

Biosecurity Economics: Conflicting results in evaluation criteria

Sarah L Goswami*

* Economist/Policy Officer, Department of Primary Industries and Fisheries, Queensland

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Abstract:

Determining the optimal policy response to a species invasion is a multidimensional problem. The choice between eradication or containment has social, environmental, political and economic dimensions. Often, economic evaluation is used as a basis to underpin policy decisions. However, under certain conditions economic evaluation criteria may provide conflicting results. Deterministic factors, such as rate of spread, degree of damage and the time until detection, are derived for identifying when caution must be taken with the results of economic evaluation criteria. The conditions under which conflicting results may be obtained between NPV and BCR are identified and linked to policy implications.

Keywords:

Biosecurity economics; eradication; containment; invasive species

Disclaimer:

The author is responsible for any errors. Opinions expressed in this paper are those of the author alone and do not necessarily represent the views of the Department of Primary Industries and Fisheries, Queensland.

Introduction:

Invasive species are a major contributor to losses in agricultural production and global biodiversity. In the United States invasive species are estimated to cost over US\$138b per year in damages and control (Pimentel et.al., 2005). In Australia the impact of invasive animals is estimated to be over \$700m annually (McLeod, 2004). Numerous other studies indicate similar losses due to invasive weeds. See for example, Tumaneng-Diete et.al. 2007 on lantana and Goswami 2008 on Siam Weed.

With the possibility for such large losses, over the past few decades there has been increasing emphasis on the use of economic analysis to help determine the efficient allocation of resources in a resource limited environment. In a biosecurity context, this idea has been extended to the determination of the optimal management strategy for invasive species incursions.

Whilst the use of economic analysis and in particular Cost Benefit Analysis (CBA) to determine management responses is justified, attention needs to be given to the circumstances where CBA has shortcomings. With knowledge of the shortcomings of CBA and in particular, knowledge of the deterministic factors that may result in inconsistent results from CBA indicators, alternative analyses and information can be conducted from the outset. As such, this can help to minimise response times and project costs when invasive species incursions occur.

The aims of this paper are three-fold:

1. To identify mathematically the conditions under which conflicting results occur between economic evaluation criteria.
2. To put these conditions into an invasive species context, drawing attention to the factors (in an applied sense) under which the conflict may arise.
3. Discuss subsequent policy implications.

Conflicting Results in Economic Evaluation:

It is often cited that conflicting results may be found between the Net Present Value (NPV) and the Internal Rate of Return (IRR) when conducting Cost Benefit Analyses (CBA). See for example, Campbell & Brown, 2003 and New Zealand Treasury, 2005. As a result, the issues between NPV and IRR are generally known (or highlighted in CBA reports) to decision makers. Conversely however, considerably less attention is given in the literature to the potential for the NPV and Benefit Cost Ratio (BCR) to favour the selection of different scenarios. That is, when NPV and BCR give inconsistent ranking results.

It has been found that conflicting results between NPV and BCR can be seen in instances where the difference between the PV of benefit streams tends toward the difference between the PV of cost streams, with the former being larger than the latter. The following proof, based on an invasive species context of what is the optimal management decision; eradication or containment, demonstrates this.

Where:

- A = PV benefits (eradication)
- B = PV costs (eradication)
- C = PV benefits (containment)
- D = PV costs (containment)

Situation 1: Both NPV and BCR give the same result

IF

$$B < D$$

AND assume that

$$\text{NPV eradication} > \text{NPV containment} > 0$$

$$\rightarrow A - B > C - D > 0$$

THEN

$$\text{BCR eradication} > \text{BCR containment} > 1$$

$$\rightarrow \frac{A}{B} > \frac{C}{D} > 1$$

This is because of the following:

When

$$A - B > C - D > 0$$

AND

$$B < D$$

Then

$$\rightarrow \frac{A - B}{B} > \frac{C - D}{D} > 0$$

$$\rightarrow \frac{A}{B} - 1 > \frac{C}{D} - 1 > 0$$

$$\rightarrow \frac{A}{B} > \frac{C}{D} > 1$$

Situation 2: NPV and BCR give inconsistent results

IF

$$B > D \text{ (by a relatively large amount}^1\text{)}$$

AND assume that

$$\text{NPV eradication} > \text{NPV containment} > 0$$

$$\rightarrow A - B > C - D > 0$$

$$\text{OR } \rightarrow A - C > B - D$$

AND

$$A - C > B - D \text{ (by a relatively small amount)}$$

THEN

¹ This difference is compared to the subsequent difference between NPVs.

