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Spatial Dimension of Externalities and the Coase Theorem: Implications for Co-existence of Transgenic Crops

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Spatial Dimension of Externalities and the Coase Theorem: Implications for Co-existence of Transgenic Crops

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Abstract:

Adopters of transgenic crops produce a negative externality for producers of transgenic free crops through potential pollen flow. Producers of transgenic free crops produce a negative externality for growers of transgenic crops if they call for keeping a minimum distance. This paper examines spatial implications of co-existence of transgenic crops from the perspective of Ronald Coase's influential paper "The Problem of Social Cost" published in 1960. First, the problem of co-existence will be assessed as a problem of social cost. Second, we discuss the impact of the distribution of different property rights on the adoption of transgenic crops. Third, we show that allocations of property rights result in different spatial agglomeration of transgenic and non-transgenic crops.

Keywords: Coase Theorem, Co-existence, Externalities, Property rights, Spatial effects, Transgenic Crops.

1 Introduction

"No form of agriculture should be excluded in the EU." Many observers see this recent statement by European agricultural commissioner Franz Fischler as a clear signal towards a nearby lifting of the quasi EU moratorium on transgenic crops (or GMs for short) launched in 1998 (European Commission 2003). One of the last obstacles towards lifting the moratorium, however, is the problem of coexistence. How can GM-crops and non-GM-crops coexist? Since the European Environmental Agency published its report on "Genetically modified organisms (GMOs): The significance of gene flow through pollen transfer" (EEA 2002) the debate has focused on the external effects that GM-farmers may cause to non-GM farmers if accidental pollen transfer takes place. While strong supporters of the GM technology argue that the current legislation is sufficient to deal with this problem (e.g. EuropaBio 2003), others demand strict liability rules for GM-farmers and those who distribute GM-crops. Furthermore, elaborated monitoring systems, GM-crop cadastre and other measures should be established according to their view (e.g. Greenpeace & Zukunftsstiftung Landwirtschaft 2003). The discussion on coexistence and private liability for GM-technology, however, is not limited to Europe. There are ongoing debates in the United States, Canada, New Zealand and other countries (see e.g. Smyth, Khachatourians and Phillips 2002; Kershen 2002; Conner 2003). Thus, the governance of the future co-existence of GM-crops, conventional crops and organic crops is becoming a burning issue.

This paper examines the current debate on co-existence from the perspective of Ronald Coase's influential paper "The Problem of Social Cost" published in 1960 (Coase 1960). Coase was very sceptical about the role of the government for resolving "harmful effects". He argued, first, that the traditional perception of the problem - making the polluter liable or taxing pollution - is misleading because it ignores the reciprocity of the problem. Second, he stated that if property rights are well defined and the costs of using the market to reallocate property rights are zero or close to zero, the allocation of resources will be independent of the initial distribution of rights. This statement became known as the Coase Theorem (see Cooter 1991; Posner 1993). Third, Coase noticed that if the costs of using the market to reallocate property rights are not close to zero, all institutional alternatives or governance structures must be evaluated in a comparative way, including the *"costs involved in operating the various social arrangements"* (Coase 1960: 44).

This contribution will basically proceed in the logic of Coase's paper but will highlight the possible implications of the Coase-Theorem for the governance of co-existence and its implications for the spatial allocation of GM and non-GM crops.

First, we characterize the problem of co-existence as a problem of social cost that can be solved institutionally as well as technically. Second, we analyze the impact of different property right structures on the adoption of GM crops and on the value of GM and non-GM production. We will show that under certain assumptions the adoption of GM crops is independent from the allocation of property and liability rights. In this case, technical and managerial solutions may be adopted to solve the problems of co-existence. However, the values of different production systems are highly affected by the allocation of liability rights. Fourth, the implications of these for the spatial allocation of GM and non-GM farms are discussed.

2 Assessing the Problem of Co-existence

The problem of co-existence is a classical "problem of social costs". Farmers who plant GM crops may cause negative (or positive) external effects to non-GM or organic farmers by cross contamination through pollen drift or other forms of admixture. The problem is illustrated in Figure 1.

[Insert Figure 1 about here]

Let us consider two supply chains that range from seed production over processing to the final consumer. At each stage, possible accidental contaminations across interfaces are possible. The contamination, in principle, can be two sided. GM crops may affect non-GM crops but non-GM crops may also affect GM crops. It is important to note here that the same physical effect, i.e. pollen flow, can have different economic impacts, depending on the institutional setting. The institutional and regulatory setting defines the rules of what is or is not to be labelled as GM and sets the threshold levels for labelling

(Smyth and Phillips 2003). The lower the threshold levels the higher the costs of governance and possible economic losses. Therefore, it is not surprising that the definition of the threshold is subject to strong political debate. In the EU the current food-labelling threshold is 1% (EU, 2000)[2]. However, the European Council agreement on GM Food and Feed proposal established a 0.9% threshold for food and feed. For seeds, the Commission is proposing even lower thresholds (EU, 2003). These thresholds are low and the likelihood of contamination is high. It should be noted that the labelling regime is different in the United States where market actors can voluntarily label food as GMO free (see Crespi and Marette 2003 for an overview of different labelling policies). In this case market participants define the thresholds, which can vary substantially. Thus, the problem of co-existence is also a problem of governing the flow of goods and services and bads and disservices along the supply chain. However, governance structures are not without costs and these costs have to be taken into account when approaching the problem. The specific admixture through pollen drift, the spatial problem, occurs at the stage of seed and plant production.

