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Quantifying the effect of buffer zones, crop areas and spatial aggregation on the externalities of genetically modified crops at landscape level

M. Graziano Ceddia [a,*], Mark Bartlett [b], Charles Perrings [c]

[a] Department of Agricultural and Food Economics, University of Reading, Whiteknights, RG6 6AR, Reading, United Kingdom
[b] Department of Computer Science, University of York, Heslington, York YO10 5DD, United Kingdom
[c] ecoSERVICES Group, School of Life Sciences, Arizona State University, Box 874501, Tempe, AZ 85287-4501, USA

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ABSTRACT

The development of genetically modified (GM) crops has led the European Union (EU) to put forward the concept of 'coexistence' to give farmers the freedom to plant both conventional and GM varieties. Should a premium for non-GM varieties emerge in the market, 'contamination' by GM pollen would generate a negative externality to conventional growers. It is therefore important to assess the effect of different 'policy variables' on the magnitude of the externality to identify suitable policies to manage coexistence. In this paper, taking GM herbicide tolerant oilseed rape as a model crop, we start from the model developed in Ceddia et al. [Ceddia, M.G., Bartlett, M., Perrings, C., 2007. Landscape gene flow, coexistence and threshold effect: the case of genetically modified herbicide tolerant oilseed rape (*Brassica napus*). Ecol. Modell. 205, pp. 169–180] use a Monte Carlo experiment to generate data and then estimate the effect of the number of GM and conventional fields, width of buffer areas and the degree of spatial aggregation (i.e. the 'policy variables') on the magnitude of the externality at the landscape level. To represent realistic conditions in agricultural production, we assume that detection of GM material in conventional produce might occur at the field level (no grain mixing occurs) or at the silos level (where grain mixing from different fields in the landscape occurs). In the former case, the magnitude of the externality will depend on the number of conventional fields with average transgenic presence above a certain threshold. In the latter case, the magnitude of the externality will depend on whether the average transgenic presence across all conventional fields exceeds the threshold. In order to quantify the effect of the relevant 'policy variables', we compute the marginal effects and the elasticities. Our results show that when relying on marginal effects to assess the impact of the different 'policy variables', spatial aggregation is far more important when transgenic material is detected at field level, corroborating previous research. However, when elasticity is used, the effectiveness of spatial aggregation in reducing the externality is almost identical whether detection occurs at field level or at silos level. Our results show also that the area planted with GM is the most important 'policy variable' in affecting the externality to conventional growers and that buffer areas on conventional fields are more effective than those on GM fields. The implications of the results for the coexistence policies in the EU are discussed.

1. Introduction

In Europe the main production-related issues associated with the introduction of GM crops are being addressed in the coexistence debate (e.g. Bock et al., 2002; Boelt, 2003). Coexistence is entirely an economic problem and therefore it does not refer to the environmental impact of GM crops, which is dealt with separately before authorization for release into the environment of these crops is granted (according to EU Directive 18/2001) and will not be addressed here[1]. The ability of transgenic crops to produce pollen and 'contaminate' conventional (and organic) produce has led the European Council to adopt two important regulations on GM food and feed. The Council has established the maximum level of tolerance for adventitious presence (AP) of GM material in conventional product at 0.9%. Beyond this threshold, products have

* Corresponding author: University of Reading, Department of Agricultural and Food Economics, Whiteknights, RG6 6AR, Reading, United Kingdom.
Tel.: +44 1183788482; fax: +44 1189352421.
E-mail address: m.ceddia@reading.ac.uk (M.G. Ceddia).

[1] This does not apply to confined commercial releases of traits that might pose human or environmental risk, but might be allowed to be cultivated in very regulated conditions which provide sufficient trait confinement.

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to be labelled as containing or originating from GM material. Should a premium for non-GM products appear in the market (e.g. Chern et al., 2002), the AP of GM material in conventional crops would generate a negative externality on conventional growers. This externality will exhibit a *threshold effect*: it will be zero for levels of AP below 0.9% but will jump to the full value of the externality for levels of AP above 0.9%. It is therefore important to understand how the extent and spatial distribution of GM crops in the landscape and the adoption of specific farm management practices (e.g. buffer areas on GM and conventional fields) affect conventional growers through the negative externality.

In this paper, we focus on oilseed rape (OSR) (*Brassica napus* L.) because it is an important crop in the EU and for which GM herbicide tolerant (HT) varieties are already extensively grown in other countries (e.g. Canada). OSR has been modified to be tolerant to broad-spectrum herbicides. The main reason for the large-scale adoption of GM HT OSR appears to be the greater flexibility in weed management allowed by such varieties (e.g. Canola Council of Canada, 2001). Surveys reveal that even European farmers consider the greater flexibility in weed control practices to be the main reason for adopting GM HT OSR (Graef et al., 2007). We look at the implications of pollen-mediated gene flow for the coexistence of GM and conventional crops and therefore exclude the impact on organic growers. We also ignore other sources of gene flow, such as seed lot contamination (e.g. Friesen et al., 2003) and ferals and volunteers[2].

