. The complete simulation model contains over 100 endogenous variables and almost 200 exogenous variables; hence, the simulation model is too large and detailed to present here.[4]

Acreage response equations in the model are specified on a regional basis for cotton and soybeans and nationally for other crops. Prices of competing crops are explanatory variables in acreage response equations. Cot-

[3]Readers interested in details on these models should contact Sam Evans and Tom Bell, U.S. Department of Agriculture.

[4]Interested readers can obtain details from the authors.

ton acreage response is dependent on the expected average variable and opportunity costs (AVOC) of production [Evans and Bell]. That is,

$$(13) \qquad A_t = \alpha - \beta(AVOC_t) + \gamma Z_t$$

where A_t = acreage, Z_t = policy shifters, and $\beta > 0$ with

$$AVOC_t = \frac{P^*Y^* - VC + VCC}{YC}$$

where P* = expected price of a competing crop by region; Y* = expected yield of a competing crop, per harvested acre by region; VC = expected production cost of a competing crop, dollars per harvested acre by region; VCC = expected costs of producing cotton, dollars per harvested acre by region; and YC = expected yield of cotton lint, pounds per harvested acre.

Using the approach outlined in the preceding section, supply functions for cotton in the Delta, Southwest, Southeast, and Western regions of the U.S. were shifted to reflect the withdrawal of cotton insecticides. Table 1 indicates estimates of per-acre yield loss and per-acre cost changes due to the withdrawal of insecticides. Estimates in Table 1 were subjectively specified after reviewing published studies of the yield advantages of cotton insecticides [Pimentel, et al.; Taylor and Lacewell] as well as consultation with entomologists familiar with cotton insect control.

Results

The linked econometric models were deterministically simulated through time with the two sets of cotton supply functions. Table 2 presents simulated average prices, production levels, and crop acreages for the 1977-85 period. Only a slight price increase for grain sorghum, corn, oats and barley occurred in response to decreased acreage and levels of production. Wheat and soybean prices increased 4.6 and 2.5 percent, respectively. With all pesticides withdrawn from cotton production, the price of lint increased an estimated 12.2 percent from 63.8 to 71.6 cents per pound, acreage increased by .5 million, and production declined by 9 percent.

Changes in producers' and consumers' surplus resulting from insecticide withdrawal from cotton production are presented in Table 3.[5] Consumers' surplus is reduced for wheat, soybeans, grain sorghum, corn and cotton by $1,160.7 million per year. Reduction in consumers' surplus from cotton accounts for about 45 percent of the total, with wheat accounting for 25 percent, soybeans for 17 percent and corn for 10 percent.

In aggregate, producers are clearly gainers. Producers' surplus increases by an estimated $386.1 million per year. Increase in producers' surplus from wheat accounts for 46 percent of the total, corn for 29 percent and cotton for 24 percent.

The overall impact on society, aside from possible external costs abated due to reduced insecticide use, is measured by the sum of producers' and consumers' surplus. For insecticide withdrawal from cotton, the net effect is a decrease in producers' plus consum-

[5]With cotton and the other grain crops being intermediate goods, "consumers" in this context should be regarded as producers of the final goods. This surplus would be shared by these producers and the ultimate consumers.

Consumers' surplus was measured as $\sum_i (Q_{oi} + Q_{li})(P_{oi} - P_{li})/2$, where P_{oi} and Q_{oi} are equilibrium price and quantity, respectively, for commodity i with pesticides; and P_{li} and Q_{li} are, respectively, equilibrium price and quantity for commodity i without pesticides. This surplus measure is an approximation for three reasons. First, some of the demand equations in the econometric model are non-linear, making the above measure a slight overestimation of surplus change. Secondly, the surplus measure is an approximation because the demand curves are not income-compensated. And thirdly, the symmetry (integrability) conditions for interrelated demand curves are not satisfied in the econometric model. Thus, the path of integration influences the measure of change in surplus between terminal prices [Silberberg, p. 357]. The above surplus measure implicitly assumes that the path of integration is a straight line between the two equilibrium points, which is a plausible path for price-quantity movements.

