Economic and Biological Variables Affecting Demand* for Publicly and Privately Provided Pest Information

Gerald A. Carlson
North Carolina State University

Several recent national reports have directed considerable attention to pest information and programs to alter current pest control information. The 1979 Office of Technology Assessment report, "Pest Management Strategies in Crop Protection" (Office of Technology Assessment, 1979) gives as a major finding and conclusion,

> "... the lack of an adequate delivery system impedes the dissemination of data necessary to support effective pest management decisions. Along with this is a shortage of properly trained personnel to conduct needed research, to develop IPM programs, and to provide information delivery systems.... A lack of practical, demonstrated interdisciplinary programs has resulted in grower skepticism and uncertainty regarding the economic benefits of IPM."

To remove the obstacles to IPM, the OTA report gives congressional options that include among others:

a) federal support for IPM training including establishing regional pest management study centers,

b) create a federally coordinated pest and weather monitoring program, support public information delivery systems, offer incentives for the formation of private information delivery systems, and increase support for state plant health clinics,

c) and overcome grower conservatism of IPM through grower education, direct grower incentives, or regulation of growers.

The Council of Environmental Quality has also just finished a report entitled "Integrated Pest Management" (Council of Environmental Quality, 1979)

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with many of the same findings and recommendations as the OTA report. In addition it calls for a feasibility study of an "early warning system" to identify problems in controlling significant pests with chemical pesticides. It recommends development of model certification requirements for independent IPM consultants. Pest-insurance schemes for farmers participating in IPM programs should also be investigated.

These recommendations and policy changes seem to depend on knowing the status of IPM information systems, and how valuable pest management advice is to growers. There are serious questions about how the extension service should assist growers and consultants. In what form if any do private consulting firms need assistance? Licensing, liability and crop insurance, specializied training and loan subsidies have been proposed. In addition, the role of more conventional grower training and crop decision making may be changing.

This paper will survey past attempts of economists and biologists to model pest control "delivery systems". I will assume that delivery of pest control information includes the functions of a) private consultants, laboratories, and scouts, b) individual growers and grower organizations, c) chemical industry salesmen and fieldmen, and d) various public organizations. To simplify, let me concentrate on the interaction between public and private sector IPM information. This will primarily leave aside the role of pest control research and the agricultural chemical industry fieldmen.

Previous IPM Consulting - Scouting Studies

There has been steady progress in the use of rigorous techniques and instruments for monitoring pests. Light traps have been used for at least 80 years for sampling agricultural pests (Harstack, et. al., 1979). Classical and sequential sampling techniques have given precision to estimates of pest populations and crop damage (Sterling,1952). Bayesian decision procedures have allowed current observations to be combined with subjective probabilities of pest infestation for improved pest control decisions for risk averse farmers (Carlson, 1970). In recent years discoveries of pest phermones and assay methods have helped lower the cost of monitoring and identifying many pest species. Computers and other communication instruments will probably further the possibilities for biological monitoring in pest management (Welch et. al., 1979).

Economic analysis of professional scouts is not a new topic. Paid specialists in insect scouting were operating in Arkansas as early as the 1930's, but they did not rapidly expand in number until the 1950's (Lincoln, Boyer and Miner, 1975). Willey (1974) provided the first analysis of California consultants. He found that farmers who were more risk averse, and had more contact with extension were more likely to hire consultants. The farmer's confidence in the quality of the information of the consultants as measured by their length of time in business was found to be another important feature in the adoption of consultant services. Hall (1977) continued the evaluation of California consultants over a longer period. His major focus was on showing that consultant-using farmers expended less for pesticides per acre. Grube (1979) found evidence of both complementary and substitute relationships between scouting and pesticide use. His production function showed a statistically significant yield increase from more insect scouting per season.

