University of Kent

Department of Economics Discussion Papers

Prioritising Biosecurity Investment between Protecting Agricultural and Environmental Systems

David C. Cook, Rob W. Fraser, Jeffrey K. Waage and Matthew B. Thomas

July 2009

KDPE 0908

Prioritising Biosecurity Investment between Protecting Agricultural and Environmental Systems

David C. Cook[1*],
Rob W. Fraser[2],
Jeffrey K. Waage[3]
and Matthew B. Thomas[4]

July 2009

Abstract

This paper is motivated by the observation that there is a difference between the time paths of damage valuations for invasions which affect agricultural compared with environmental systems. In particular, unlike agricultural systems, studies have shown that the social valuation of an environmental system is likely to be exponentially positively related to the extent of its deterioration. This paper explores the implications of this difference in determining biosecurity investment priorities. It is concluded that because of this difference an environmental system will often not be prioritised for such protection over an agricultural system even though its ultimate social value exceeds that of the agricultural system.

Key Words: Biosecurity, invasive species.

JEL Classification: Q51, Q57, Q58

[1] Research Economist, CSIRO Entomology, GPO Box 1700, Canberra ACT 2601, Australia, tel. +61 (0) 2 6246 4093, email: david.c.cook@csiro.au; Visiting Fellow, Fenner School of Environment and Society, Geography Building (48), Linnaeus Way, The Australian National University, Canberra ACT 0200, Australia, tel: +61 (0) 2 6125 3632; Cooperative Research Centre for National Plant Biosecurity, LPO Box 5012, Bruce ACT 2617, Australia, tel. +61 (0) 2 6201 2882.
[2] Professor of Agricultural Economics, Department of Economics, The University of Kent, Canterbury CT2 7NZ, United Kingdom, tel.: + 44 (0) 1227 827404, email: r.w.fraser@kent.ac.uk.
[3] Director of the London International Development Centre, 36 Gordon Square, London WC1H 0PD, United Kingdom, tel: +44 (0) 20 7958 8251, email: jeff.waage@lidc.bloomsbury.ac.uk.
[4] Professor of Entomology, The Pennsylvania State University, Chemical Ecology Lab, University Park, P.A. 16802, U.S.A., tel. +1 814-865-2480, email: mbt13@psu.edu.
[*] To whom correspondence should be addressed. CSIRO Entomology, GPO Box 1700, Canberra ACT 2601, Australia, tel. +61 (0) 2 6246 4093, fax +61 (0) 2 6246 4000, email: david.c.cook@csiro.au.

1. Introduction

Biological invasions have long had important economic implications for agriculture (Assessment, 1993; Pimentel et al., 2000; Pimentel et al., 2005). Alien insect pests of crops, plant and animal diseases and weeds can cause outbreaks that spread and reduce agricultural production over broad areas (Lonsdale, 1994; Mumford et al., 2001; Stansbury and Pretorius, 2001; Cook, 2005; Wittwer et al., 2005). Regulatory institutions have been developed to prevent introductions of these "agricultural invasives", backed up by tools like chemical pesticides and biological control, for their eradication or control (GATT, 1994). Nonetheless, these problems remain considerable, with economic costs arising from losses of production, costs of control and losses to trade for invasive species which are banned under international agreements (Waage et al., 2005; Cook et al., 2006; Fraser et al., 2006).

In the 1990s, research by ecologists revealed the dramatic potential environmental impacts of invasive alien plants, animals, and micro-organisms (Williamson, 1996), and this led to the international agreement, embodied in the Convention on Biological Diversity (1991), that countries should prevent, eradicate or control species which threaten local species, habitats or ecosystems. The major effects of these bioinvasions are two – the reduction of native biodiversity (including the extinction of native species) and the disruption of ecosystem service, e.g. when an invasive alien tree disrupts fire regimes and water and nutrient cycling in native grasslands.

While agricultural and environmental systems both face growing threats from alien invasive species, government responses are often profoundly different between these two sectors, because responsibilities for invasive alien species fall into different ministries of agriculture and environment. Further, these ministries often clashed over balance of agricultural growth (including control of pests and disease) with the need to conserve native species.

Recent years have seen efforts to better coordination of national policy on agricultural and environmental invasions, driven by a need to make better use of government expertise and resources. The merger of environmental and agricultural ministries in some countries, and the agreement to coordinate international activities between, for instance, the International Plant Protection Convention and the Convention on Biological Diversity, create opportunities for a more cohesive approach (Bowornwathana, 1996).