2.2 A simple model

Think about a region that consists of a number of farms *i= 1,…,k,* which show similar cropping patterns and share several borderlines and initially grow only one crop. Further, assume a situation similar to the one observed in Europe: only non-GM crops are grown. The regional value of non-GM production V_N is then given by

$$V_N = p_N Q_N - C_N \tag{1a}$$

$$V_N = \sum_{i=1}^{k} v_{N_i} = \sum_{i=1}^{k} \left(p_{N_i} q_{N_i} - c_{Ni} \right) \tag{1b}$$

[2] It should be noted here that for organic farming no threshold has been decided yet. It is usually assumed that the relevant threshold is at the detection level that is currently 0.1 %.

where p_N, Q_N, and C_N are the respective price, quantity and cost vectors for non-GM products at the regional level. Further, v_{N_i} indicates the farm level value of non-GM production and $p_{N_i}, q_{N_i}, c_{N_i}$ are the respective farm level price, quantity and cost vectors.

If all farmers in the region were to shift to the GM-crop variety, e.g. from corn to Bt-corn, the regional value of GM-crop production, V_G, is given by:

$$V_G = p_G Q_G - C_G \tag{2a}$$

$$V_G = \sum_{i=1}^{k} v_{G_i} = \sum_{i=1}^{k} \; p_{Gi} q_{Gi} - c_{Gi} \tag{2b}$$

with p_G, Q_G, and C_G as the respective price, quantity and costs vectors of GM-crops at the regional level. Again v_{G_i} represents the farm level value of GM production and p_{G_i}, q_{G_i}, c_{G_i} are the respective price, quantity and cost vectors for GM crops at the individual farm level.

Since it is expected that consumers are willing to pay a price premium for GM-free food, we assume further that the farm gate price of non-GM crops is universally higher than for GM crops[3]. This assumption is represented by the equation (3):

$$p_{N_i} > p_{G_i}, \forall i = 1,...,k \tag{3}$$

If the farm gate prices of GM-crops are assumed to be below non-GM crops, GM-crops must allow for sufficient cost reductions or yield increases in order to be attractive to be grown. At least for one farmer the value of GM crop production must exceed the value of non-GM crops, $v_{G_i} > v_{N_i}$. Otherwise GM-crops will not be grown. Figure 2 shows the borderline between farms that will adopt GM-crops and those that will not. A farm will only adopt GM-crops if the value exceeds the value of non-GM crops and not otherwise.

[Insert Figure 2 about here]

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[3] However, there is no reason to believe that this should always be the case. It is also possible that the price of GM-food exceeds the price for non-GM products. In the following, however, we will not consider this case.

Assume now, that the whole group of *k* farmers could be divided into two different subgroups. The first group, $i = 1,\ldots,h$, say group A, has a comparative advantage in non-GM crop production, $v_{N_i} \geq v_{G_i}$; the second group $i = k - h,\ldots,k$, say group B, has a comparative advantage in GM crop production, $v_{G_i} > v_{N_i}$.[4] Farms belonging to group A with $i = 1,\ldots,h$ are indicated with the small letter *a* and farms belonging to group B with $i = k - h,\ldots,k$ with the small letter *b*. Different regions may show a different population structure with regard to the type of farms. One region may be populated mostly with type A farmers, another region mostly with type B farmers, and a third region may be equally populated by type A and B farmers. If the latter is the case, then the co-existence of both farm types, if it can be established cost free, will be socially preferable compared to the status quo and to the unified adoption of GM-crops, since the value of co-existence in the region, *VC*, will exceed the value of uniform adoption represented by equation (4):

$$VC = \sum_{a=1}^{h} v_{N_a} + \sum_{b=k-h}^{k} v_{G_b} > V_N, V_G \tag{4}$$

2.2 Co-existence, Economic Damage and Technical Measures

Equation (4) assumes that there is no co-existence problem. However, if accidental pollen transfer from GM crops to non-GM crops occurs, the non-GM farmer may face the risk that his non-GM crops will be contaminated with pollen from GM crops. If, as a consequence, he cannot sell his product at a price premium, he will face an economic loss or damage, d_a. The occurrence and magnitude of the economic damages is influenced by a number of factors represented in equation (5a).