Other economic studies have directed attention to the interaction between farmer and hired pest monitoring. Pridgen (1980) analyzied cotton insect monitoring across the cotton belt. She found that farm size, extension subsidies and farmers' off-farm opportunity costs increased the probability of farmers hiring IPM services. She also found that higher consultant fees and farmer education decreased the use of these services. Grube (1979) showed that there were more total (hired and self) field inspections per season when expected pest damage and farmer managerial ability were higher. Pridgen (1980) also evaluated explanations of why farmers might join pest control cooperatives with a model similar to the hiring choice model.

None of the above studies have directed attention to the spatial aspects of IPM services. The question of the effect of extension activities on the profitability of similar private IPM practices has not received adequate analysis. There seems to be a need for a model which can evaluate future changes in state licensing of consultants.

Delivered IPM Advice

To facilitate the discussion let us divide the production and dissemination of IPM advice into three components: transportation-communication, monitoring activities, and diagnosis and recommendations. The components have primarily the same focus regardless of whether the main labor source is farmers, scouts, consultants or extension (public information). Consider momentarily this to be a model of supply of private consulting time.

The transportation-communication function is more important for pest management inputs than other agricultural inputs because of the frequent need for timely service, specific to a particular field. Production of the transportation-communication component (t) is dependent upon capital (cars, two-way radios, telephone, computers, etc.) (K), professional consultant time used in travel (T), lay labor travel time (L), farmer travel time (F) and the particular configuration of roads and crop density in the area (d):

(1) $t = t(K,T,L,F,d)$.

The field monitoring function has had considerable long-run input from research on sampling under various crop, environmental and pest conditions. At the operational stage it usually involves monitoring crop growth status, and beneficial insects, as well as pest status at the field level. Regional public pest monitoring, weather conditions and crop status changes can serve as indicators for sequential sampling schemes. Innovations in trap technology, instrumentation, phermones, weather modeling and pest separation techniques are rapidly changing the monitoring function (Rabb and Kennedy, 1979; Sterling, 1979). Also, machines and traps do not have the human behavorial biasis that may affect the effectiveness of human monitors. The production of monitoring (m) can be written as:

(2) (m) = m(K,T,L,F,I,f)

where the first four inputs (K,T,L,F) are the same as in equation (1), I is public monitoring information (extension news letters, radio reports or weather bulletins), and f refers to the particular field sizes that are in a region.

The final component of delivered IPM advice is that of diagnosis and recommendations. In some cases this component can also include IPM decision making such as when a farmer asks his consultant to contract for pesticide applications, or other actions. Alternatively, it can be entirely a grower function when he only receives monitoring reports and not recommendations from scouts. This function depends much more on stocks of knowledge on the part of growers, consultants and extension specialists. The recommendations (r) function is:

(3) r = r(T,F,I,N,s),

where T is professional consultant time in giving recommendations, F is farmer time in consultation, I is extension input in providing specific actions given specific pest conditions, N is the stock of knowledge of the consultants and the farmers, and s is the farm size. Farm size is important since uniform recommendations for all acreage of a given crop on a farm can be given in a single farmer-consultant session. Each session may have considerable set-up costs.

Total production of IPM advice includes each of the three components. If one omits capital and lay labor (they can be assumed to be perfectly elastically supplied), then the final IPM advice (A) production function is:

(4) $A = A(T,F,N,I,d,s,f)$.

By assuming that IPM consulting firms are profit maximizing firms, whose services are divisable and excludable between customers, then one can derive a supply curve for professional consultant time (T^S):

(5) $T^S = T^S(F,N,I,d,f,s,A_p)$.

A_p is the contract price per acre-year for the consultant firm advice, and T^S is the total consultant time supplied. Given that there is some constant labor-leisure choice across consultants, then T^S represents numbers of consultants. The stock of knowledge (N), public information (I), and farmer inputs (F) are considered to be substitutes for consultant time in equation (5). More consultants will be supplied where regional crop density (d), large field (f) and farm size (s) favor lower cost provision of service.

Grower Demand for IPM Advice

Grube (1979) and Hall (1977) have shown that scouting and consultant advice can enter the agricultural production function.

