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Analysis

Coexistence of GM and non-GM crops with endogenously determined separation

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ABSTRACT

The possibility that genetically modified (GM) crops may contaminate non-GM crops through pollen-mediated gene flow presents a challenge to coexistence of GM agriculture with conventional and organic farming systems. In this paper an analytical model of coexistence is developed that allows for endogenous derivation of efficient widths and allocation of pollen barriers to limit contamination of non-GM crops. To reflect the uncertainty that surrounds pollen dispersal mechanisms the model contains a stochastic contamination function and safety rule decision mechanism, constraining the level of contamination to remain below a tolerated adventitious presence with a given probability. Two policies are considered and their performance is tested: the tolerance level of adventitious presence, and the allocation of responsibility for implementing coexistence measures to either GM or non-GM farmers. The relative size of GM rents (the value of productivity gains and the non-pecuniary benefits from GM crops), rents for identity preserved non-GM crops (price premiums realised over the GM crop price), characteristics of farms, and possible variation in agricultural landscapes are also taken into account. The findings indicate that conventional adventitious presence tolerances can be met without *ex ante* mandating large widths of pollen barriers. At the policy level, the findings of this paper are relevant for setting region-specific pollen barriers widths, and/or for establishing institutions that facilitate cooperative coexistence.

1. Introduction

The possibility of continued consumer opposition to genetically modified food crops (GM crops) has significant implications for the production and marketing of agricultural commodities. Heterogeneous consumer preferences for GM and non-GM foods make it necessary for GM and non-GM production systems to coexist. Coexistence is compromised by the possibility of GM adventitious presence: the likelihood that GM material would inadvertently mix with non-GM crops, preventing non-GM producers from marketing their crop as GM-free. If GM-free products command a price premium, GM adventitious presence (hereafter, adventitious presence) and the consequent loss of GM-free identity (and the related price premium) may constitute a negative spatial externality (Beckmann and Wesseler, 2007).

Adventitious presence due to cross pollination may also have aggregate consequences for the organisation of agricultural landscapes. If non-GM farmers' cropping decisions are shaped by the economic consequences of adventitious presence to the extent that farmers relocate or switch to GM varieties to avoid the externality, then cultivation of GM crops may be clustered spatially (Beckmann and Wesseler, 2007; Lewis et al., 2008). Simulation studies of pollen dispersal and adventitious presence patterns over real and hypothetical agricultural landscapes suggest that the ability to produce and market non-GM crops will be compromised by an increasing share of GM crops and spatial clustering of GM and non-GM fields (Belcher et al., 2005; Ceddia et al., 2007; Ceddia et al., 2009; Munro, 2008).

The welfare effects of this possible re-organisation of cropping patterns are central to the coexistence problem and to the institutional arrangements intended to ensure that farmers and consumers have a genuine choice between GM and non-GM crops. The principle of coexistence states that farmers should be able to cultivate the crops of their choice, whether conventional, organic or genetically modified, and coexistence policies are aimed at ensuring non-GM crops can be grown, marketed and consumed in the presence of GM crops. To this end, coexistence institutions range from crop stewardship guides in Australia and North America (Brookes and Barfoot, 2004), to mandatory labelling of GM products, strict separation and special liability regimes in some EU-27 member states (Beckmann et al., 2006).

While coexistence policies may reduce the risk of adventitious presence faced by non-GM farmers or provide for redress of economic losses, simulations suggest that farmers' GM adoption decisions are influenced by institutional arrangements for coexistence (Demont et al., 2008b). Whether GM crop cultivation remains feasible given spatial *ex ante* coexistence regulations and *ex post* liability regimes depends not only on the accepted tolerance thresholds for GM adventitious

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presence and on consumer demand that translates into price premium for GM-free products, but also on landscape and field geography: specifically, the proportion of the landscape planted to the relevant crop, field size and proximity to neighbouring fields, and the extent to which fields are scattered in the landscape. Further, published findings suggest that not all farmers will be equally affected by uniform spatial *ex ante* coexistence regulations, with farmers in agricultural landscapes characterised by small fields, monoculture, and GM crops adopted on randomly dispersed fields likely to be disproportionately affected (Devos et al., 2007; Devos et al., 2008b; Sanvido et al., 2008; Skevas et al., 2010). Other studies suggest that compliance with mandatory isolation distances can manifest at the landscape scale as a 'domino effect' (Demont et al., 2008a,b; Demont et al., 2009; Lewis et al., 2008). In addition, the existence of stringent coexistence measures in some jurisdictions have prompted researchers to question whether the underlying purpose of coexistence regulation might be deterrence of GM crop adoption (Beckmann et al., 2006; Devos et al., 2008a; Devos et al., 2009).

In response, the literature has increasingly argued for alternative, more flexible coexistence regulation based on negotiable measures that are proportional to the economic incentives of coexistence (for example, see Messean et al., 2006; Demont et al., 2008b; Devos et al., 2009). The objective of this paper is to add to this literature by: (i) endogenising the width of non-GM pollen barriers planted on the borders of GM and non-GM fields to trap GM pollen; (ii) relaxing the assumption of deterministic adventitious presence; and (iii) testing a system of alternative property rights for growing GM crops. This is pursued by adopting a decision framework for regulating environmental and health risks with stochastic pollution-generating process (Lichtenberg and Zilberman, 1988), and applying it to the problem of coexistence. This framework has been extensively used in the context of nutrient contamination of groundwater, including by nitrates (Kampas and White, 2003; Lichtenberg and Penn, 2003), and by pesticides (Harper and Zilberman, 1992; Lichtenberg et al., 1989), and to the regulation of the health or environmental risks of GM crops (Lichtenberg, 2006). However, to the best of authors' knowledge, the current paper is the first application of this framework to the problem of coexistence of GM and non-GM cropping.

