Compensation payments, animal disease and incentivising on-farm biosecurity: the role of biosecurity investment spillovers between farmers

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April 2018

Abstract:

This paper explores the consequences of removing the assumption in Fraser (2017) of no spatial spillovers of biosecurity investment impacts between farmers in the context of animal disease outbreaks. It modifies the methodological framework of Fraser (2017) to introduce such spatial spillovers and undertakes a numerical analysis of this modified framework. This analysis evaluates the impact of allowing for biosecurity investment spillovers between farmers on the scope for using compensation payments to incentivise both disease reporting and on-farm biosecurity investment by farmers, as well as suggesting several low cost policy implications of the analysis which support the successful use of compensation payments to incentivise farmers.

Acknowledgement:

I would like to thank Nick Hanley for encouraging me to think about the problem of biosecurity investment spillovers between farmers.

Introduction

In Fraser (2017) one of the key simplifying assumptions was that there were “no spillovers” in relation to “the decision contexts of other farmers” (p 4). Moreover, based on this assumption a central finding of Fraser (2017) was that “a relatively high base line likelihood of a disease outbreak discouraged farmers from incurring the cost of on-farm biosecurity measures because such an action was risk-increasing” (p 12). As a consequence it was suggested that “there may be no level of compensation payments which incentivises farmers both to comply with disease reporting requirements and to undertake on-farm biosecurity" (p 12).

However, it is precisely in the context of “a relatively high base line likelihood of a disease outbreak” that the existence of biosecurity investment spillovers could reasonably be expected. More specifically, a relatively high probability of a disease outbreak would typically be characterised by a larger proportion of farmers in a particular spatial context being affected by the disease. It follows that the risk of a disease outbreak on a specific farm is more likely to be reduced not just by biosecurity investment on that farm, but also by biosecurity investment on spatially contiguous farms.

Therefore, the analysis in this paper explores the consequences of removing the assumption in Fraser (2017) of no spatial spillovers of biosecurity investment between farmers in order to evaluate whether the presence of biosecurity spillovers supports the scope for compensation payments to incentivise both disease reporting and on-farm biosecurity investment by farmers. Note that the particular focus of the analysis to follow is on the situation of a relatively high risk of a disease outbreak as this is the context in which biosecurity investment spillovers between farmers are expected to be most relevant.

The structure of the paper is as follows: Section 1 outlines how the methodological framework of Fraser (2017) is modified in order to take account of biosecurity investment spillovers between farmers. Section 2 then undertakes a numerical analysis of this modified framework in order to evaluate the impact of allowing for biosecurity investment spillovers on the scope for successfully using a policy of compensation payments to incentivise both disease reporting and on-farm biosecurity investment. The paper concludes with a brief summary and a discussion of the policy implications of its findings.

Section 1: Framework Modification

Fraser (2017) specified the methodological framework such that "if the farmer chooses to incur the cost of on-farm biosecurity measures (B) then the likelihood of no disease outbreak is increased from q to p (ie p > q)" (p 4) where q is the likelihood of no disease outbreak in the absence of on-farm biosecurity investment.

In order to introduce the role of biosecurity investment spillovers between farmers this specification is modified here so that the likelihood of no disease outbreak on a particular farm is a function not just of that farmer's biosecurity decision, but also of the on-farm biosecurity decisions of spatially contiguous farmers. To achieve this joint impact the likelihood of no disease outbreak if the farmer invests in biosecurity measures (p_B) is re-specified to:

$$p_B = q + e + f.n/N \tag{1}$$

where:

e = direct impact of on-farm biosecurity investment on the likelihood of no disease outbreak ($e < 1$)

n/N = proportion of spatially contiguous farmers investing in biosecurity

f = factor governing the indirect (spillover) effect of biosecurity investment by other farmers

and where: $q + e + f.n/N < 1$.

Note that in this case the post-biosecurity investment probability of no disease outbreak (p_B) is increased by both the direct (on-farm) and indirect (spatially contiguous farmers) impacts of on-farm biosecurity investment.