Ultimately, policy makers will need to choose between management actions to prevent, eradicate and control pests and diseases threatening agriculture and/or the environment. These may be different threats, or the same, for instance an invasive weed that both affects grassland ecosystem services and displaces grazing livestock.

A pressing issue for economists dealing with natural systems involves the questionable reliability of prices as measures of willingness to pay (or willingness to accept). Economic agents do not possess sufficient data, expertise or inclination to factor the potential invasive species damage costs that might result from a consignment of imported commodity being biologically contaminated. For any rational, profit maximising individual entering into a contract to supply or purchase such a commodity on an international market, it is impossible to account for every eventuality within the contract itself given the uncertainty surrounding the distribution of expected profits (Scholz and Stiftel, 2005). While the impacts of a particular species on an agricultural industry poses no particular methodological problems (beyond determining expected supply curve shifts), non-market impacts are more complex.

The challenge associated with eliciting values for environmental flow-on effects is well documented. The large growth in the literature following the Exxon Valdez disaster is without precedent (Adamowicz, 2004), but several problems with stated and revealed valuation techniques persist. It is difficult to understand and appreciate the willingness of an economic agent to pay to protect an environmental good (or to guard against changes in its wellbeing) without sociological information involved in that agent's decision-making process (Cook and Fraser, 2008). The income elasticities associated with environmental goods are thought to be significantly positive, implying income has a relatively large influence on a person's willingness to pay to protect the environment (Whitby, 2000). Non-use values for environmental amenities are also important. While an individual may lack financial incentives to invest in activities promoting the protection of ecosystems, their utility function may be partially dependent on environmental variables. As a result they may be prepared to forgo other consumption possibilities in order to gain utility from merely knowing the environment or a component of an environmental system remains in a favourable state.

However, for species invading the environment, where the impact will probably be on biodiversity or ecosystem services, it is likely that a proportionately greater amount of spread and damage must be incurred before a negative effect is perceived. This problem has been identified in the context of environmental valuation, with researchers attempting to elicit values which are contingent on the state of environmental deterioration of the habitat or species. For example, Blamey et al. (2000) asked survey respondents to distinguish between "non-threatened" and "endangered" species in eliciting valuations. While Hanley et al. (2003) evaluated respondents' views on protecting "all goose species" compared with "endangered goose species". In such cases the findings support an exponential dependence of social valuations of environmental goods on the extent of damage to those goods. It follows that the social valuation of an environmental good is likely to be not just positively but also exponentially related to the time path of its deterioration.

Moreover, this time-dependence of environmental values represents a contrast to values in agricultural systems, where the extent of deterioration in production capacity simply determines the extent of import substitution of agricultural goods, resulting in a linear positive relationship between damage value and the extent of deterioration over time. As a consequence, in situations where a government is attempting to prioritise investment in biosecurity measures between the protection of agricultural and environmental systems, these different time paths of damage values may play an important role in determining such investment priorities.

The aim of this paper is to explore the implications of this basic difference between the time paths of damage valuations of agricultural and environmental systems in order to determine its role in influencing biosecurity investment priorities. Our hypothesis is that this difference leads to a general investment bias towards preventing invasive species incursions in agricultural systems over environmental systems because of their more immediately observable damage costs. However, we also expect a sensitivity of this bias to the set of parameters contained in the decision-making framework.

The structure of the paper is as follows. Section 2 sets out the bioeconomic model of the biosecurity investment decision-making framework. It characterises the decision problem for both agricultural and environmental systems, including the specification of the time path of damage costs for each system. In so doing it also identifies the set of parameters which are expected to influence investment priorities. Section 3 then undertakes a numerical analysis of this model, including a sensitivity analysis of investment priorities to the model's set of parameters. As a consequence of this analysis, clear implications are identified for government policy design for biosecurity investment decisions. The paper ends with a brief Conclusion.

2. The Bioeconomic Model

The bio-economic model assumes that an alien species establishes in a region and then spreads over time to infest a particular commodity, which may be agricultural (e.g. a nation's potato crop) or environmental (e.g. a region's wetland habitats). The rate at which this happens depends on the biology of the invasive species. The potential economic loss from bioinvasion has a maximum value, as there is a maximum amount of agricultural or environmental good which can be affected. This may comprise of a loss in market value (in the case of the agricultural good) or in non-market value (in the case of the environmental good). As the invasive species spreads, it infests a greater proportion of that total area and reduces asset value until this maximum is reached.