Specifically, the model developed in the paper allows efficient widths of pollen barriers to be derived endogenously, rather than using exogenously-specified isolation distances. Adventitious presence in non-GM crops is modelled by a stochastic, distance-dependent function, such that the efficient width of pollen barriers is determined according to a safety rule that ensures the adventitious presence tolerance is not exceeded with some probability. The model is used to test a system of alternative property rights based on scenarios where: (i) property rights for growing GM crops are assigned *ex ante* to GM or non-GM farmers; and (ii) GM and non-GM farmers engage in bargaining to determine whether pollen barriers are planted in the GM or non-GM field. The latter represents a Coasean setting, introduced in the coexistence literature by Beckmann et al. (2011), Demont et al. (2008b) and Demont et al. (2009). Unlike *ex ante* regulations, negotiations on pollen barriers will depend on the assignment of property rights, and on whether the opportunity costs of coexistence are proportional to the relative 'GM' and identity preservation 'IP rents'.[2]

2. Methods

Assume that there are two types of farms in a hypothetical landscape. These differ with regard to pest pressure, managerial expertise and access to markets. Farmers of the first type have a comparative advantage in producing a GM crop (GM farmers), while farmers of the second type have a comparative advantage in producing a non-GM crop (non-GM farmers). In the absence of a coexistence problem, GM farmers earn a higher profit from cultivating the GM variety of a crop than the non-GM variety (or an alternative crop). Similarly, in the absence of a coexistence problem, non-GM farmers earn a higher profit from cultivating the non-GM variety of a crop than the GM variety (or an alternative crop).

Let the index for GM farmers in the landscape be $g=1,2,\ldots,G$, and that for non-GM farmers be $n=1,\ldots,N$. Assume further that i ($i=1,\ldots,I$) of a given GM farmer's neighbours are growing non-GM crops, where $I\leq N$. Also assume that m ($m=1,\ldots,M$) of a given non-GM farmer's neighbours are growing GM crops, where $M\leq G$.

Coexistence of GM and non-GM farmers in the landscape is compromised when the level of adventitious presence of GM material in non-GM crops (due to cross pollination by GM crops) prevents non-GM farmers from marketing identity preserved non-GM crops and from realising the associated price premiums. The spatial externality manifests as a threshold effect on non-GM farmers' profits (Ceddia et al., 2007). Denoting the level of adventitious presence in the *nth* farm by C_n, a non-GM farmer will only be able to market the produce as non-GM and realise the price premium awarded for identity preserved non-GM crops if adventitious presence is less than or equal to a tolerated adventitious presence threshold ($\bar{C}$), that is if $C_n\leq\bar{C}$.

To protect non-GM farmers and consumers, governments commonly impose mandatory isolation distances between GM and non-GM farms. These are thought by many to be overly stringent. A more flexible approach would be for GM farmers and their non-GM neighbours to engage in negotiations about cultivating a pollen barrier to reduce cross pollination (Beckmann and Wesseler 2007; Demont et al., 2008b). In this case, pollen barriers with width that is corresponding to the economic incentives of coexistence may be put in place subject to the allocation of initial property rights for growing GM and non-GM crops, the income effects, and transactions costs. Assuming transaction costs are not so high as to impede the voluntary exchange of property rights, the resulting allocation of land to GM and non-GM crops and pollen barriers will be efficient, by virtue of the Coase theorem, reflecting consumer preferences for non-GM foods (as transmitted by prices to farmers), and the pecuniary and non-pecuniary gains from cultivating GM crops.

Because adventitious presence in the non-GM field depends on distance from the GM pollen source, the cross pollination can be termed an 'edge-effect externality' (Parker and Munroe, 2007). The frequency of cross pollination is expected to be highest at a common boundary of the GM and non-GM fields and then to rapidly decline with distance from the GM pollen source (the edge-effect). Let $c_n(x)$ denote the rate of cross pollination of the *nth* non-GM field occurring at distance x from the GM field. To meet the adventitious presence tolerance, a non-GM farmer may cultivate pollen barriers of width x_n on the edge of their field closest to the GM field, thereby removing the crop with the highest levels of adventitious presence, as demonstrated in Fig. 1. Adventitious presence in the non-GM crop may also be reduced by cultivating a pollen barrier of width x_g in the GM field, as demonstrated by Fig. 2.

Average adventitious presence (C_n) across the non-GM field can be described by a general function (Damgaard and Kjellsson, 2005) that takes into account the width of the non-GM field and widths of pollen barriers cultivated in the GM (x_g) and non-GM fields (x_n):

$$C_n\left(x_n, x_g\right) = \frac{1}{X_n - x_n}\int_{x_n+x_g}^{X_n+x_g} c_n(x) \quad dx \tag{1}$$

where X_n is the width of the whole non-GM field.

The integral in Eq. (1) represents total adventitious presence. Average adventitious presence is derived by averaging the value of this

[2] In this context, the term 'GM rents' represents the value of productivity gains and the non-pecuniary benefits from adopting GM crops (see Marra and Piggott, 2006). 'IP rents' are the increases in revenue from realising price premiums for identity preserved non-GM crops over the GM crop market price.