1 < BCR eradication < BCR containment

$$\rightarrow 1 < \frac{A}{B} < \frac{C}{D}$$

The exact point where this conflict arises is when

$A - C$ tends to $B - D$ ($A - C$ is minimised)

AND

$B - D$ tends to $A - C$ ($B - D$ is maximised)

AND

$A - C > B - D$

Figure 1 shows this turning point where conflict arises (left) and conversely when it does not arise (right).

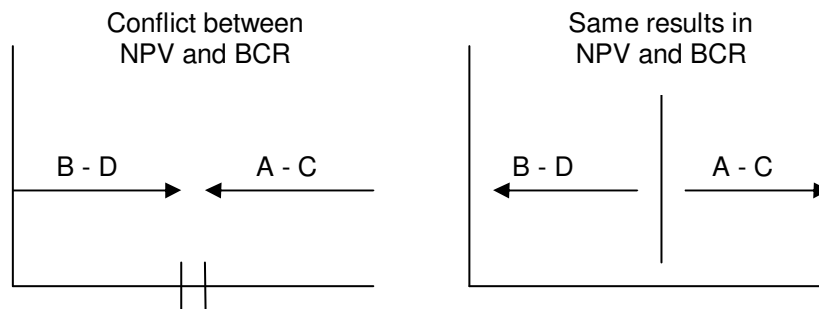


Figure 1: The points at which a conflict will and will not arise between the NPV and BCR

The threshold associated with yielding inconsistent results is most effectively shown by use of numerical examples.

Example 1: NPV and BCR yield same results

Where:

$A = 2030$

$B = 940$

$C = 1880$

$D = 890$

Maximising $A - C$ and minimising $B - D$ (i.e. tending the two numbers away from each other)

$$\begin{aligned} \rightarrow A - C &\uparrow \\ &= 2030 - 1880 \\ &= 150 \end{aligned}$$

AND

$$\begin{aligned} \rightarrow B - D &\downarrow \\ &= 940 - 890 \end{aligned}$$

$$= 50$$

AND

$$\begin{aligned} A - C &> B - D \\ &= 150 > 50 \end{aligned}$$

THEN

NVP eradication > NPV containment > 0

$$\begin{aligned} \rightarrow 2030 - 940 &> 1880 - 890 &> 0 \\ \rightarrow 1090 &> 990 &> 0 \end{aligned}$$

AND

BCR eradication > BCR containment

$$\rightarrow \frac{A}{B} > \frac{C}{D}$$

$$\rightarrow \frac{2030}{940} > \frac{1880}{890}$$

$$\rightarrow 2.16 > 2.11$$

Example 2: Conflict arises between NPV and BCR

Where:

$$A = 2030$$

$$B = 940$$

$$C = 1920$$

$$D = 831$$

A - C is minimised and B - D is maximised ensuring that A - C > B - D

$$\begin{aligned} \rightarrow A - C &\downarrow \\ &= 2030 - 1920 \\ &= 110 \end{aligned}$$

AND

$$\begin{aligned} \rightarrow B - D &\uparrow \\ &= 940 - 831 \\ &= 109 \end{aligned}$$

AND

$$\begin{aligned} A - C &> B - D \\ &= 110 > 109 \end{aligned}$$

THEN

NVP eradication > NPV containment > 0

$$\rightarrow 2030 - 940 > 1920 - 831 > 0$$

$$\rightarrow 1090 > 1089 > 0$$

AND

$$1 < \text{BCR eradication} < \text{BCR containment}$$

$$\rightarrow 1 < \frac{A}{B} < \frac{C}{D}$$

$$\rightarrow 1 < \frac{2030}{940} < \frac{1920}{831}$$

$$\rightarrow 1 < 2.16 < 2.31$$

Deterministic Factors:

The situation shown in the previous section whereby the NPV and BCR yield conflicting results can often arise when evaluating biosecurity options; notably when choosing between mutually exclusive options of eradication and containment programs. In a practical context, this is due inherently to three factors;

1. the characteristics of the incursion,
2. the structure of costs and benefits of the two scenarios, and
3. the time preference of money.

The following scenarios highlight the deterministic factors² under which it may be possible for a conflict to arise between the NPV and BCR.

