Classical Biological Control of Insects:

A Benefit-Cost Approach

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Abstract

A simple benefit-cost framework suggests that we are seriously underinvesting in classical biological control (CBC) research. The analysis shows minor costs and the potential for major benefits. Because the benefits of CBC research are widespread and difficult to assign, such research should be funded from general government revenues.

Introduction

Recent years have seen increased concern about the role of pesticides in crop production, in particular about their effects on human health and environmental quality. As a result, alternative crop production strategies which require reduced use of pesticides have attracted considerable interest. This paper is a benefit-cost approach to one of those alternative crop production strategies, classical biological control.

Pest control is important. According to the 1987 Census of Agriculture, U.S. farmers spent about $4.7 billion on pesticides in attempting to control pests during that year (U.S. Department of Commerce, 1989). This is a substantial use of resources (about 4.4 percent of all farm production expenses), and suggests that large incentives exist to develop more efficient means of pest control. Numerous pest control technologies (ranging from chemical pesticides to gigantic vacuum cleaners which suck insects directly from crops) have been developed, often by private industry. There is, however, an important form of pest control which has not attracted much interest from private industry.

Biological control (or biocontrol) involves using naturally occurring organisms to control pest species. While there are examples of private industry involvement in biocontrol (for example, see Dietrick, 1980), they are the exception. As van den Bosch, et. al. (1982) note, "The private sector has largely restricted itself to insect production and inundative release of a relatively few imported and native natural natural enemies. Such a demand develops if the population of an *effective* foreign introduction or and indigenous biological control can adequately suppress the pest population within the season, but for some reason becomes too scarce between seasons as a result of severe winter conditions or low host densities." (pg. 216) Thus, private industry has become involved in biological control where circumstances are such that repeated application of biocontrol agents is necessary and thus there is a continuous market for purchased products.

In this paper, we are concerned with a different kind of biocontrol, namely classical biological control (CBC). Cate (1990) describes CBC as "...an approach almost exclusively directed at insect and weed pests which have been introduced into a country by accident, leaving behind their natural enemies. The methods of this approach are to identify the geographical origin of the pest, travel to that origin, locate potential natural enemies, and (following rigorous quarantine screening) colonize these natural enemies with the newly colonized pest." (pg. 25) When successful, the natural enemies (biocontrol agents) subsequently build up populations which are self-sustaining and sufficient to hold the pest species in check. Further inputs into the system are unnecessary.

As van den Bosch et. al. (1982) put it, "This is both the beauty and the bane of this control technique. This method may be initially spectacular and is often observed as it occurs by the farmers and the public. Fortunately, the pest problem is reduced, but unfortunately, the farmer soon forgets about it. It no longer provides a lasting advertisement of biological control." (pp. 209-210) This is certainly a contrast with chemically-based control systems which require repeated applications. The company which can develop pesticides which effectively control pests may look forward to many years of sales. A company which offered its services in the development of CBC agents would be offering a one-shot deal and would not be able to profit from continued pest control.

The identification and introduction of CBC agents can be extremely cost effective. DeBach (1974) recounts the success of a program to control cottony-cushion scale in California, a pest which threatened to destroy that state's citrus industry in the late 1880s. Within a year of the release of 514 Australian lady-bird beetles, it had become difficult to find cottony-cushion scale in citrus-growing regions of California. The cost, according to DeBach, was "...all told less than $5000.00. Benefits to the citrus industry have amounted to millions of dollars annually ever since." (pg. 99)

It is important to realize that CBC is applicable only to pest species introduced into this country, and that only about 40 percent of insect pests are foreign in origin (Sailer, 1983). Nevertheless, exotic species are disproportionately important causes of crop damage (van den Bosch, 1971), and this suggests that CBC has great potential in controlling insect pests.

Many of the technologies used to control agricultural pests are developed in the expectation that they can be sold. This is not generally the case with CBC technologies. They are based on the establishment of free-living populations of control organisms which do not respect property boundaries. When a CBC system is set up for one user, it necessarily becomes available to all users - it is by its very nature a non-exclusive (or "public") good.

It is precisely because CBC agents are non-exclusive goods that normal market mechanisms will not provide them in "optimal" quantities. There is no way to collect payments from parties which benefit from the technology, and hence no incentive to invest the substantial up-front costs usually associated with developing CBC systems. The implications of this will be explored later in the paper.

This paper will address two related questions. When does it make financial sense to develop CBC technologies, and who should pay for doing so?

Methodology

Unlike deciding what rate at which to apply agrichemicals, the decision to undertake development of a CBC agent is not a "continuous" one. It makes no sense to speak of developing 0.673 CBC agents. The decision is a binary (yes/no) one, and any development criterion must take this fact into account. In addition, development of a CBC agent is not a "sure thing". It requires substantial up-front investment and long lead times, and after having made these investments the control agent may not be effective. In this paper, we develop a simple (but appropriate) cost-benefit analysis framework which provides a criterion for the yes/no development decision.