It is further assumed that once an alien invasive species becomes established in the region it will inevitably spread to carrying capacity in this new environment. Eradication programs, be they localised or regionalised, are not considered. Hence, we essentially model a "prevention only" policy approach to invasive species.

More specifically, assume the region for each good is circular in shape with an area of *A*, and that each new introduction occurs at the centre of this circle and achieves the same radial rate of spread, *r*. This specification of uniformity is made to simplify the biological component of the model and will be reviewed in the next Section. On this basis the section, s_t, occupied by the invasive species at time *t* is described by:

$$s_t = r^2 t^2 \pi \qquad (1)$$

Hence, the proportion of total area affected at time *t* is s_t / A.

Consider next the cost of the invasion. In the case of the agricultural good it is assumed that each unit of production lost to the invasion is valued at the import replacement cost (V^a) and is constant over time. Also assuming a one-to-one relationship between invaded area and production lost means that the cost of the invasion at time *t* (C_t^a) is given by:

$$C_t^a = V^a.r^2.t^2.\pi \qquad (2)$$

which has a maximum value of $A.V^a$ when the invasion is complete.

In the case of the environmental good, account needs to be taken of the assumed increase in the social value per unit of the good as the extent of the invasion increases. In what follows this is done by assuming:

(i) a maximum social value per unit of the environmental good at the point of extinction (V^e)

(ii) a social value per unit of the environmental good at time *t* which is a function of this maximum value and the proportion of the total area invaded at time *t*.

This specification means that the social value of the environmental good per unit lost to the invasion at time *t* (V_t^e) is given by:

$$V_t^e = V^e.\left(\frac{s_t}{A}\right) \qquad (3)$$

which has a maximum value of V^e when the invasion is complete. By combining this per unit cost of the invasion with the specification of its rate of spread, the cost of the invasion at time *t* (C_t^e) is given by:

$$C_t^e = V^e.\left(\frac{s_t}{A}\right).r^2.t^2.\pi \tag{4}$$

which has a maximum value of $V^e.A$ when the invasion is complete.

Given these specifications of the annual cost of the invasion for both agricultural and environmental goods, the discounted present value (*PV*) of the total damage cost over the decision-making time horizon (*T*) can be represented (respectively for the agricultural and environmental goods) as:

$$PV\left(C^a\right) = \sum_{t=1}^{T}\left(\frac{V^a.r^2.t^2.\pi}{(1+d)^t}\right) \tag{5}$$

and:

$$PV\left(C^e\right) = \sum_{t=1}^{T}\left(\frac{V^e.\left(\frac{s_t}{A}\right).r^2.t^2.\pi}{(1+d)^t}\right) \tag{6}$$

where *d* is the rate of discount of future values.

Given this specification, if:

$$PV(C^a) \succ PV(C^e) \tag{7}$$

then biosecurity investment in protecting the agricultural good will be prioritised. While if:

$$PV(C^a) \prec PV(C^e) \tag{8}$$

then biosecurity investment in protecting the environmental good will be prioritised.

Finally, it follows from (5) and (6) that the relative size of $PV(C^a)$ and $PV(C^e)$, and therefore the priority for biosecurity investment, depends on the various parameters of the bioeconomic model: *r*, *A*, V^a, V^e, *d* and *T*. A numerical analysis of the role of these parameters in determining priorities for biosecurity investment is presented in the next Section.

3. The Numerical Analysis

In order to undertake a numerical analysis of the bioeconomic model of prioritising biosecurity investment developed in the previous section, consider first a Base Case set of values for the parameters of the model. As previously stated in relation to the biological parameters, it is assumed that the total susceptible area of the agricultural and environmental goods (*A*) is identical, and that the rate of spread of the invasive species (*r*) is the same for both host goods:

$$A = 10{,}000\text{ha}$$

and:

$$r = 2.5.$$

In addition, the decision-making parameters for the Present Valuation of damage cost, specifically the time horizon (*T*) and the rate of discount (*d*), are set to:

T = 30 years

and:

d = 3% .

