Coexistence of genetically modified (GM), conventional and organic crops: Are the two main property rights regimes symmetric?

Authors: Volker Beckmann, Claudio Soregaroli, Justus Wesseler

Abstract: Two major regulatory regimes for planting of genetically modified (GM) crops have emerged: one, where the property right of growing GM crops is mainly with the GM farmer and one where the property right is mainly with the non-GM farmer. In this contribution the regulatory model chosen by Canada and the United States will be compared with the model of the EU and its different variants, the ex-ante regulations and ex-post liability rules chosen by EU member states and analyzed from an efficiency point of view. While the general result in the literature on ex-ante regulation versus ex-post liability rules under uncertainty shows the most efficient regulatory regime does depend on the specific case under investigation, we will investigate the analytical conditions for one or the other regulatory system to be more efficient. The results show the property right systems are almost symmetric as long as transaction costs are not prohibitively high and using the court system is costless. As using the court system is not cost free, property right regimes where the GM farmer is not liable are preferable from a social welfare point of view.

Keywords: Coexistence, genetically modified crops, property rights, transaction costs

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1. Introduction

The planting of genetically modified organisms (GMOs) is regulated. Regulations change the comparative advantage of those being directly regulated. Two major regulatory regimes have emerged: one, where the property right of growing GM crops is mainly with the GM farmer and one where the property right is mainly with the non-GM farmer. Under the former non-GM farmers will invest in protecting their GM-free status while under the later GM farmers have to ensure the GM-free status of the non-GM farmers. The regulatory regime provides incentives for regional agglomeration of GM and non-GM farms independent of the type of property right (Beckmann and Wesseler, 2007). Regulators can further differentiate between ex-ante regulations and ex-post liability rules to govern the planting of GM and non-GM crops (Beckmann, Soregaroli, and Wesseler, 2006, 2010).

Under a "free-market" system and zero transaction costs the problem between GM and non-GM farmers would be solved efficiently independent of the property right system. As transaction costs under both property right systems are non-zero and are often increased through additional ex-ante regulations the question of what characterizes an efficient regulatory regime arises. While previous studies did investigate the effect of ex-ante regulations and ex-post liability rules on comparative advantages (Beckmann and Wesseler, 2007; Beckmann et al., 2006; Consmüller et al., 2009a,b; Demont et al., 2008; Furtan et al., 2007; Skevas et al., 2009; Soregaroli and Wesseler, 2005) a systematic and analytical comparison of different regulatory regimes is still missing.

In this contribution the regulatory model chosen by Canada and the United States will be compared with the model of the EU and its different variants, the ex-ante regulations and ex-post liability rules chosen by EU member states and analyzed from an efficiency point of view. While the general result in the literature on ex-ante regulation versus ex-post liability rules under uncertainty shows the most efficient regulatory regime does depend on the specific case under investigation, we will investigate the analytical conditions for one or the other regulatory system to be more efficient.

The starting point for our analytical investigation will be the model by Beckmann and Wesseler (2007). The analytical results will be discussed using the latest EU report on coexistence regulations and case study results provided by a number of authors.

The results show the property right systems are almost symmetric as long as transaction costs are not prohibitively high and using the court system is costless. As using the court system is not cost free, property right regimes where the GM farmer is not liable are preferable from a social welfare point of view.

2. Coexistence Regulations

2.1 Regulating coexistence: an overview

According to the European Commission "Coexistence refers to the choice of consumers and farmers between conventional, organic and GM crop production, in compliance with the legal obligations for labelling defined in Community legislation. The possibility of adventitious presence of GM crops in non-GM crops cannot be excluded. Therefore, suitable measures are needed during cultivation, harvest, transport, storage and processing to ensure coexistence. Coexistence pursues the aim to *achieve a sufficient segregation between GM and non-GM production*. Coexistence always refers to GMOs that have passed the very strict EU authorization process, including comprehensive assessments of health-related or environmental risks. Therefore, environmental or health-related risks do not concern the formulation of coexistence rules. Agriculture is an open process, which means that *perfect segregation of the different agricultural production types is not possible in practice*. Coexistence between GM and non-GM production requires specific segregation measures designed in a way that takes these limitations into account" (European Commission, 2010).