Scenario 1: Both NPV and BCR give the same result

Assumptions:

- Species incursion with rapid spread and high level of associated damage
- Response time until eradication/containment programs commence is short
- Eradication is difficult; expensive and lengthy to eradicate

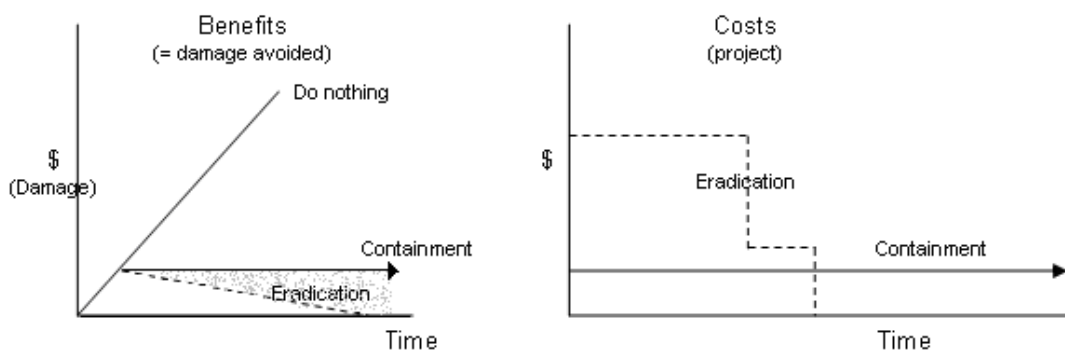


Figure 2: Benefit and cost streams for eradication and containment programs; given rapid spread, short response time and difficulty in eradication.

² Conditions have been simplified for this analysis; however they could be extended to include such factors as the length of monitoring which is required to determine eradication has been achieved, the time until initial detection and biological characteristics such as juvenile survival and seed longevity.

An underlying condition for the achievement of eradication is that the rate of species removal exceeds the rate of spread/breeding. If this does not occur then the time until eventual eradication will be increased and/or eradication may not ever be achieved (Panetta & Timmins, 2004). Following from this condition; the more rapid the spread/breeding, the greater the effort that is required to achieve eradication. Similarly, if an eradication program was underfunded (determined as species spread > species removal) then program costs will drag on into the future.

Conducting an eradication program for an invasive species incursion with rapid spread often leads to a large difference in the PV of costs between eradication and containment³. This is due to the time preference of money. The indefinite (and relatively smaller) costs of containment into the future become negligible as they are weighted less heavily, whilst the large upfront costs of eradication become comparatively large as they are weighted more heavily (Figure 2 – costs graph).

When faced with a species that has rapid spread rate and the response time is short the difference between the PV benefits of eradication versus containment is generally small. This can be seen by the difference between the damage associated with containment and that associated with eradication; the shaded area in Figure 2 – benefits graph. At the point in time when the difference in benefits is the largest the effect of the time preference of money is also large. This effectively results in the actual difference in benefits being minimised.

Under these set of factors the NPV and BCR will most likely yield the same results as:

- A large difference in PV costs, and
- A small difference in PV benefits

Will result in the

- Difference in PV costs > Difference in PV benefits

And thus the

- NPV and BCR will yield the same results

Scenario 2: NPV and BCR may yield same results

Assumptions:

- Species incursion with slow spread and low level of associated damage
- Response time until eradication/containment programs commence is short
- Eradication is relatively quick and inexpensive

As stated previously, species removal must exceed species spread/breeding in order to achieve eradication. Thus, it follows that it is relatively quick and inexpensive to eradicate an incursion which has a slow spread rate and low associated level of damage⁴. In this situation, the difference between the PV costs of eradication versus the PV costs of containment is relatively small and the time preference of money has less of an impact than it did in scenario 1.

³ Note it is assumed that the species will be contained at its program commencement level.

⁴ This could also be extended to include biological attributes such as seed longevity, which if long would mean that eradication costs increase and thus the difference between the PV costs also increases.