Finally, the per unit social value of the environmental good at the point of extinction (V^e) is set to:

$$V^e = £8.00$$

while the (constant) per unit value of lost agricultural production (V^a) is set to:

$$V^a = £6.00 .$$

Note that these two settings imply the social value of the environmental good at its point of extinction exceeds the value of lost agricultural production.

Given this set of parameter values, Table 1 contains the Base Case results for the Present Value of invasion damage cost for both the agricultural and the environmental goods. The results show that the biological spread of the invasive species through each good's total susceptible area takes 23 years to complete. In addition, during this period the annual damage cost of the agricultural good invasion exceeds that for the environmental good invasion until year 20 (at which point 78.5% of A is invaded), after which the annual damage cost for the environmental good invasion is larger in every year until the time horizon is reached at year 30. Also in this context, note that the maximum annual damage cost for both goods occurs in year 23, after which there are no increments to the areas damaged and so the discounting of annual damage costs results in a gradual decrease in the Present Value of these costs. Finally in relation to Table 1, this Base Case set of parameter values results in the Total Present Value of damage cost for the environmental good invasion exceeding that for the agricultural good invasion (i.e. £498,123 vs. £493,713). As a consequence, in this example the priority for biosecurity investment would be given to protecting the environmental good from invasion.

Table 1 near here.

Consider next a sensitivity analysis of the parameters of the model in relation to the Base Case set of results. In what follows each of the parameter values are varied in magnitude such that biosecurity investment to protect the agricultural good becomes prioritised over biosecurity investment to protect the environmental good. On this basis it will be possible to demonstrate the role of each of the model's parameters in determining this investment priority. In particular, Table 2 contains results of the effects of such a sensitivity analysis on the Total Present Value of damage cost for each good where:

(a) parameter values assume their Base Case values (as above);

(b) the rate of spread of the invasion has been reduced from r = 2.5 to r = 2.0;

(c) the total susceptible area for invasion has been increased from A = 10,000 to A = 11,000;

(d) the rate of discount of future damage costs has been increased from d = 3% to d = 4%

(e) the time horizon for the Present Valuation has been reduced from T = 30 to T = 28

(f) the ratio $\frac{V^a}{V^e}$ has been increased from 75% to 80% (i.e. V^a increased from £6.00 to £6.40; V^e = £8.00).

Figure 1 plots the Present Value of damage to the agricultural good and the environmental good over time under each of these scenarios, with each panel corresponding to the scenarios listed above.

Table 2 near here.

Figure 1 near here.

More specifically, Table 2 shows that if the rate of spread of the invasive species is smaller (i.e. *r* = 2.0 instead of 2.5), or the total susceptible area is larger (i.e. *A* = 11,000ha instead of 10,000ha), then in both cases the relative size of the Present Value of damage cost for the agricultural and environmental goods is reversed, and biosecurity investment in protecting the agricultural good becomes prioritised over protecting the environmental good. The effects of these scenarios on Total Damage Cost over time is illustrated in panels (b) and (c) of Figure 1, while the Base Case appears in panel (a). In the case of both an increased spread rate or an increase in susceptible area the explanation for the priority reversal can be attributed to the time-dependent variation in the social value of the environmental good – specifically the dependence of this value on the proportion of the total susceptible area which has been invaded. For example, in the case of a slower rate of spread, it is not until year 25 that the annual damage cost of the environmental good exceeds that of the agricultural good (compared with year 20 in the Base Case). While in the case of the larger total susceptible area, this reversal does not occur until year 21.

In addition, Table 2 shows that if the rate of discount of future damage costs is increased (i.e. *d* = 4% instead of 3%), or if the time horizon for decision-making is decreased (i.e. *T* = 28 instead of 30), then in both cases the relative size of the Present Values of damage costs is also reversed. Panels (d) and (e) of Figure 1 illustrate the effects of these scenarios on Total Damage Costs over time. In both cases biosecurity investment in protecting the agricultural good again becomes prioritised. And once again the explanation for this reversal can be attributed to the time-dependent variation in the social value of the environmental good. However, in these cases, while there is no change in the biological consequences of the invasions, the changes to the decision-making framework act to reduce the relative importance of high annual damage costs further into the future, thereby tilting the priority for biosecurity investment away from protecting the environmental good.

Finally, Table 2 shows that if the per unit damage cost of lost agricultural production is a larger proportion of the social value of the environmental good at the point of extinction (i.e. 80% instead of 75%), then the annual damage costs of lost production of the agricultural good are across-the-board larger and, as previously, the priority for biosecurity investment is reversed. Panel (f) of Figure 1 demonstrates the effects of this change on Total Damage Cost over time.