This official statement on the European perspective on coexistence make some important general points that can be summarized as follows: coexistence is (1) an economic problem of (2) preserving the choices of consumer and farmer among different methods of production by (3) controlling agro-ecological dynamics through measures of segregation (4) embedded in a broader regulatory framework of (4a) labeling and (4b) approval for GM crops. The economic problem of coexistence, therefore, always consists of at least three framing factors: first, consumer and farmers preferences for different production methods; second the agro-ecological dynamics depending on the biology of the crops concerned and the agro-ecological environment in which they are released; and third, the broader institutional framework. It should be noted that all these key factors vary internationally, nationally or even regionally. This diversity has profound implications for coexistence regulation, implications that have not been completely analyzed in the literature yet. Different preferences of consumer and farmer are fundamental (Gaskell et al., 1999, 2000) and suspected to affect the institutional environment of GMO labeling and approval (e.g., Crespi and Marette, 2003; Bernauer and Meins, 2001). Agro-ecological dynamics are crop and location specific and are extensively addressed in the agronomic literature (e.g. Ma et al., 2004; Jarosz et al., 2005). In the following we will therefore focus on the institutional environment.

The agro-biological dynamics in particular cross-pollination and other forms of admixture by itself do not generate any economic problem. The economic problem purely emerges from the social construction of what is considered as GMO, conventional or organic and need or need not to be approved or labeled in order to be marketed legally (Bender and Westgren, 2001; Beckmann and Wesseler, 2007). In other words the problem is related to the legal definition of goods and the segmentation of markets by labels and approval procedures. When a GM crop is approved in the US or Canada but not in the EU, cross-pollination may generate an economic problem/damage for the U.S. and Canadian non-GM farmer if exporters are no longer able to export non-GM crops to Europe as the example of adventitious presence of GM flax seeds in exports to Europe illustrates (Falck-Zepeda et al., 2010). When GM crops need to be labeled, agro-ecological dynamics may generate an economic problem for a non-GMO farmer if he can not sell his produce as non-GMO. Thus, different approval and labeling regimes are fundamental to the regulation of coexistence as an economic problem (Boisson de Chazournes and Mbendgue, 2005).

Two distinct regimes emerged, which largely distinguish the US and Canada from Europe.

The approval process for GM crops in the US and Canada can be characterized as product and science based following the substantial equivalence principle. Decisions on the approval are made by public agencies (the Food and Drug Authority (FDA), the US Department of Agriculture (USDA) and the Environmental Protection Agency (EPA) in the U.S. (see Belson, 2000), the Canadian Food Inspection Agency (CFIA) and Health Canada in Canada. In Europe, the approval procedures changed significantly between 1990 and 2001. Since the Directive 2001/18/EC on the release on GMO in the environment came into force, the approval of GM crops is process based and guided by the precautionary principle. However, risk assessment and risk management at the European level are divided. Risk assessment based on scientific evidence is prepared by the European Food Safety Agency (EFSA), whereas the approval decision is complex and political involving the Commission of the European Communities (European Commission - EC), the European Council and the European Parliament. These different approval regimes have resulted in significant asymmetries with an increasing number of GM crops being approved in the US and Canada but not in Europe (Stein and Rodriguez-

Cerezo, 2009). For GM crops which are not approved within the EU, a zero-tolerance policy is applied for its adventitious presents in imported food or feed.

Difference also exists regarding labeling regimes: whereas the U.S. and Canada do not require any GMO labeling and allow for voluntary labeling of non-GM food and feed, the EU introduced strict mandatory labeling and traceability of GM food and feed (Regulation (EC) No 1830/2003). Whereas under the mandatory labeling and traceability system the GM sector has to bear the costs of labeling, documentation and tracing it is otherwise the non-GM sector (Philips and Isaac, 1998). Besides the question of mandatory or voluntary labeling, it is also important how labeling rules are defined in detail. Goods can be defined and labeled on the basis of process and product standards (see Kayzer, 2004). Organic farming, for example, usually relies on voluntary labeling and is defined by process standards (e.g. no use of synthetic pesticides and fertilizer). Such a definition, as it is applied worldwide, does however not exclude the possibility that organic food or feed may contain pesticide residues. In fact, organic food sometimes does contain pesticides residues, although far less than conventional produce, due to the dynamics of agricultural systems and possible pesticide drifts from other neighboring fields (e.g. Baker et al. 2002). If in a similar fashion GM and non-GM food and feed would be defined in process standards the dynamics of nature would not pose a problem. The non-GM label would not exclude the possibility of the adventitious presence of GM in food and feed, it would just guaranty that no transgenic material was intentionally used in the production process. Such rules are adopted for the labeling standards between GM and non-GM in the US and Canada but not in Europe. In Europe a system of labeling has developed that defines organic food and feed in product standards. If a produce contains more than 0.9% of GMO material it must be labeled as a GM produce. This standard applies currently for conventional as well as for organic food and feed, although the organic food sector asks for higher standards.