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[4] This does not imply that the alternative non-GM crop will be of the same variety. It includes cases such as Bt-corn in comparison to non-GM spring wheat, e.g.

$$d_a = \begin{cases} 0 & \text{if } \dfrac{\alpha_{N_a} Q_G}{q_{N_a}} < T \\ (p_{N_a} - p_{G_a}) q_{N_a} & \text{if } \dfrac{\alpha_{N_a} Q_G}{q_{N_a}} \geq T \end{cases} \tag{5a}$$

$$D = \sum_{a=1}^{h} d_a \tag{5b}$$

The occurrence of the damage at the individual non-GM farm, d_a, is determined by (1) the quantity of GM-crops grown in the region Q_G, (2) the diffusion coefficient α_{N_a} that indicates the farm and crop specific impact of pollen drifts from GM crops to non-GM crops and (3) the threshold for the good being defined as GM or non-GM *T*. As it was already argued, the threshold *T* is an important factor for the occurrence of economic damage. Economic damage occurs only if the fraction of GM crops in non-GM crops exceeds the threshold level. The magnitude of the damage is influenced by (1) the price difference, $p_{N_a} - p_{G_a}$ and the (2) quantity q_{N_a} of non-GM products affected. The damage, of course, is zero if the quantity of GM crops or non-GM crops is zero, if the price difference is zero or if the contamination is always below the threshold level. The total damage in the region, *D*, is the sum of the farm level damages, d_a.

The diffusion coefficient is of specific importance here. This coefficient can be influenced by different technical measures and management practices, i.e. by isolation distances between fields, buffer zones, pollen barriers, crop rotation systems or by genetic use restricted technologies (GURT) such as infertile pollen (e.g. van de Wiel et al., 2005). These management practices are either related to border management or to the spatial and temporal co-ordination of agricultural activities and can be subsumed as fencing activities. However, influencing the diffusion coefficient requires the introduction of different management practices and is connected with additional costs. If we denote m_i as the farm-level management practices that are ranked and f_i as the farm-level fencing costs of these practices, the following relationships are assumed:

$$\alpha_i = \alpha_i(m_i, m_{k-i}) \tag{6a}$$

$$f_i = f_i(m_i, q_{N_i}, q_{G_i}, Q_N, Q_G) \tag{6b}$$

$$F = \sum_{i=1}^{k} f_i = \sum_{a=1}^{h} f_a + \sum_{b=k-h}^{k} f_b \tag{6c}$$

The diffusion coefficient at the farm level is influenced by the farm management practices m_i but also by the management practices of all other farms. Let us take the example of the buffer zone as one management system and two neighbouring farms. The diffusion coefficient can be reduced if the buffer zone is implemented by a farm that grows non-GM crops and it will be reduced even more if the GM crop farm establishes a buffer zone as well. However, equation (6a) indicates that there is a coordination problem due to the management practices adopted by different farms. The variable costs of establishing the management and fencing systems as in equation (6b) are not only dependent on the management practices of the farmer, m_i, but also on the quantity of non-GM and/or GM crops grown on the farm and the quantity of non-GM crops and GM crops grown in the region. To give an example, it makes a difference if a non-GM farm is surrounded by one GM farmer and four non-GM farmers or by five GM-farmers. Finally, the management and fencing costs in the region are the sum of the individual management and fencing costs as indicated by equation (6c). Through coordinated action farmers may reduce damage and/or fencing costs. They can agree on voluntary solutions such as different rotation practices, planting times or buffer zones. These co-ordination activities are not cost free because of transaction costs. Here, we will differentiate between two situations: one, where the transaction costs are prohibitively high and one, where the transaction costs are zero.[5]

Considering the additional costs discussed above except for the transaction costs equation (4) can now be rewritten:

$$VC = \sum_{i=1}^{h} v_{N_i} + \sum_{i=k-h}^{k} v_{G_i} - \sum_{i=1}^{k} d_i - \sum_{i=1}^{k} f_i > V_N, V_G \tag{7}$$

Now, the regional value of co-existence is the sum of the values of GM and non-GM crops at the farm level minus the sum of damage and/or fencing costs. Equation (7)

[5] For an analysis explicitly considering positive transaction costs that are not prohibitively high, consult Beckmann and Wesseler (2005a).

reflects the sum of the individual decisions. These individual decisions are affected by the distribution of liability rights as shown in the remaining part of the paper.

2.3 Liability Rights and Distribution of Costs and Benefits

To incorporate different distributions of property rights in the form of liability rights in the analysis, let us denote vc_{N_i} as the farm level co-existence value of non-GM crops and vc_{G_i} as the farm level co-existence value of GM crops. We introduce a superscript ℓ that indicates if the GM-farmer is liable for the damages he causes and *n* if he is not. We assume further, first, that there are no additional costs of holding the GM farmer liable and hence there is no uncertainty involved in proving admixture and, second, that transaction costs between GM and non-GM farmers are prohibitively high. Under this setting two different liability systems are discussed.