Consider a simple single crop production function:

(6) $V = V(P,A',O)$,

where V = yield of crop output, P is expected pest density, A' is the level of all types of advice on pest management, and O represents all other inputs. The derived demand for the advice input is:

(7) $A'^D = A'^D(P,A'_p,O_p,V_p)$,

where the p subscript denotes the purchase price for the advice and other inputs, and V_p denotes crop value. However, this is not the demand for consultant advice, since A' is composed of advice from extensionists, the farmer himself, and consultants. Including the selection between type of advice leads to:

(8) $A^D = A^D(I_p, F_p, V_p, A_p, O_p, P)$.

In this demand for a farm input equation, extension information price (I_p) and farmer advice price (opportunity cost of farmer time) (F_p) are expected to increase the demand for consultants.

With no barriers to entry into consulting, then market clearing prices for advice should determine the equilibrium number of consultants. If there was state certification of consultants, then consultant wages need not be equal across location. The reduced form of equations (4) and (8) can be written as:

(9) $T = T(P, I, V_p, N, s, F, f, d, A_p, F_p, I_p, O_p)$.

This model could be used to evaluate each of the major sources of IPM advice. A model similar to this one has been used by Taylor (1978) to estimate the regional distribution of veterinarians. He found that having a school of veterinarian medicine in a state does not increase veterinarian density. This model should enable one to evaluate the geographical effects of the proposed IPM training centers and the regional specificity of other IPM training.

For a test of this model for private consultants, consider a simplification of equation (9) in which crop density, consultant fees, farmer opportunity cost and time, extension information cost, and all other input prices are assumed constant across regions. Field and farm size (s) will be measured by acres per farm, expected pest level (P) will be measured by pesticide expenditures per crop acre in an earlier period, and public information (I) is measured by the number of extension and state IPM specialists. The stock of knowledge of farmers and consultants in a region (N) is measured by regional cotton production. Cotton has a long history of IPM consultation, and IPM experience has been accumulated by consultants and farmers in those regions growing cotton. Crop value is crop value per acre of crop produced. The final model to be estimated is:

(10) $T = (P, I, V_p, N, s)$

One of the most difficult problems is finding a good measure of private IPM consultants. There are many crop consultants which are not IPM specialists. Also there is no association to which all IPM specialists belong. The Inter-society Consortium for Plant Protection (ICPP) performed a survey of land-grant university department heads in 1978 (ICPP, 1979). They obtained estimates of numbers of IPM consultants (M.S. and Ph.D.), scouts (B.S.), IPM extension specialists, and departments of agriculture IPM specialists by states. Table 1 shows a regional tabulation of their results. The scout category undoubtedly includes individuals who only work at IPM about three to four months per year. The number of independent consultants show a high degree of variability by region. There were 471 public IPM employees.

Table 2 gives a similar regional tabulation of the number of nematode samples processed in 1979. It shows critical IPM service. The western U.S. is primarily private, while there are large fee-for-service laboratories operated by public agencies (universities and state plant health clinics) in the southeast, Delta States and Appalachian regions. Nematode samples are more excludable than some IPM advice because nematode densities are often farm and field specific. Farmers can not easily be a free rider on the advice given to a neighbor farmer. There appears to be a justification for encouraging private development of this service.

Analysis of Regional IPM Consulting

The effect of extension and other public IPM specialists is not unambiguous in the above IPM advice model. More extension effort in monitoring and recommen-

Table 1. Number of Public and Private IPM Specialists, 1978[1]

Region[2]	Scouts (B.S.)	Independent Consultants (M.S., Ph.D)	IPM Extension Specialists	State Dept. of Agri.
Northeast	40	9	24	17
Lake States	117	15	16	14
Conn. Belt	126	31	33	20
Northern Plains	94	41	20	10
Appalachia	142	5	43	9
Southeast	150	33	35	15
Delta States	115	85	18	29
Southern Plains	137	118	48	7
Mountain	112	30	29	35
Pacific	317	113	20	29
U.S. Total	1350	486	286	185

[1]Estimates made by department heads in crop protection disciplines at land grant universities (Intersociety Consortium for Plant Protection).