However, note also that even without direct on-farm biosecurity investment the value of p for a particular farmer will be affected by any biosecurity investment on spatially contiguous farms (p_{NB}):

$$p_{NB} = q + f.n/N \tag{2}$$

In this case the farmer benefits from the biosecurity investment of spatially contiguous farmers even if the farmer undertakes no biosecurity investment of their own.

In addition, recall from Fraser (2017) that biosecurity investment (whether direct or indirect) has the following effects on the farmer's expected income (E(I)):

$$dE(I)/dq = (M-D) > 0 \tag{3}$$

and on the farmer's variance of income (Var(I)):

$$\mathrm{dVar(I)/dq} = (M - D)^2(1 - 2q) \qquad (4)$$

where:

M = value of the farmer's livestock if they remain disease free

D = compensation paid if the farmer experiences and reports a disease outbreak

which implies:

$$\mathrm{dVar(I)/dq} > \text{or} < 0 \text{ as } q < \text{or} > ½ \qquad (5)$$

Note that in this paper the focus of the analysis is on situations where the base line likelihood of no disease outbreak is relatively low (ie $q < ½$). As a consequence, although both the direct and indirect effects of biosecurity investment will act to increase the farmer's expected income, biosecurity investment may act to increase or decrease the farmer's variance of income depending on the strength of these individual effects (ie $q < ½$ but p_B and p_{NB} may be > or < ½). These impacts will be evaluated in the numerical analysis to follow.

Finally in this section note that as a consequence of the modifications to the likelihood of no disease outbreak specified above, equations (1) and (2) in Fraser (2017) specifying the expected utility of income (E(U(I))) associated with the options of choosing both disease reporting and biosecurity investment (BR) and choosing disease reporting, but not biosecurity investment (NBR), also need modification to:

$$\text{BR:} \quad E(U(I)) = E(U(p_B M + (1 - p_B)D - B)) \qquad (6)$$

$$\text{NBR:} \quad E(U(I)) = E(U(p_{NB} M + (1 - p_{NB})D)) \qquad (7)$$

where:

B = cost of on-farm biosecurity investment.

Note also that there is no need to consider here the options in Fraser (2017) relating to not reporting a disease outbreak as in the numerical analysis to follow the particular values are specifically chosen so that not reporting a disease outbreak is always an inferior option.[1] This approach is consistent with this paper's focus on the direct and indirect impacts of biosecurity investment by farmers.

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[1] In general terms, this can be achieved my setting compensation payments (D) large enough to discourage not reporting a disease outbreak. See Fraser (2017) for more details.

Section 2: Numerical Analysis

As stated in the Introduction, the aim of this section is to undertake a numerical analysis of the modified framework developed in Section 1 in order to evaluate the impact of allowing for biosecurity investment spillovers between farmers on the scope for successfully using compensation payments to incentivise both disease reporting and on-farm biosecurity investment by farmers (ie so that farmers choose option “BR”).

In the numerical analysis in Fraser (2017) the approach taken was to identify a base case set of parameter values which incentivised the desired pair of choices by the farmer. This base case was then subjected to a sensitivity analysis in order to evaluate the role of the various model parameters in influencing the farmer’s decisions. The last part of this sensitivity analysis focused on “the impact of the farmer’s base level of likelihood of no disease outbreak on the incentive to incur the cost of on-farm biosecurity measures” (p 10). In particular, it was observed that decreasing the base level of likelihood of no disease outbreak dis-incentivised farmers from undertaking biosecurity investment, and especially so for more risk averse farmers. Below is Table 6 reproduced from Fraser (2017) to illustrate this finding.[2]

Table 6

			D (%D/M)			
	44 (44%)	45	45.3	46	47.8	48 (48%)
q = 0.25						
R = 0.2	BNR	BNR	BR	BR	BR	NBR
R = 0.5	NBNR	NBR	NBR	NBR	NBR	NBR

Source: Fraser (2017)

In particular, it can be seen by comparing Table 6 above with Table 2 in Fraser (2017) that lowering q from 0.55 to 0.25 completely eliminates the range of values of the compensation payment (D) for which both disease reporting and biosecurity investment choices (ie option “BR”) would be made by the more risk averse type of farmer (ie R = 0.5), although a small range of values of D (around D = 46) still remains for the less risk averse type of farmer (ie R = 0.2).