In summary, it can be seen from this analysis that the prioritisation of investment to protect the environmental good is vulnerable to any change in the model's parameter values which means that the higher annual costs of damage to the environmental good further into the future are less important in the decision-making process. In particular, if the biological parameters of the invasions are such that damage to the environmental good is less noticeable until further into the future, or if the decision-making framework focuses more heavily on short-term annual damage costs, then biosecurity investment to protect the environmental good is less likely to be prioritised over that for the agricultural good, even if the social cost of damage to the environmental good as it nears extinction exceeds the value of lost agricultural production.

Of course, the model and numerical example presented above are purely hypothetical. In reality, policy-makers face uncertainty about the model parameters, and consequently the value of potential environmental losses relative to agricultural losses. However, our stylised discussion suggests a need to investigate the time-dependence characteristic of environmental system values on a case-by-case basis. Unless this information is taken into account in biosecurity resource allocation decisions environmental systems stand to receive a disproportionate amount of protection from invasive species relative to agricultural systems.

4. Conclusion

This paper has been motivated by the observation that there is a difference between the time paths of damage valuations for invasions which affect agricultural compared with environmental systems. In particular, the per unit damage valuation for lost production from agricultural systems is typically based on the associated cost of import replacement, and is therefore largely unrelated to the extent to which the agricultural system is damaged. However, studies have shown that the per unit social valuation of damage to environmental systems is likely to be exponentially related to the extent of its deterioration. As a consequence, the aim of this paper has been to explore the implications of this basic difference between the time paths of damage valuations for agricultural and environmental systems in order to determine its role in influencing biosecurity investment priorities.

To do this a bioeconomic model of prioritising biosecurity investment between protecting an agricultural and an environmental system was developed in Section 2. Then in Section 3 this bioeconomic model was subjected to a sensitivity analysis of the role of the parameters of the model in influencing investment priorities. Overall it was shown that because the environmental system only displays relatively high annual damage costs well into the future, a decision to prioritise its protection is vulnerable to any change in the model's parameter values which means that these future damage costs are less important in the decision-making process.

From a biosecurity policy perspective, it follows that unless this time-dependent characteristic of the social value of environmental systems is clearly recognised in the investment prioritising process, environmental systems will be less well-protected even though their ultimate social value exceeds that of agricultural systems.

5. References

Adamowicz, W. L., 2004. What's it worth? An examination of historical trends and future directions in environmental valuation. The Australian Journal of Agricultural and Resource Economics 48, 419-443.

Assessment, O. o. T., 1993. Harmful Non-Indigenous Species in the United States, OTA-F-565. U.S. Government Printing Office, Washington, D.C.

Blamey, R., J. Rolfe, J. Bennett, and M. Morrison. 2000. Valuing remnant vegetation in Central Queensland using choice modelling. Australian Journal of Agricultural and Resource Economics 44, 439-456.

Bowornwathana, B., 1996. The Phenomenon of New Ministries and the Politician-Bureaucrat Perspective: The Case of Thailand. Asian Review of Public Administration 8, 23-32.

Convention on Biological Diversity. 1991. Convention Text. Convention on Biological Diversity.

Cook, D. C., 2005. The ‘paradox of thrips’: Identifying a critical level of investment in pest exclusion activities in Western Australia. Australasian Agribusiness Review 13.

Cook, D. C., and R. W. Fraser. 2008. Trade and Invasive Species Risk Mitigation: Reconciling WTO Compliance with Maximising the Gains from Trade. Food Policy 33, 176–184.

Cook, D. C., J. K. Waage, J. D. Mumford, R. W. Fraser, and A. Wilby. 2006. The benefits of potato ring rot exclusion from the United Kingdom. Technical Report T8.11, Department of Trade and Industry, Office of Science and Innovation, London.

Fraser, R. W., D. C. Cook, J. D. Mumford, A. Wilby, and J. K. Waage. 2006. Managing outbreaks of invasive species: Eradication versus suppression. International Journal of Pest Management 52, 261-268.

GATT. 1994. Agreement on the Application of Sanitary and Phytosanitary Measures. Pages 69-84 The Results of the Uruguay Round of Multilateral Trade Negotiations: The Legal Texts. General Agreement on Tariffs and Trade Secretariat, Geneva.