The following assumptions are made for tractability. First, the development costs are spread evenly over m development periods and are borne before any benefits accrue. There is some probability p ($0<p<1$) that the CBC program will be successful and that benefits will accrue; if so, they accrue at a constant rate beginning in the period immediately after the last development period and continue indefinitely.

The decision criterion in this case indicates that development should begin if the net present value of the project is positive; that is, if

[1] *p (discounted benefits) > (discounted costs)*,

where p is the probability of success. More formally, project development should begin if

$$[2] \qquad p\left(\frac{B}{r}\right)-\sum_{i=1}^{m}(a^{i}B) \quad > \quad \sum_{i=1}^{m}(a^{i}C)$$

where B = constant annual benefit of reduced pesticide use,

C = constant annual development cost,

a = 1/(1+r), where r is the discount rate,

m = project development time, in years,

and p is defined as before.

Note that B/r is the value of an annuity payment (B) received in perpetuity.

Given the above framework and assumptions, it is possible to solve [2] for B. Doing so, we obtain an expression for the minimum annual benefit necessary tojustify initiation of the project:

$$[3] \qquad B > \frac{CrF}{p(1-rF)},$$

where B, C, r, and p are defined as before, and

$$[4] \qquad F = a^1+a^2+\ldots+a^m,$$

where m is defined as before, and

Thus, if we know the constant annual project development cost (which depends on the development time requirement), probability of success, and discount rate, it is possible to calculate the magnitude of the annual benefit stream "trigger" necessary to justify initiating project development. Fortunately, some estimates of these are available.

Djerassi, et. al. (1974) provide estimates of project development time and total cost for entomophagous (insect-eating) CBC projects. Development times are dependent upon the reproductive cycles of hosts and biocontrol agents, but wide-scale releases of control agents typically occur 4 to 7 years after project initiation. Two different estimates of total project costs are provided; namely $293,000 and $461,000 (adjusted to 1987 dollars). Both values are used in the analysis, since we have no means of determining which estimate is more accurate.

Our estimate of p, the probability that any given project will succeed, is based on the past success rates for CBC projects worldwide provided by Hall, et. al. (1980). They emphasize that many factors can affect the probability of success for a given project. Nevertheless, we take the success rate they report (0.16) as a general probability that control of a pest species will be complete. In some cases, control of pests is partial; those cases are not included in the estimate of p, nor is any information available about the variance of this estimate.

Finally, the choice of discount rate is crucial to the value of the benefit "trigger". The choice of a discount rate is controversial, and a vast literature has built up which addresses some of the problems associated with choosing a discount rate. We will not attempt to deal with any of that here. Rather, we perform our analysis with three different discount rates (0%, 3% and 10%) and present the results in tabular form. The zero discount rate was chosen as representing the views of those who feel that discounting is inappropriate when decisions are made that affect individuals (i.e., future generations) who are not included in the decision-making process. The 3 percent discount rate was chosen as being close to the long-term real rate of interest. The 10 percent rate was chosen as being perhaps the most common rate in use in project analysis.

Results

Annual benefit triggers were calculated for each combination of four different development times, three different discount rates, and two different total development costs. The results are presented in Table 1. All figures reported in Table 1 are in thousands of dollars. Several results deserve discussion.

First, the choice of the discount rate is critical to the size of the annual benefit trigger necessary to financially justify project initiation. In the extreme case of a zero percent discount rate, any positive benefit flow is sufficient to justify project development costs. This is because the benefit flow is assumed to exist in perpetuity.

Increases in the discount rate are accompanied by increases in the benefit trigger. An increase in the discount rate from 3% to 10% in the lowest cost seven year development time frame causes a more than fourfold increase in the level of the trigger. The annual benefit stream necessary to financially justify the development costs goes from $60,000 to $248,000 a year, a substantial difference.

While the choice of the discount rate has a drastic effect on the trigger level, the time required for development is less important. Expanding development time from 4 to 7 years at the 10 percent discount rate (lowest cost estimate) increases the trigger amount from $212,000 to $248,000 a year. In this example, a 75 percent increase in development time increases the benefits trigger by only 17 percent. These increases are even smaller at lower discount rates.

The relative importance of the discount rate has important implications. The biological and regulatory requirements that determine project development time have very little impact on the decision to implement development. What *is* important in the decision-making process is the way in which society and its decision makers value current benefits over future benefits. Policymakers with a long-term outlook (i.e., those who would likely favor a low discount rate) will be more inclined to see CBC as a financially worthwhile proposition than would those persons with a short-term perspective. Likewise, private companies which require a high rate of return on their R & D investments may choose not to invest in CBC research, even assuming that they could capture all of the benefits.

Discussion

We turn now to the second question posed in the introduction to this paper: who should pay the costs of developing CBC mechanisms? To answer this question, we need to ask who would benefit from CBC. Several groups can be identified:

- Agricultural producers would see a reduction in production costs, since chemical controls would no longer be necessary for those pests affected.
- To the extent that these lower production costs are reflected in lower food prices at the supermarket, consumers would benefit.
- Persons exposed to dangerous pesticides would benefit from a reduction in health risks. This category would include individuals involved in the manufacture of pesticides, farm workers who apply or are otherwise exposed to pesticides, and third parties who are inadvertently exposed to pesticides through groundwater contamination, drift from aerial application, or ingestion of

pesticide residues on foods.