GM farmer not liable

If farmers have the unrestricted right to grow GM crops and are not liable, every farmer switching to GM technology will reduce the value of non-GM crops on fields in the neighbourhood due to damages from the GM field. The co-existence value of non-GM farming of farm *i*, $vc_{N_i}^n$, will be reduced if neighbouring farms plant GM crops by the expected damage d_i and/or by the costs f_i of the management and fencing practices that prevent potential damages. The co-existence value of GM farming, however, does not change for farmer *i*:

$$vc_{N_i}^n = v_{N_i} - d_i - f_i \qquad (8a)$$

$$vc_{G_i}^n = v_{G_i} \qquad (8b)$$

Farmer *i* will now choose to plant GM crops, if $vc_{G_i}^n > vc_{N_i}^n$. The distribution of rights and therefore costs and benefits as indicated by equation (8a) and (8b) can be assumed not only to influence distribution of economic benefits but also technology adaptation and investments in the management and fencing system. Under the circumstances described, a GM farmer has no incentive to invest in management and fencing practices that prevent damages. The non-GM farmer, however, has an incentive to invest in management systems that prevent damages. Cost minimizing behaviour requires that the non-GM farmer introduces management technologies up to the level where the marginal costs of these technologies are equal to the marginal damages. If the damage and/or the management and fencing costs exceed the incremental value of non-GM crops, $d_i + f_i > v_{N_i} - v_{G_i}$, the farmer will stop non-GM production. Thus, this type of liability rights increases the adoption rate of GM technology. However, as long as the equation does not hold for all farmers in group A, non-GM crop farming will not disappear.

This is illustrated in Figure 3. The borderline between GM and non GM farmers moves downwards. All farmers that are still to the right of the new borderline will continue planting non-GM crops. Those farmers that now find themselves to the left of the new borderline will switch to GM crops.

[Insert Figure 3 about here]

GM farmer liable

The costs are distributed in a different way if the potential GM-farmer is liable. If the GM farmer causes damages to the non-GM farmer, he has to pay compensation payments cp_{G_i} at the rate of the damage. The damage could be caused on more than one farm.[6] The compensation payment sets incentives for the GM farmer to undertake managing and fencing practices that reduce the damages. The value of GM farming therefore will be reduced by the compensation payments and the fencing costs. The value of non-GM farming will remain the same since the damage is fully compensated by the GM farmer.

$$vc_{N_i}^{\ell} = v_{N_i} \quad (9a)$$

$$vc_{G_i}^{\ell} = v_{G_i} - cp_{G_i} - f_i \quad (9b)$$

[6] For simplicity we assume that the source of GM-pollen can be clearly identified, a system similar to the German one with total liable adhesion. The quality of our results does not change, if we assume that a group of farmers will be held liable, such as under the Danish system, only the compensation payment per GM farmer will be reduced.

If the expected compensation payments for economic damages and/or the fencing costs exceed the value of GM production, $cp_{Gi} + f_i > v_{Gi} - v_{Ni}$, GM crops will be prevented from being grown. This situation is illustrated by an upward move of the borderline in figure 3. Farmers that were to the left of the borderline before the introduction of liability rules and are to the right of the borderline after the upward move do not plant GM crops. However, they would have done so without the liability risk.

In this section we have assumed that transaction costs are prohibitively high and therefore no negotiation and coordination between GM and non-GM farmers takes place. In the next chapter we will analyse the case of zero transaction costs.

3 Co-existence: A Coasian View

Economists have two different readings of Coase's paper "The Problem of Social Costs" which are important to note here. The first reading is that Coase was purely in favour of private bargaining solutions of the problem of social costs. Under the assumption that the "*costs of using the price mechanism*" are zero or negligible, he argued that private bargaining would lead to efficient outcomes independent of the distribution of property rights. [7] This came to be known as the Coase Theorem. The only role of the government is to assign the property rights and there is nothing for the government to add. This point of view is usually labelled the Coasian view (Glaeser, Johnson and Shleifer 2001). The second reading is that Coase advocates a comparative institutional analysis of all possible relevant alternatives taking the costs of operating various social arrangements into account. All organizational alternatives such as markets, firms, laws, and regulations have different benefits and costs and these have to be accounted for. As Coase argued in his Nobel lecture (1992) the introduction of the comparative institutional view was his main intention (see also Ellickson 1991; Williamson 1995, and Claeser, Johnson and Shleifer 2001).

[7] We note that compensation payments may change preferences of individuals and result in different forms of allocating goods. The outcome is still efficient (Perman et al., 2003). But, in our case we look at profit maximizing farms.

The following sections will discuss the problem of co-existence from both points of view. However, it will also be argued that both perspectives have their limitations because they ignore the distributional conflicts involved in assigning property rights and establishing governance structures. Further, it is assumed that farmer's know already whether or not it is profitable to grow either GM or non-GM crops ignoring damage costs.