Hanley, N., D. MacMillan, I. Patterson, and R. E. Wright. 2003. Economics and the design of nature consewrvation policy: a case study of wild goose conservation in Scotland using choice experiments. Animal Conservation 6, 123-129.

Lonsdale, W., 1994. Inviting trouble: Introduced pasture species in northern Australia Australian Journal of Ecology 19, 345-354.

Mumford, J. D., J. D. Knight, D. C. Cook, M. M. Quinlan, J. Pluske, and A. W. Leach. 2001. Benefit Cost Analysis of Mediterranean Fruit Fly Management Options in Western Australia. Imperial College, Ascot.

Pimentel, D., L. Lach, R. Zuniga, and D. Morrison. 2000. Environmental and economic costs associated with non-indigenous species in the US. BioScience 50, 53-65.

Pimentel, D., R. Zuniga, and D. Morrison. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics 52, 273-288.

Scholz, J. T., and B. Stiftel. 2005. Introduction: The Challenges of Adaptive Governance. Page 300 In J. T. Scholz and B. Stiftel, Eds. Adaptive Governance and Water Conflict: New Institutions for Collaborative Planning. Resources for the Future Press, Washington, DC.

Stansbury, C. D., and Z. A. Pretorius. 2001. Modelling the potential distribution of Karnal bunt of wheat in South Africa. South African Journal of Plant Soil 18, 159-168.

Waage, J. K., R. W. Fraser, J. D. Mumford, D. C. Cook, and A. Wilby. 2005. A New Agenda for Biosecurity Department for Food, Environment and Rural Affairs, London.

Whitby, M., 2000. Challenges and Options for the UK Agri-Environment: Presidential Address. Journal of Agricultural Economics 51, 317-332.

Williamson, M., 1996. Biological Invasions. Chapman and Hall, London.

Wittwer, G., S. McKirdy, and R. Wilson. 2005. Regional Economic Impacts of a Plant Disease Incursion Using a General Equilibrium Approach. The Australian Journal of Agricultural and Resource Economics 49, 75-89.

Table 1. Base Case Results for the Present Value of Invasion Damage Cost

Time	Area Affected (Ag. good)	Area Affected (Env. good)	Ag. Annual Damage Cost	Env. Annual Damage Cost
0	-	-	£0	£0
1	20	20	£114	£0
2	79	79	£444	£5
3	177	177	£970	£23
4	314	314	£1,675	£70
5	491	491	£2,541	£166
6	707	707	£3,552	£335
7	962	962	£4,694	£602
8	1,257	1,257	£5,952	£997
9	1,590	1,590	£7,314	£1,551
10	1,964	1,964	£8,766	£2,295
11	2,376	2,376	£10,298	£3,262
12	2,827	2,827	£11,899	£4,486
13	3,318	3,318	£13,558	£5,998
14	3,848	3,848	£15,266	£7,833
15	4,418	4,418	£17,014	£10,022
16	5,027	5,027	£18,794	£12,596
17	5,674	5,674	£20,599	£15,585
18	6,362	6,362	£22,421	£19,018
19	7,088	7,088	£24,254	£22,922
20	7,854	7,854	£26,091	£27,323
21	8,659	8,659	£27,928	£32,244
22	9,503	9,503	£29,758	£37,707
23	10,000.00	10,000.00	£30,402	£40,535
24	10,000.00	10,000.00	£29,516	£39,355