Gene flow through pollen is controlled by a number of factors including level of outcrossing and mode of pollen dispersal. A large body of research has established that pollen concentration decreases rapidly within a few metres from the source (e.g. see Salisbury (2002) for a review). This can be represented graphically by a leptokurtic curve (e.g. Klein et al., 2006; Lavigne et al., 1998). Because pollen mediated gene flow is distance-dependent, the level of transgenic presence in conventional fields will depend (among other things) on the number of GM and conventional fields in the landscape, the width of buffer areas and the level of spatial aggregation. In its guidelines for coexistence the European Commission (EC) explicitly refers to the necessity of adopting buffer areas on adjacent GM and conventional fields (European Commission, 2003). In the same document the EC suggests that voluntary collaboration among farmers to achieve a more spatially aggregated configuration of GM and conventional fields would be desirable.

Our objective is to assess the impact of different ‘policy variables’ on the magnitude of the externality associated with the AP of GM material in conventional produce at the landscape level. Ceddia et al. (2007) assessed the effect of spatial aggregation and extent of GM and conventional OSR area in the landscape on the magnitude of the externality to conventional growers. In this paper we expand the analysis in order to also account for the effect of specific farm management practices aimed at reducing the level of AP. On the basis of the policy indications on coexistence developed in recent years (e.g. Bock et al., 2002; Tolstrup et al., 2003) we include in our analysis the adoption of buffer areas on adjacent GM and conventional fields. This is important to understand the nature of the GM externality, and hence to develop strategies for minimizing the external costs of GM technology. The effect of separation distances between GM and conventional fields has not been included in the analysis. The omission is due to the fact that the concept of separation distance is meaningful only when referred to the distance between two individual fields. When looking at a landscape containing many fields (GM and conventional) it can be substituted by some measure of average distance. We feel that the use of an index of spatial aggregation, reflecting the degree of clustering of GM and conventional fields, will, to some extent, also reflect the average distance between GM and conventional fields in the landscape (i.e. higher aggregation implies higher average distance between GM and conventional fields). Finally, our analysis is essentially a static one (i.e. based on a single year), since it does not account for the impact of volunteers and feral populations. The structure of the paper is as follows. In Section 2, on the basis of the coexistence approach, we develop an analytical model for the externality associated with pollen-mediated gene flow under the alternative hypothesis that AP is detected at the field level or at the landscape level. We then illustrate the Monte Carlo experiment used to generate data on pollen mediated gene flow starting from an OSR individual plant pollen dispersal function (IDF). In Section 3 we use the generated data to estimate the analytical expressions developed in section 2. In the final section we discuss the most important findings and draw the major conclusions.

[2] In the EU the area of organic OSR is extremely limited (Brookes and Barfoot, 2004). Begg et al. (2006) note how GM volunteers might also represent a source of AP, but only in those fields where GM varieties were previously sown. This problem entirely pertains to the private decisions of each individual grower and therefore does not need regulatory intervention. The effects of seed lot contamination would be equivalent to operating with lower thresholds for maximum AP, and therefore would not affect the structure of our analysis.

2. Materials and methods

In the EU the coexistence of GM, conventional and organic agriculture is admitted as long as the economic consequences AP of GM material in conventional (and organic) crops are accounted for. When looking at the aggregate value of the externality across all conventional growers, the stage at which the AP of GM material is detected (at the farm gate or at the silo level) is important for the magnitude of the externality and for the policy options available to the regulator. At the moment it is safe to assume that detection of adventitious GM presence in conventional produce will occur at the field level (as in speciality grains). However, it is also interesting to look at the case where detection occurs at the silo level (e.g. because of accidental mixing). In this case it is possible that farmers will still receive the higher price (e.g. if the accidental mixing is not attributable to their fault or negligence), and the economic loss will fall on grain buyers instead. We model the two cases separately.

2.1. No grain mixing

In this case the test to ascertain whether the AP of GM material in conventional produce exceeds the 0.9% threshold is performed at the individual field level (i.e. at the farm gate). This is standard practice in the production of speciality grains, where the existence of significant premiums favours the use of contract farming and allows the contractor to check the quality of the individual crop harvests (e.g. Fulton et al., 2003). The farmer will lose the premium if the average AP level in his/her field exceeds the threshold. At the landscape level, the loss to conventional farmers will depend on the number of conventional fields generating produce with average AP levels above the threshold. The magnitude of the externality (E) across all conventional growers can then be expressed as

$$E = \Delta p \times C \tag{1}$$

where Δp indicates the premium for conventional produce and C indicates the conventional output originating from those fields with AP of GM material above the 0.9% threshold. From expression (1) it is clear that if $\Delta p = 0$ (i.e. if consumers show no preference for