The institutional differences between North America and Europe are important for understanding and analyzing the regulation of coexistence. The institutional environment of approval and labeling generates asymmetries between these countries in the way that only very few GMOs are available to consumer and producer in the EU and the GMO sector has to bear the costs of the approval and labeling standards. Due to the zero-tolerance policy of the EU concerning the import of non-approved GM crops and the 0.9 percent threshold for labeling approved GM food and feed the agro-ecological dynamics can be expected to be more consequential within the EU and for countries exporting to the EU.

2.2 Coexistence Regulations in Canada and the United States

Canada and the United States do not have explicit regulations addressing the issue of coexistence. According to the regulations, if a new crop has been approved for cultivation farmers are free to choose planting them. In case private standards go beyond the standards set by the regulator those following the higher private standards have also to bear the additional costs. Private organizations and individual farmers have tried to challenge this view for the case of the introduction of transgenic crops but so far have not been successful (Kershen and Smyth, 2010). Possible damages through the cultivation of transgenic crops are addressed via ex-post liability rules. Farmers planting transgenic crops do not have to follow mandatory ex-ante coexistence measures. Farmers that want to maintain a GM-free status need to implement measures on their farm and have to bear the additional costs. In case plaintiffs complaining against the current regulations would have been successful in claiming damages from the introduction of transgenic crops it could be expected that as a result also ex-ante measures for coexistence would be introduced. Even so, the lack of ex-ante coexistence measures does not imply coexistence is not possible. The adoption rates for transgenic crops illustrate that a percentage of crops planted are still non-transgenic. The standards for organic agriculture in Canada and the United States are process based. This excludes the planting of transgenic crops. Cross pollination of organic crops by transgenic crops or other forms of adventitious presence of transgenic material does not result in loosing the organic status of the farm in the US and Canada. However, in case of cross pollination organic products can not be sold as organic anymore under the Canadian scheme, while they still can be sold under the US certification scheme. The standard set by the US regulators can be seen as a minimum standard. Many private organic certification schemes do have standards that go beyond the federal standard and imply that organic producers can not sell their product as organic anymore in case of cross pollination. As Kershen and Smyth (2010) describe, until now neither a case for the United States nor Canada has been reported where an organic farmer did loose his certification because of adventitious presence of transgenic material.

While the regulatory system in Canada and the United States does require the non-transgenic farmer to invest in avoiding cross pollination the question is do such kind of voluntary coexistence measures take place or are they just a theoretical possibility without empirical relevance? There are a number of examples, where farmers did voluntary invest in coexistence measures. Furtan et al. (2007) report voluntary segregation between mustard and oilseed rape when oilseed rape was introduced in Canada in the 1960s and could not visually be distinguished form mustard while the oil and meal products have been very different. As there was at the time of introduction no technical separation mechanism for mustard and oilseed rape available, "… farmers and landowners collectively agreed not to grow the two oilseed crops in the same rural municipality. Each municipality made its own decision regarding which of the two crops to grow, and each municipality monitored and enforced this arrangement through moral suasion." (Furtan et al., p. 193, 2007).

Other examples include the production of high quality bread wheat, production of malt barley, seed production or high erucic acid rapeseed (HEAR). The HEAR example is of interest as during early years of HEAR production HEAR growing farmers had to maintain an isolation distance of 100 meter which was later reduced to 5 meters (Smyth and Phillips, 2002). The requirements for seed production in the US and in Canada include isolation distances that vary depending on the crops from a few meters up to several hundred meters.

What is also noteworthy, the last examples all include contract farming where the benefits for maintaining coexistence are obvious.

2.3 Co-existence regulations in Europe[1]

Following the general guidelines for coexistence developed by the European Commission (CEC, 2003), EU27 Member States are progressively regulating coexistence at the national level. CEC (2009b) reports that, as of February 2009, 15[2] over 27 Member States adopted specific regulations for coexistence while other countries had legislation at the draft level. Only a few countries did not develop specific coexistence measures since they are not expecting future GM cultivations in their territory. Member States are supported by the newly, 2009, established European Coexistence Bureau (ECoB) which organizes exchange of technical information related to coexistence and develops crop-specific guidelines for coexistence measures (ECoB, 2010).