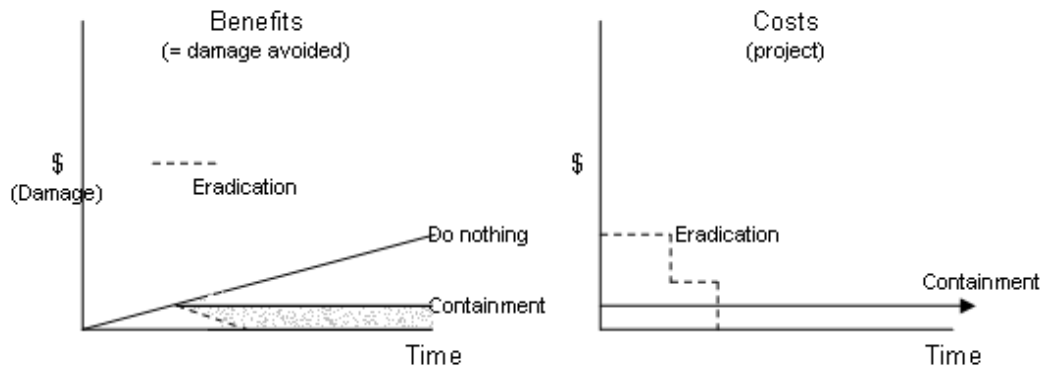


Figure 3: Benefit and cost streams for eradication and containment programs; given slow spread, short response time and relative ease in eradication.

The shaded area in Figure 3 shows a small difference in benefits between eradication and containment programs in relation to a species incursion that spreads slowly and is easily eradicated. This difference translates into a small difference between the NV benefits of the two scenarios.

The important factor in this example is not the size of the differences in PV cost streams and PV benefit streams, but the relative similarity in their size. The size of the differences is not significant in determining if the NPV and BCR will yield conflicting results. Rather for inconsistent results to be seen, it is only necessary that the two differences are similar in size and that the difference in the PV of benefits is greater than the difference in the PV of costs.

Under the assumptions of scenario the NPV and BCR may yield inconsistent results as:

- A small difference in PV costs, and
- A small difference in PV benefits

May result in:

- Difference in PV benefits > Difference in PV costs,

where the two differences tend toward each other.

Thus the conditions for NPV and BCR giving inconsistent results are met.

Policy Implications:

“Cost-benefit analyses serve to aid decision making. However, [it] does not replace the need for sound judgment based on a wide range of considerations, and in accordance with the various obligations officials face” (Commonwealth of Australia, 2006). This is especially true in relation to biosecurity projects, where there is typically a choice between mutually exclusive projects (eradication versus containment) which together often have deterministic factors that may lead to conflicting results in CBA evaluation criteria. Too heavy a reliance on CBA in this case may result in a sub-optimal decision being taken. For example, containment may be chosen over eradication (or vice versa) if looking at BCR, when in fact the latter may have been the optimal choice when all other factors were considered.

Effective decision making is most likely to occur when there is full information knowledge. As such, understanding the conditions which may lead to inconsistent results between NPV and BCR should aid decision makers in their role. Specifically, this knowledge will enable them (decision makers) to determine when economic analysis alone is not sufficient for ensuring the selection of the optimal management decision. If decision makers can anticipate the need

for additional information and analyses at the outset then delays in responding to an invasive species incursion can be minimised.

Given that it was shown in the previous section that inconsistencies are most likely to arise under the following conditions:

- Species incursion with slow spread and low level of associated damage,
- Response time until eradication/containment programs commence is short, and
- Eradication is relatively quick and inexpensive.

Caution needs to be taken by decision makers when dealing with species incursions of this nature. If caution is not exercised and other decision making tools are not utilised then it is quite probable that some species incursions which are capable of being eradicated, and which yield positive present economic benefit may remain in the environment indefinitely under a containment program. As such economic losses to the environment and industry and community will persist indefinitely.

An example of this is in relation to Australia's national cost sharing eradication program for Siam Weed (Goswami, 2008). If for this invasive species incursion, economic CBA is relied upon solely in deciding between allocating funds at levels attributable to eradication and containment, the sub-optimal goal of containment may be chosen (as opposed to increasing funds to step-up efforts to a level consistent with eradication) due to inconsistencies between NPV and BCR.

Conclusion:

This paper has highlighted the conditions under which a conflict may arise between the NPV and BCR when conducting CBA. The exact point at which this will occur can be summarised as point where the following figures tend toward each other, the difference in the benefit streams of two scenarios and the difference in the cost streams of two scenarios, and the former is greater than the latter.

This is particularly interesting in a biosecurity context as the nature of costs and benefits of project alternatives for invasive species incursions can often give rise to inconsistencies between NPV and BCR. It was shown that caution should be exercised when dealing with species incursions that have:

- A slow spread rate and a low level of associated damage,
- A short response time until eradication/containment programs; and
- Eradication is relatively quick and inexpensive.

Under these circumstances tools other than economic analysis must be an essential part of the decision making process to ensure the optimal decision is selected. If decision makers are aware of the shortcomings of CBA under these circumstances then unnecessary delays can be avoided by ensuring other forms of analyses are conducted, alongside economic analysis, from the outset.

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