3.1 Efficient Allocation

In order to repeat the result of the Coase Theorem for the case of GM-crops, let us first assume that the GM-farmer is perfectly liable for the possible damages he causes. Thus we are considering equation (9b). The GM farmer has to pay compensation equivalent to the damage caused $cp_{G_b} = d_a$ or he has to invest in technologies in order to prevent damages. The value-maximizing amount of GM-crops grown will be determined where the marginal value of growing GM-crops equals the marginal damages.

Now, let us assume that the GM-farmer has the unrestricted right to grow GM crops. He is not liable and does not bear any costs of cross contamination. A naïve interpretation would be that the GM farmer now has an incentive to expand GM crops until the marginal value is equal to zero. At this point he will cause a damage of d'. However, if the costs of using the price system are zero, the non-GM farmer will negotiate and be willing to pay for the reduction of damages in order to prevent the GM-farmer from growing GM-plants, $cp_{N_a} = d_a' - d_a$. Thus the willingness to pay for reduced damages creates an opportunity cost for the GM-farmer. If the GM farmer reduces the amount of GM-crops grown he will be compensated by the non-GM farmer. The amount will be reduced until the marginal benefits from planting GM crops are equal to the compensation payments, which are equal to the marginal damage cost.

In conclusion, no liability as well as liability of GM farms will result in efficient allocation of GM and non-GM crops. This is the core argument of the Coase Theorem.

3. 2 Spatial Implications

The spatial allocation of GM and non-GM crops will be affected by the distribution of liability rights. A farmer will not adopt GM crops if the expected value is less than the expected value of non-GM crops, i.e. $v_{N_i} - v_{G_i} > 0$ but he also has to consider the damage and/or fencing costs. The non-GM farmer's willingness to pay compensation to the GM farmer in order to prevent damages has limits. The first limit is given by the incremental value of growing non-GM corps. If the expected damage exceeds the incremental value of non-GM crops, the non-GM farmer will quit non-GM farming instead of paying compensation. The second limit is given by the costs for a technical solution to the problem. Given these two limits the following three situations are possible:

$v_{N_a} - v^n_{G_a} > v^n_{G_b} - v_{N_b} < d_a + f_a$	non-GM farmer compensates GM farmer for not growing GM crops	(10a)
$v_{N_a} - v^n_{G_a}, v^n_{G_b} - v_{N_b} > d_a + f_a$	non-GM farmer accepts damages and/or undertakes fencing	(10b)
$v^n_{G_b} - v_{N_b} > v_{N_a} - v^n_{G_a} < d_a + f_a$	non-GM farmer switches to GM farming	(10c)

The situation explained in equations 10a, 10b, 10c is summarized in figure 4. The horizontal axis indicates the incremental benefits for non-GM farms and the vertical axis the incremental benefits for GM-farms. The 45-degree line is the boundary where possible compensation payments equal incremental benefits. Take a point above the 45-degree line. There the GM farmer could compensate the non-GM farmer for not growing GM and still maintain a profit. Damage and fencing costs are introduced by the vertical line d_a+f_a. Equation (10a) describes the area to the right of the 45-degree line and below the dotted line. In this case the GM farmer will become a non-GM farmer and result in spatial agglomeration of non-GM farms. Equation (10b) describes the area above the dotted line and to the right of the vertical line d_a+f_a. In this case there are no spatial agglomeration effects and GM and non-GM farms will coexist. Equation (10c) describes the area above the 45-degree line and to the left of the vertical line d_a+f_a. In this area the incremental benefits from staying non-GM are less than the damages and fencing costs from neighbouring GM farms, and farmers switch to growing GM crops. In this case a spatial agglomeration of GM crops can be observed.

[Insert Figure 4 about here]

If the GM farmer is liable for possible damages, he will only be willing to plant GM-crops as long as the compensation payment cp_{G_i} does not exceed the incremental value of GM production or the cost of fencing investments. The farmer's decision can be illustrated in the following three arrangements[8]:

$v^{\ell}_{G_b} - v_{N_b} > v_{N_a} - v^{\ell}_{G_a} < cp_{G_b} + f_b$	GM farmer will compensate non-GM farmer for not growing non-GM	(11a)
$v^{\ell}_{G_b} - v_{N_b} > v_{N_a} - v^{\ell}_{G_a} > cp_{G_b} + f_b$	GM farmer compensates the non-GM farmer and/or undertakes fencing	(11b)
$v^{\ell}_{G_b} - v_{N_b} < cp_{G_b} + f_b < v_{N_a} - v^{\ell}_{G_a}$	GM farmer will switch to non-GM crops	(11c)

The situation explained in equations 11a, 11b, 11c is summarized in figure 5. Now, the damage and fencing costs are introduced by the horizontal line cp_b+f_b. Equation (11a) describes the area above the 45-degree line and to the left of the dotted line. In this area the GM farmer will compensate non-GM farmers for not planting non-GM crops and the non-GM farmer will start planting GM crops. This leads to an agglomeration of GM farms. Equation (11b) describes the area to the right of the dotted line and above the cp_b+f_b line. In this area the GM farmer will compensate the non-GM farmer for the damages and/or invest in fencing but neither will change their crops and GM and non-GM farms will coexist. Equation (11c) describes the area below the 45-degree and cp_b+f_b line. In this area the GM farmer will switch to non-GM crops as the damage costs are higher than incremental benefits from GM crops resulting in a spatial agglomeration of non-GM farms.