This specification, and fixing D = 46, becomes the base case in this paper for a numerical analysis of the impact of taking account of a spillover effect from biosecurity investment on spatially contiguous farms on the farmer’s likelihood of a disease outbreak on their own farm. And, as noted in Section 1, this spillover effect will have such an impact regardless of the farmer’s own decision regarding biosecurity investment. In particular, the spillover effect increases the likelihood of no disease outbreak (p) for all the farmer’s decision options (ie BR, NBR, BNR and NBNR – see Fraser (2017)). As a consequence, as shown in Section 1, this will increase the farmer’s expected income, and may increase or decrease the farmer’s variance of income. Moreover, since this base case (see Table 6 for D = 46) features the less risk averse farmer already preferring to undertake biosecurity investment

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[2] Note that the numerical analysis in Fraser (2017) is based on a quadratic approximation of the constant relative risk aversion functional form of utility to represent the farmer’s attitude to risk, as well as the following base case numerical values: M = 100; B = 10; and e = 0.2.

(ie BR), the question is whether the introduction of such an indirect effect acts to incentivise more risk averse farmers to also undertake biosecurity investment.

Therefore, consider initially the results presented in Table A. Note that the specification of the model's parameter values for this set of results is identical to that for Table 6 in Fraser (2017), and with the fixing of D = 46, but with the addition of a range of values for the spillover effect (f) on p of biosecurity investment on spatially contiguous farms. The focus of the results is on the minimum proportion of spatially contiguous farmers (n/N) investing in biosecurity measures which is required to incentivise the farmer to undertake their own biosecurity investment, and for a range of values of risk aversion (R).

Table A

Minimum proportion of spatially contiguous farmers investing in biosecurity required to incentivise the farmer to undertake their own biosecurity investment – sensitivity to the strength of the spillover effect (f)

	Attitude to Risk (R)		
	0.2	0.5	0.8
Value of Spillover Effect (f)			
0.35	0	0.15	0.35
0.25	0	0.21	0.44
0.15	0	0.35	0.73

As expected from Table 6, the results in Table A show that for the least risk averse type of farmer (R = 0.2), no spillover effect is required to incentivise their own biosecurity investment (ie required n/N = 0). However, for the more risk averse types of farmer (R = 0.5 and 0.8), it is now the case that if a sufficient proportion of spatially contiguous farmers are investing in biosecurity, then these types of farmers are also incentivised to invest in biosecurity. In particular, this minimum proportion is lower the stronger is the spillover effect (ie f = 0.35 compared with f = 0.25 and 0.15), but is higher for the most risk averse type of farmer (ie R = 0.8). Note that the latter result follows from the fact that biosecurity investment itself increases the farmer's variance of income, and so a more risk averse farmer requires a stronger spillover benefit (arising from the size of n/N) in order to justify this action.

Consider next the results in Table B, which examine the sensitivity of the findings in Table A to the strength of the direct effect of on-farm biosecurity investment (e) on the likelihood of no disease outbreak (p). To do this the central value of f (= 0.25) in Table A is chosen for the analysis, and the value of e is varied upwards and downwards from 0.2 (as used in Table A).

Table B

Minimum proportion of spatially contiguous farmers investing in biosecurity required to incentivise the farmer to undertake their own biosecurity investment – sensitivity to the strength of the direct effect of on-farm biosecurity investment (e)

	Attitude to Risk (R)		
	0.2	0.5	0.8
Value of Direct Effect (e)			
0.25	0	0	0
0.2	0	0.21	0.44
0.15	> 1	> 1	> 1

The results in Table B show a relatively strong sensitivity of the farmer's investment choice to the direct effect of on-farm biosecurity investment on the likelihood of no disease outbreak. In particular, decreasing e from 0.2 to 0.15 is sufficient for farmers with all levels of risk aversion to be dis-incentivised from undertaking biosecurity investment, regardless of the proportion of spatially contiguous farmers undertaking this investment (ie for n/M = 1 the farmer's preferred choice is NBR regardless of the value of R). Moreover, if e is increased from 0.2 to 0.25, then farmers with all levels of risk aversion prefer to undertake their own biosecurity investment, even if none of the spatially contiguous farmers do so (ie required n/N = 0 for BR to be chosen).