[2]See USDA Pesticide use surveys (Blake and Andrilenas) for regional deliniations.

Table 2. Nematode Samples Processed Per Year by Public and Private Sources by Region, 1979.

Region	SAMPLES PER MILLION CROP ACRES		NO. OF[3] PRIVATE LABS.-NEMATODE SERVICE
	Public[1]	Private[2]	
Northeast	129	192	1
Lake States	76	0	0
Corn Belt	72	66	5
Northern Plains	11	22	1
Appalachia	1534	79	2
Southeast	1857	70	1
Delta States	694	55	1
Southern Plains	54	0	0
Mountain	229	115	3
Pacific	360	1350	39

1- Based on a telephone survey of each state by Department of Economics and Business, N.C. State University, 1980.
2- Based on a telephone survey of a sample of private labortories, Department of Economics and Business, N.C. State University, 1980.
3- See (Quick and Hipp, 1979) for a partial listing.

dations will lower the supply price of consultant time and increase the supply of consultants in a region for a given consultant advice demand. On the other hand, lowering the price of extension specialist information (I_p) can lead to its substitution for private consulting in equation (8) and reducing the demand for this advice. It would be difficult to sell a nematode assay service if the extension service provides the same information at a much lower cost.

A final estimation problem is present in the model of equation (10). The crop value (V_p), the level of pesticide expenditures (P), and public employees (I) may not be exogenously determined. However, on a regional basis expected crop value may not be determined by numbers of consultants even though it may be at the farm level. Using a previous pesticide expenditure level to indicate expected pest level may also help with the simultaneity problem. Only pesticide data other than herbicides was used because of the lack of variability in herbicide practices, and the general absence of IPM consultants for weed problems. For the public employee variable one may be able to argue that the public employees preceeded the private ones in time.

The regional estimate of the reduced form equation for consultants was estimated by least-squares using the data of Table 1. Individual state date were not used because of the absence of state data on pesticide use.

The estimated regional model of consultants per million crop acres with t values in parenthesis is:

$$(11) \quad T = -.53 + \underset{(2.00)}{.47P} + \underset{(2.26)}{.07V_p} + \underset{(.93)}{1.495} + \underset{(11.46)}{.03N} - \underset{(-1.92)}{.37I} \qquad R^2 = .98$$

Each of the variables has the expected effect. The demand side substition effect of the public IPM service (I) outweighs the supply effect to give a negative influence on number of consultants.

The elasticities computed directly from equation (11) are .34, .52, .11, .7 and -.4 for expected pests, crop value, farm size, knowledge stocks and public employees, respectively. The relatively large impact of cotton production probably measures season length and pest complexity, as well as accumulated experience. A data set which had direct measures of experience could separate these effects. The highly significant effect of cotton production on consulting needs further analysis. Because of the few degrees of freedom, only the stock of knowledge variable is highly significant. However, these preliminary results suggest that a state-level analysis should be undertaken. A simultaneous model of public and private consulting with more complete measures of farmer opportunity costs, consultant experience, crop density, and other measures of expected pest level and variability of pest level is being developed.

There is little analysis of the substitution possibilities between consulting and pesticide use in the model above. To see what type of information is being collected on concurrent use of pesticides, non-pesticide controls and consulting, let us turn to recent USDA pesticide use surveys.

USDA Pesticide Use Surveys

The non-pesticide information gathered in the latest USDA pesticide-use surveys is extensive. In recent years, there is a distinct trend toward asking farmers more about their non-pestcide pest control practices at the same time that pesticide use is measured. Table 3 summerizes some of these changes. Beginning with the 1977 cotton survey, questions on target pests, scouting and farmer management practices were first collected. Recent surveys also have information on social costs. Target pest tabulations give which common pest species farmers believe they are controlling with particular pesticide applications. Such information is helpful in establishing crop protection research priorities,