[Insert Figure 5 about here]

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[8] Please note, that equations 10a 10b, 10c and 11a, 11b, 11c imply a negative attitude of farmers towards GM crops.

In both cases, with and without liability, incentives for spatial agglomeration exist. If fencing and damage costs in both cases are the same, the spatial agglomeration will be the same as well. As farms are heterogeneous, it is reasonable to assume that damage and fencing costs differ between farms. Further, the diffusion coefficient α will depend, among others, on the local geography and will result in different damage and fencing costs between farms. Also, the costs of buffer-zones, as one possible fencing mechanism, decrease with farm size (Soregaroli and Wesseler, 2005). This indicates that the liability system can result in different spatial distribution of GM crops.

The results presented in equations 10a, 10b, 10c and equations 11a, 11b, and 11c have additional implications for the spatial distribution of transgenic crops to the ones already mentioned. In the case where GM farmers are not liable for cross pollination of neighbouring fields, incentives for non-GM farmers to cooperate and organize GM free zones exist. Collaboration with neighbouring non-GM farmers increases the total area of non-GM crops and reduces the average damage per unit of area as the average distance to fields with GM crops increases. Also, fencing costs decrease. As we assume that transaction costs are zero the results will change with positive transaction costs. The transaction costs will increase with the number of farmers participating in the GM free zone. The higher the transaction costs the smaller the number of participating farmers will be.

With the introduction of a liability rule for GM-farmers, incentives change. Now, GM-farmers have an economic incentive to collaborate and organize GM crop zones. The average damage costs per unit of area can be reduced. Each additional unit of land increases the amount of land within the minimum distance to non-GM crops. As a result, agglomeration of land planted with GM crops is further enforced.

3.3 Distributional Implications

Even though resources are allocated efficiently under the two liability systems, they have distributional implications. In the case where GM farmers are held liable, they have to shoulder additional costs. The compensation payments non-GM farmers receive cover the additional costs. In this case the non-GM farmers will not gain economically. Even

though the GM-farmer has to bear additional costs in the form of the compensation payment, he will still be better off than in the case without the availability of GM crops.
In the case where the GM farmer is not liable, he receives the full gain from planting GM crops, but the non-GM farmer has to bear costs and his economic situation will be worse than before the introduction of GM crops. Holding GM farmers liable can be justified from a distributional perspective.

4. Conclusions

Our analysis of externalities and their regulation applied to the special case of GM-crops shows that different spatial agglomerations of production may result. In the case where transaction costs are low, spatial agglomeration of GM and non GM farms can be expected. The empirical relevance of this theoretical result is supported by the appearance of GM zones in Germany and non-GM zones in France and Germany, although regulations and low transaction costs might not be the major reason for the development of non-GM zones (Lavelle, 2005; Beckmann and Wesseler, 2005b). However, our results support the argument that liabilities will be important for the adoption of transgenic crops.

The model we presented considers a symmetric case where under one scenario the “polluter” has the right and under the other not the right to “pollute”. Under both scenarios spatial agglomeration may occur.

Furtan et al. (2005) report similar results using almost the same approach. They show using field data from Canada that economic incentives exist for organic wheat and oilseed rape farmers to form a club. Our specification differs from their model as they only consider the asymmetric case where the property right is with the GM farmer (as provided under the Canadian legislation).

The extend of spatial agglomeration largely depends on the heterogeneity among farmers. This is similar to the results found in the literature on spatial pollution (e.g. Goetz and Zilberman, 2000), where the total damage depends on individual farm characteristics. In our case the amount of damage the GM-farmer, the “polluter”, produces, provides incentives for zoning to reduce the damage, while in most spatial pollution models differences in damages are used to improve the efficiency of government control through zonal taxes, zonal permits and/or zonal standards.

Our results are also similar to those reported on tradable pollution permits, where polluters (GM –farmers) have the right (possibility) to buy (compensate) from others (non-GM farmers for) additional permits to continue production. In studies on spatial pollution and tradable permits polluters in most cases are assumed to be liable for violation of government regulations. In this sense our contribution is an extension as we consider symmetric responsibilities, although the general argument has already been made by Coase in 1960.