In addition, this relatively strong sensitivity applies to other parameter values in the model. Specifically, consider the impact of varying the cost of a farmer's on-farm biosecurity investment on the minimum proportion of spatially contiguous farmers investing in biosecurity required to incentivise this farmer to also invest in biosecurity. The results of this sensitivity analysis are presented in Table C which evaluates the impact of a relatively small (ie 5%) increase and decrease in B for the central values of e (0.2) and f (0.25) and the other base case parameter values.

Table C

Minimum proportion of spatially contiguous farmers investing in biosecurity required to incentivise the farmer to undertake their own biosecurity investment – sensitivity to the cost of on-farm biosecurity investment (B)

	Attitude to Risk (R)		
	0.2	0.5	0.8
Cost of On-farm Biosecurity Investment (B)			
10.5	0.31	0.68	0.78
10	0	0.21	0.44
9.5	0	0	0.13

In particular, a decrease in B to 9.5 is sufficient for the type of farmer with the central value of risk aversion (R = 0.5) to now be willing to undertake on-farm biosecurity investment regardless of the biosecurity investment behaviour of spatially contiguous farmers (ie the required n/N decreases from 0.21 to 0), while for B = 9.5 the most risk averse type of farmer (R = 0.8) requires only 13% of spatially contiguous farmers to also undertake biosecurity investment, down from 44% for B = 10. Moreover, a 5% increase in B to 10.5 results in even the least risk averse type of farmer (R = 0.2) now requiring 31% of spatially contiguous farmers to also invest in biosecurity in order for themselves to be incentivised to do so, compared with zero in the case of B = 10.

Note also in the context of an increase in B that, although both of the more risk averse types of farmers (R = 0.5 and 0.8) now require a much larger proportion of spatially contiguous farmers to also undertake biosecurity investment in order for themselves to be incentivised to do so (ie increased from 21% to 68% and from 44% to 78% respectively), the difference in this required proportion between R = 0.5 and R = 0.8 is compressed for B = 10.5 compared with B = 10 (ie only a 10% higher required proportion for B = 10.5 compared with 23% for B = 10). The explanation for this difference stems from the differential impact of on-farm biosecurity investment on the variance of income, as outlined in Section 1 (see equation (5)). Specifically, in this case the likelihood of no disease outbreak with just the spillover effect associated with n/N = 0.78 is 45% (ie p_{NB} = 0.45). Therefore, in this situation the undertaking of on-farm biosecurity investment further increases the likelihood of no disease outbreak to 0.65 (ie p_B = 0.65 as e = 0.2), which has a substantial dampening effect on the overall variance of income (ie see equation (5)). It follows that in this situation the most risk averse type of farmers are benefiting from both an increase in expected income and a (much appreciated) decrease in the variance of income by investing in on-farm biosecurity because such a high proportion of spatially contiguous farmers are also investing in biosecurity on their farms.

Finally in this section consider the sensitivity of the findings to the base level of likelihood of no disease outbreak (q). With the results in Tables A, B and C using a specification of q = 0.25, Table D presents the results of both increasing and decreasing the value of q (ie to 0.15 and 0.35).

Table D

Minimum proportion of spatially contiguous farmers investing in biosecurity required to incentivise the farmer to undertake their own biosecurity investment – sensitivity to the base level likelihood of no disease outbreak (q)

	Attitude to Risk		
	0.2	0.5	0.8
Base Level Likelihood of No Disease Outbreak (q)			
0.35	0	0	0.04
0.25	0	0.21	0.44
0.15	0	0.61	0.84