Table 3. USDA PESTICIDE USE SURVEYS - Non Pesticide Information

CROP(S)-Year	TARGET PEST				SCOUTING		MANAGEMENT			
	Sample size[3]	Infest. level[4]	Target pest	Crop stage	Type	Cost	Pesticide substitutes[5]	How start trt.[6]	Demog.[7]	Crop value
General 1964	10,800									
General 1966	9,600									
General 1971	8,600									
General[1] Field Crops 1976	6,200		x							
Cotton 1977	4.000		x	x	x	x	a, b, c, d	x	x	
Citrus 1977	3,500		x		x	x	a, b	x		x
Deciduous Fruit 1978	5,100		x	x	x					
Potato 1979	2,100	x	x	x	x		a, b	x		
Grape 1979	300	x	x	x	x		b			x
Vegetables 1979	3,700						a,b,c	x		x
Cotton 1979	2,400	x	x	x	x	x	a,b, c,d	x	x	
(Corn, Soybean[2] Grain Sorghum) 1980	2,900 1,900 700	x	x	x	x		a,b, c,d	x		

1- 12 crops or crop groups and livestock
2- Preliminary draft
3- Selected sample size, not actual number of valid questionnaires
4- Infestation level probabilities
5- a: crop rotation, b: cultural practices, c: natural enemy enhancement, d: other
6- What pest or other information determines the decision to take a pest control treatment
7- Demographic characteristics of the farm manager are included
8- Protective clothing use is tabulated in the Potato and vegetable surveys

RPAR evaluations by EPA, and effectiveness evaluations of particular pest specie control activities like eradications. Infestation levels refer to farmer estimates of the relative level of pest attack in the year of the survey. Crop stage indicates whether information was collected on the physiological stage of the crop when a pesticide was applied.

The scouting data collection is limited in scope, but 3 surveys have collected fees charged, and six will have some tabulation of type of scout employed or source of scouting information. Typical scout deliniations are pesticide dealers, commercial scout, extension service, and commodity fieldman. But some questionnaires merely ask "sources of information." There does not seem to be a consistent way of tabulating farmer scouting in the survey, and often it is omitted. The studies by Willey (1974) and Grube (1979) point to the need for complete information on amount and quality of self and hired scouting. Quantitative analysis of tabulations of "sources of information" for IPM decisions is not likely to be helpful.

The farm management information on pesticide surveys is usually limited. The interactions of other factors of production (labor, fuel, land, fertilizer, etc.) with pests and pesticides may be more accurately measured in commodity surveys or the agricultural census. (See Carlson (1977) and Headley (1968) for analyses with these data.) However, there has been a conscious effort in recent ESCS surveys to tabulate direct pesticide substitutes such as crop rotation, cultural practices, natural enemy enhancement, and some other factors. One type of management question which is directly related to scouting which appears in almost all recent surveys is "How do you decide when to initiate treatment with pesticides?" Responses involve use of particular pest infestation levels, first observed pests, and answers based on advice from various sources. This does give information on whether "economic thresholds" are being used. However, Pridgen (1980) found this type of information was not sufficient to develop a pest management skill measure for each farmer. The work of Hall (1977) in giving farmers more complete "exams" to measure their skill levels needs further evaluation.

For the USDA pesticide use surveys to be most effective for evaluation of IPM information services, there needs to be some modifications. First, minimal farmer demographic data is necessary to estimate farmers' opportunity costs of time. Consultant and farmer IPM experience should also be tabulated. Average field and crop acreage sizes per farm will also be helpful in evaluating transportation. Use of traps, IPM computer links and other capital items could also be easily tabulated.

Summary

Many changes are being proposed in pest control information. There is still considerable disagreement about the most effective means to reduce crop losses and control costs associated with pests. Studies of pest consulting have just begun to unravel the various interactions between extension, farmer and consultant participants.

This study separates the IPM advice process into three components, and provides a supply and demand model which can be estimated. With a limited, regional set of data encouraging results were obtained. More complete data from USDA pesticide use surveys may permit better specification of such models. Policy questions on IPM information certainly require more attention by economists.

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