This last group is the most problematic. The dose-response relationship between pesticides and human health is extremely difficult to assess. Indeed, even if the dose-response relationship can be reliably estimated, it is virtually impossible to determine, except in the most unusual cases, who has been exposed to how much of a particular compound. Nevertheless, attempts have been made to estimate excess cancer deaths from pesticide residue exposure (see National Research Council, 1987, for example). These estimates are highly controversial; but granting their credibility does not resolve the problem - it merely moves us to the next problem - that of valuing human life.

This is one of the most controversial topics in economics, and numerous studies have tried to assign a monetary value to human life (see Viscusi, 1983, for a survey), and a wide array of values have been reported. Of course, excess cancer deaths are not the only concern here, since non-lethal deleterious effects have been ascribed to pesticide exposure.

Given these problems, an economic analysis of the health benefits of avoiding a particular pesticide on a particular crop would likely be controversial, time consuming, unconvincing, and quite possibly more expensive to perform than the CBC program it would be used to justify. Practicality (and the judicious use of scarce resources) calls for using the cost of pesticide application avoided as a *lower bound* on the level of the potential annual benefits realized from a transition to successful CBC. If health effects from the use of the pesticide are considered significant, an upward adjustment in the potential annual benefits may be warranted. The point, however, is that such adjustment may not even be necessary to justify initiating a CBC research program.

If, as seems likely, farm workers and persons employed in manufacturing pesticides would reap the greatest *health* benefits from reduced pesticides use, they can hardly be viewed as a source of funding for CBC projects. We leave the reader to consider the ramifications of asking pesticide factory workers to pay for research that might leave them unemployed, or migrant farm workers to pay for the health benefits of reduced pesticide use. Other groups will have to bear the burden.

Thus, we turn to producers. Cost recovery from producers might not be necessary. A monopoly producer or cartel would be able to capture the benefits of CBC and would thus have an incentive to shoulder development costs. We are not aware of any agricultural product of consequence which is produced in the United States under these conditions, but if there were one, the individual producer or cartel could be relied upon to take advantage of any cost-reducing technology.

Producer groups might be a source of voluntary funding of CBC research, but such groups face a free-rider problem. Their members incur temporarily higher costs in the hope of obtaining lower costs in the future. However, if realized, these lower costs accrue to producers who are not members of the producer group - hence, the free rider problem. The larger the number of growers, the more difficult obtaining universal cooperation would likely be. If sufficient cooperation could be achieved to make voluntary funding financially worthwhile in spite of the free-rider problem, then we would expect to see such groups willing to fund CBC research. This could occur if the benefits to a group were sufficiently large to cover the costs.

In the case of perfect competition (plausibe, since most agricultural commodities are produced by many farmers), the long-run supply curve is essentially flat, meaning that any decrease in marginal costs results in an identical reduction in price. This implies that the benefits of the decrease in production costs are captured by consumers in the form of increased consumer surplus. In this situation, a production tax used to finance CBC research would simply be passed on to consumers.

If this is the case, it seems reasonable to look to consumers, as the ultimate beneficiaries of lower production costs, to pay for the research that lowers those costs. All residents of the United States are consumers of food; hence the average burden of a \$100,000 per year CBC program is about \$0.0004. An annual levy of \$1 per person could finance approximately 2,500 such CBC projects.

From a commodity point of view, the per-pound tax required to raise \$100,000 per year varies according to the crop. The necessary amounts for some agricultural commodities are shown in Table 2. Under the column "Programs" in this same table, the number of CBC programs which could be financed by a one-cent-per-pound tax on each commodity is indicated.

What these results suggest is that it is probably not worthwhile to attempt to collect the funds to support CBC research at the grocery checkout. The required tax for all of the commodities in Table 2 is much smaller than any unit of currency.[1]

In all of these cases, the critical questions are: how much does it cost to collect the tax, relative to what is collected, and how does this method compare with using funds from general tax revenues? While schemes could doubtless be devised that protect individuals like President Bush (who doesn't eat broccoli) from having to finance CBC research on broccoli pests, the costs of implementing them would likely be far greater than the benefits that would accrue from the attempt. There are more important inequities for the government to address.

Conclusions

Because we have little information about expenses incurred in the control of specific pests, there is nothing we can conclude about the advisability of initiating CBC programs for any particular pest problem. Nevertheless, given the overall magnitude of resources expended in the control of pests, it's virtually certain that large numbers of CBC research projects could be justified using the benefit-cost framework developed in this paper.

Because the benefits of successful CBC research are so

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[1] An alternative is to collect the tax at the wholesale level. For example, a tax of one penny could be imposed for every X pounds of the commodity handled at the wholesale level. (In this case, it happens to be true that X for each of the commodities is equal to the corresponding number under the programs column in Table 2)

widespread and difficult to accurately assign to individuals, practicality argues for funding such research out of general tax revenues. Attempting to recover costs from most beneficiaries would likely result in considerable administrative expense, a dubious use of scarce resources.

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