These results show that the importance of the spillover effect in the farmer's decision making regarding on-farm biosecurity investment varies inversely with the likelihood of no disease outbreak. Specifically, an increase in q to 0.35 means that the type of farmer with the central level of risk aversion (R = 0.5) is now incentivised to invest in on-farm biosecurity regardless of the biosecurity investment behaviour of spatially contiguous farmers (ie required n/N = 0), and even the most risk averse type of farmers (R = 0.8) require only 4% of spatially contiguous farmers to also invest in biosecurity for their own investment to be incentivised. In contrast, for a decrease in q to 0.15, the results show that even though the least risk averse type of farmer remains incentivised to invest in on-farm biosecurity regardless of the biosecurity investment behaviour of spatially contiguous farmers (ie required n/N = 0), for more risk averse farmers a much larger proportion of spatially contiguous farmers also investing in biosecurity is now required to incentivise their own biosecurity investment. Finally, note that even for q = 0.1 the type of farmer with R = 0.2 still only requires 7% of spatially contiguous farmers to also invest in biosecurity for them to be incentivised to do so.

Conclusion

The aim of this paper has been to explore the consequences of removing the assumption in Fraser (2017) of no spatial spillovers of on-farm biosecurity investment between farms. Section 1 of the paper outlined the modifications to the methodological framework of Fraser (2017) required to introduce such spatial spillovers, while Section 2 undertook a numerical analysis of this modified framework in order to evaluate the impact of allowing for biosecurity investment spillovers on the scope for successfully using compensation payments to incentivise both disease reporting and on-farm biosecurity investment by farmers.

The analysis in Section 1 has shown that biosecurity investment spillovers are in general a positive factor for farmers in that by increasing the likelihood of no disease outbreak such spillover effects from spatially contiguous farms increase a particular farmer's expected income. However, depending on the size of the likelihood of no disease outbreak, such spillover effects may increase or decrease the farmer's variance of income.

In relation to the impact of biosecurity investment spillovers on a farmer's own biosecurity investment decision, the numerical analysis of Section 2 demonstrated that the proportion of spatially contiguous farmers required to invest in biosecurity in order to incentivise the farmer in question to invest as well is:

i) inversely related to the strength of the biosecurity investment spillover effect on the likelihood of no disease outbreak (ie the value of f – see Table A)

ii) inversely related to the strength of the direct on-farm biosecurity investment effect on the likelihood of no disease outbreak (ie the value of e – see Table B)(strong sensitivity)

iii) positively related to the cost of on-farm biosecurity investment (ie the value of B – see Table C)(strong sensitivity)

iv) inversely related to the base level likelihood of no disease outbreak (ie the value of q – see Table D).

It follows from the perspective of government policy implications that the finding of strong sensitivity of on-farm biosecurity investment incentives both to the cost and effectiveness of such investment (ie findings ii) and iii) above) raises (as in Fraser (2017)) the question of the potential subsidisation by government of on-farm biosecurity investment in order to incentivise such investment. Moreover, the strong sensitivity of this incentive to the level of B identified in finding iii) suggests only relatively small levels of subsidisation may be needed to deliver the desired impact on the incentive of farmers to undertake on-farm biosecurity investment.

In addition, findings i) and iv) relate to the spatial characteristics of a farmer's biosecurity investment decision environment. In particular, while finding iv) suggests that being located in a region with a low base level likelihood of no disease outbreak is a dis-incentive to on-farm biosecurity investment, if this base level of risk is also strongly influenced by the spatial contiguousness of farmers, then finding i) suggests that agreement among only a relatively small proportion of spatially contiguous farmers may be required to incentivise a joint on-farm biosecurity investment programme by those farmers. It follows that the facilitation of such a joint agreement by government may be readily achievable.

Therefore, it may be concluded that the findings of this paper suggest a policy of using compensation payments in the context of potential animal disease outbreaks to incentivise farmers may be more effective if supplemented both by modest levels of subsidy for on-farm biosecurity investment in areas of high disease risk and by facilitating agreements between spatially contiguous farmers in such areas to jointly invest in on-farm biosecurity.

Reference

Fraser, R. (2017). Compensation Payments and Animal Disease: Incentivising Farmers Both to Undertake Costly On-farm Biosecurity and to Comply with Disease Reporting Requirements. *Environmental and Resource Economics* [Online]:1-13. Available at: https://doi.org/10.1007/s10640-016-0102-7.