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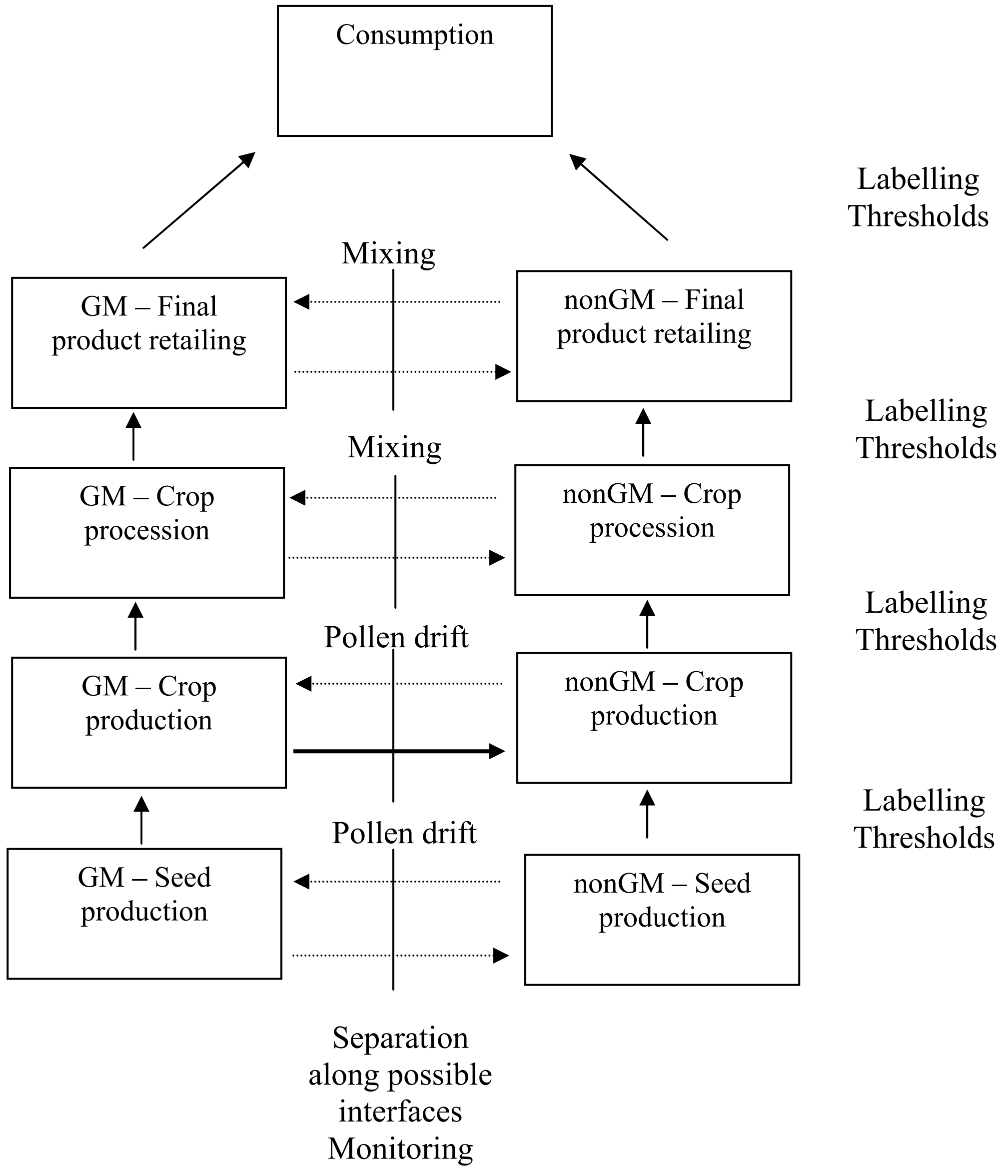