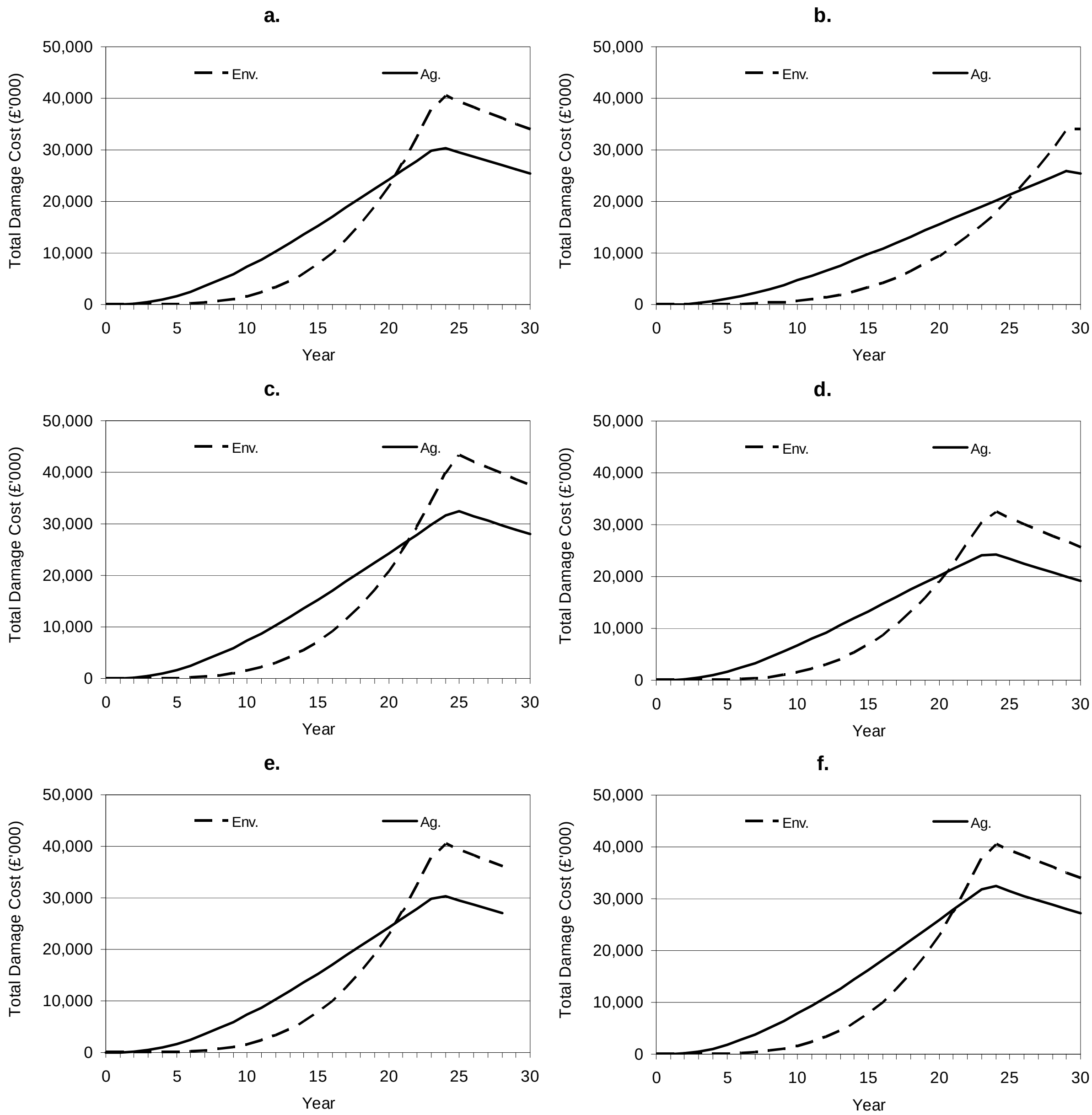
25	10,000.00	10,000.00	£28,656	£38,208
26	10,000.00	10,000.00	£27,822	£37,096
27	10,000.00	10,000.00	£27,011	£36,015
28	10,000.00	10,000.00	£26,225	£34,966
29	10,000.00	10,000.00	£25,461	£33,948
30	10,000.00	10,000.00	£24,719	£32,959
	Present Value of Total Damage Costs		**£493,713**	**£498,123**

Notes: A = 10,000; r = 2.5; T = 30; d = 0.03; $V^a = 6$; $V^e = 8$.

Table 2. Sensitivity Analysis of the Base Case Results

	PV(Ag. Damage) over 30 Years	PV(Env. Damage) over 30 Years
(a) Base Case (parameters as above)	£493,713	£498,123
(b) r = 2.0	£363,773	£303,925
(c) A = 11,000	£513,830	£503,959
(d) d = 0.04	£404,731	£398,971
(e) T = 28	£443,533	£431,216
(f) $V^a = 6.4$	£526,627	£498,123

Figure 1. Sensitivity of Total Damage Costs Over Time



UNIVERSITY OF KENT AT CANTERBURY

Studies in Economics

Recent Titles

Editor: Prof. J.S. Chadha

Co-ordinator: N. A. Newton

http://www.kent.ac.uk/economics/papers/index.html