A secondary advantage of this surplus measure is that it can be computed from price-quantity solutions and does not require integration of the many demand curves in the model.

TABLE 1. Estimated Per-acre Yield and Production Cost Effects Due to Withdrawal of Pesticides from Cotton Production

Region	Estimated impact of withdrawing cotton insecticides on: Per-acre yield (percent)	Per-acre variable production cost (dollars)
Delta	−11.	−11.25
Southeast	−28.	−20.16
Southwest	− 5.	− .97
West	−19.	− 7.63

ers' surplus of $774.6 million annually. This result suggests that insecticide withdrawal from cotton is not socially desirable unless environmental and other external costs of insecticides used on cotton exceed $774.6 million annually.

Discussion

In a feasibility study such as this, strengths and weaknesses of the extraneous information-econometric approach as compared to partial budgeting and mathematical programming models need to be identified.

The most appealing advantage of the partial budgeting approach is that it permits one to obtain "quick and dirty" estimates in a very short time period, often just a day or two. These estimates are usually subject to considerable errors in data and model specification; however, partial budgeting may be superior to the absence of any economic analysis. One basic weakness of partial budgeting is that many intercommodity relationships must be subjectively specified and there may be widely varying estimates, none of which may have any sound logical or factual basis or which can be duplicated by other researchers making the same apparent set of assumptions. Also, because the economic system is so complex, it is difficult for the analyst to comprehend all relevant relationships in following the partial budgeting approach.

An advantage of the econometric approach relative to the programming approach is that other analysts familiar with this general type of model can readily see the critical assumptions that were made. Consequently, they can more readily evaluate the validity of the particular econometric model that was used. With a mathematical programming model, however, other analysts would have to spend much time studying the model structure and data to assess their validity. If other analysts

TABLE 2. Expected Effect on Prices, Acreage and Production of Major Crops due to Withdrawal of Pesticides from Cotton

Crop	Price (dollars)		Acreage (million)		Production (million)	
	Current Practices	Without Insecticides Used On Cotton	Current Practices	Without Insecticides Used On Cotton	Current Practices	Without Insecticides Used On Cotton
Wheat	3.25/bu	3.40/bu	65.2	64.4	1916 bu	1891 bu
Soybeans	5.61/bu	5.74/bu	55.9	55.7	1551 bu	1545 bu
Grain Sorghum	2.23/bu	2.27/bu	17.5	17.4	724 bu	720 bu
Corn	2.24/bu	2.26/bu	78.1	78.0	5981 bu	5973 bu
Oats	1.71/bu	1.70/bu	17.7	17.7	666 bu	675 bu
Barley	2.57/bu	2.57/bu	9.6	9.6	366 bu	366 bu
Cotton Lint	.6375/lb	.7159/lb	13.4	13.9	14.6 bales	13.3 bales

TABLE 3. Impact of Withdrawing Pesticides from Cotton Production on Consumers and Producers

Crop	Change in annual average economic surplus to: (million dollars)	
	Consumers	Producers
Wheat	−285.5	179.0
Soybeans	−201.3	2.3
Grain Sorghum	− 28.9	.1
Corn	−119.5	110.7
Cotton	−525.5	94.0
Total	−$1,160.7	$386.1

are reluctant to make this type of investment, then few if any checks on validity of large mathematical programming models will occur. Also, a properly specified and estimated econometric model will account for risk and uncertainty. Considering risk in the mathematical programming approach is theoretically possible but nearly infeasible in a large and complex model.

For the econometric approach, one should ideally estimate yield as a function of input variables (including technology) that have changed over time. However, without historical data on all of these variables, which is typically the case, this is impossible. Consequently, a bias is introduced into the model unless input and technological changes are smooth over time with yield impacts following a specific algebraic time-trend form. This model bias is a shortcoming of the econometric approach; however, the bias may be small compared to other potential estimation biases in econometric models or biases in other models that can be used to evaluate economic impacts and technological change.

Overall, the test of feasibility of the extraneous information-econometric approach for evaluating pesticide withdrawal is most promising and encouraged by the authors. Estimates can be made in a timely fashion and adjustments in basic assumptions included for sensitivity analyses.

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