Figure 1 Co-existence: the Governance Problem

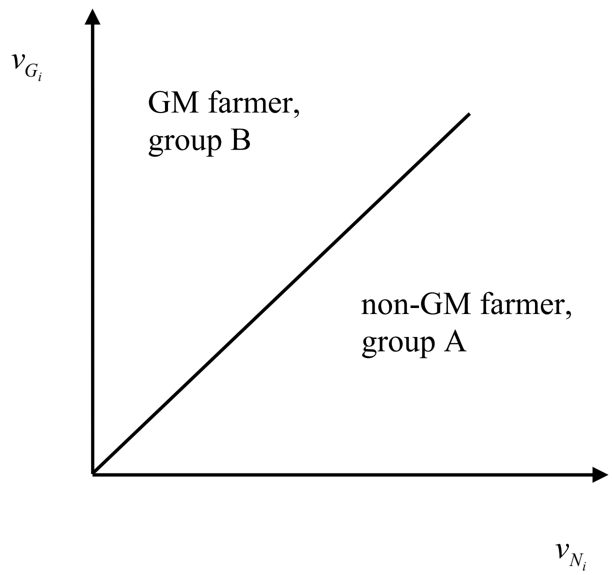

Figure 2 Value of production systems and potential technology adoption

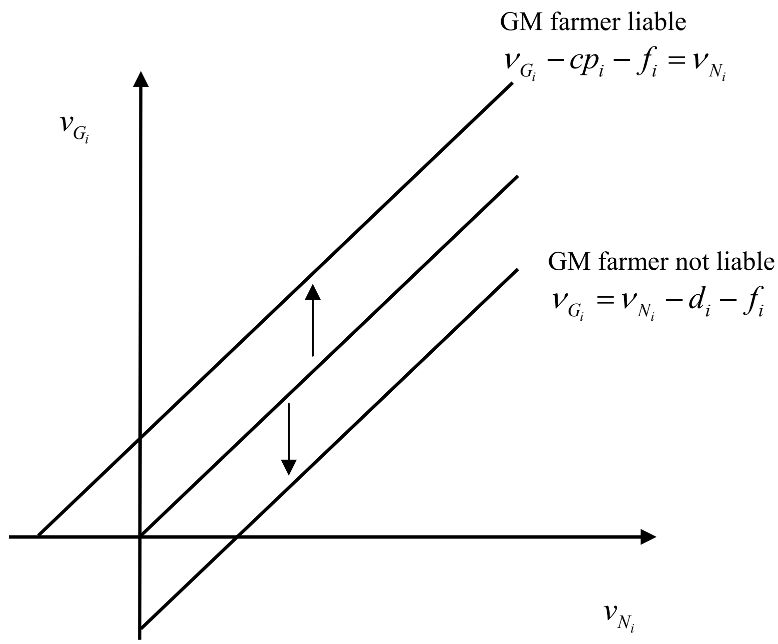

Figure 3: Liability rules, values and technology adoption

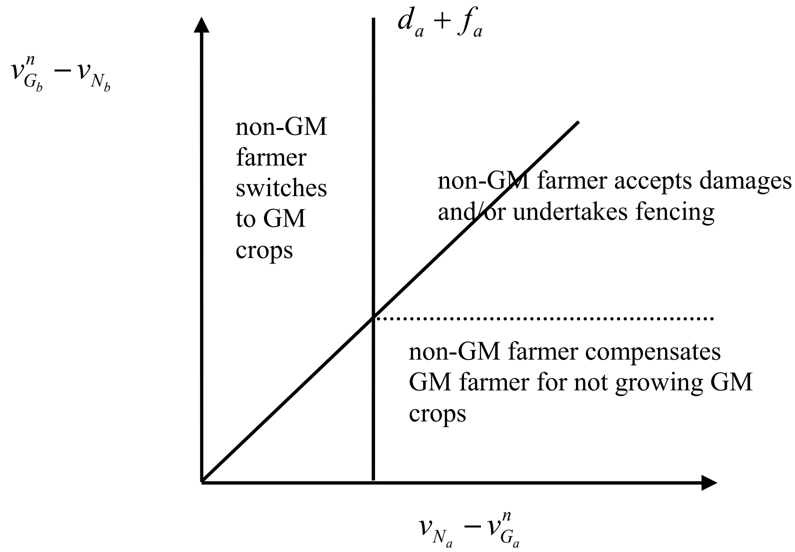

Figure 4 Adjustment strategies under no liability regime

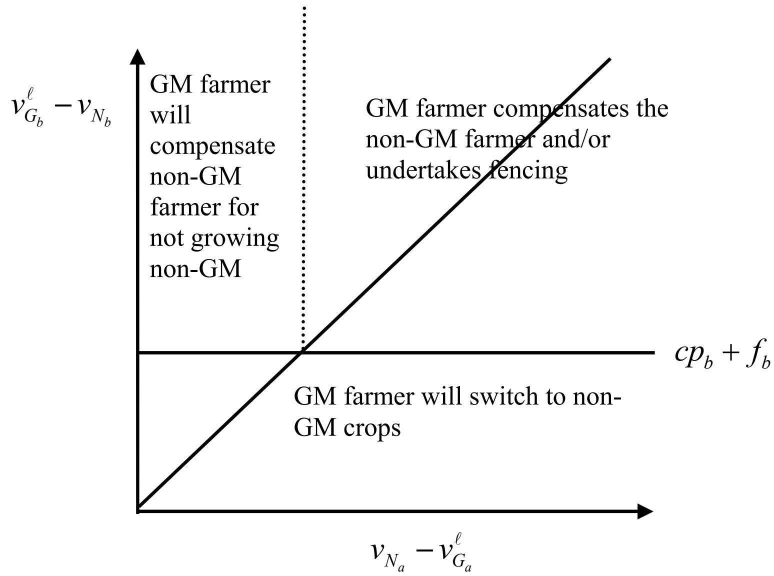

Figure 5 Adjustment strategies under the liability regime