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[1] The analysis is mainly based on a document published by the CEC (2009a) and constitutes an update of the evaluation of coexistence regulation in the EU provided by Beckmann et al. (2006).

[2] AT, BE, CZ, DE, DK, FR, HU, LT, LU, LV, NL, PT, RO, SK, SV (see note of table 1 for country names).

Table 1 summarizes the ex-ante regulations and ex-post liability rules using information provided in the Check's report (CEC, 2009a). Draft regulations are distinguished since they are still subject to change especially during the notification process to the EU Commission.

The policies in the EU governing coexistence can be differentiated into ex-ante regulations and ex-post liability rules. This differentiation is useful as the economic implications between the two differ (e.g. Kolstad et al., 1990; Posner, 2007; Shavell, 1987).

Ex-ante regulations

Approved GM crops should be freely grown in the territory of the EU, provided that farmers respect administrative regulation and agricultural practices. However, this is often not the case among Member States. Some countries ban or *de facto* ban approved GM crops[3] and/or allow for the possibility of banning the planting of GM crops in specific areas, mainly nature reserves. The banning issue goes beyond coexistence itself and refers to more general socio-economic or political reasons (LNV, 2009).

[3] This is the case of Austria, France, Germany and Hungary for the cultivation of MON810 maize. Italy is *de facto* banning GM crops since it does not allow GM cultivation until regional government adopt coexistence plans.

Several Member States require farmers to get official approval before they are allowed to plant GM crops. In most cases this is only a formal step following the correct application to authorities by the farmer. Instead, in some regions of Austria and in Hungary it is a case by case approval of each field. Moreover, Hungarian authorities adopt a case by case definition of isolation distances and cultivation conditions and, before the final approval, also require the farmer to get a written approval of the neighboring farmers within the isolation distance. In general, in some countries, the consent from the neighbors is required when the GM farmer cannot respect the minimum isolation distance. A consent from the landowner is also required in Austria, Luxemburg, in two Baltic Republics and is foreseen in Italy.

Almost all Member States include registration and information responsibilities for GM farmers. These include registration of areas in databases, with individual locations being often publicly available, the duty to previously inform authorities, neighbors and landowners and record keeping. Only a few countries (Spain, France, and Sweden) do not require a prior information to the authorities on the intention to cultivate GM crops.

The aforementioned factors can have important consequences on the optimal producer's choice. New variables are introduced in the cost function, such as negotiating costs and the risk of public exposure (with potential destruction of fields or personal injury). Prior information duties also reduce the flexibility in production decisions since in most cases farmers have to decide and notify to public authorities months before the sowing the optimal allocation of land. Finally, prohibition of cultivation and case by case approval decisions transfers the decision making rights from the farmer to public authorities.

Technical segregation measures with sexually compatible crops are adopted in the different countries and are quite similar in nature, while their application differ widely. The main instruments are the use of isolation distances, buffer zones, different plant cycles, and rotation intervals. The stated objective of these measures is to guarantee non-GM harvest being below the GM labeling threshold of 0.9% for food and feed.

The definition of the minimum distances requirements are different depending on the country and on the type of crop. Among the different Member States, measures are defined for maize, potato, sugar beet, wheat, and oilseed rape. Maize is regulated in the highest number of countries. Some countries differentiate additionally between distances to conventional non-GM crops and organic crops and crops for seed production. Isolation distance can be used as the unique requirement, as in Germany and Denmark, or in conjunction with buffer zones that often allow a reduction of the distance requirement.

In general, minimum distance requirements are lower for potatoes, followed by sugar beet, maize and oilseed rape and are higher for organic non-GM crops and non-GM seeds. Luxemburg has the largest distances for maize (600 meters), while Hungary imposes a minimum distance of 400m that can be extended in the case by case approval process. Lithuania and Latvia define a distance of 4,000m for GM-rapeseed, while this crop is not even allowed in Italy, virtually willing to impose an infinite isolation distance.

A few states consider the use of different plant cycles as a parameter for segregation: this includes using plants with different cycle length and flowering time or simply having a different sowing period. Other countries require attention to the general crop rotation of the farm or to the specific crop interval between GM and non-GM crops. For example, in Slovakia non-GM plants cannot be grown for two years after GM crops of the same species.

Segregation measures impose costs to the GM-farmer that go beyond the measure itself. A higher number of neighbors increases transaction costs that can be either reversible or irreversible. Farm size and minimum distance requirements influence the actors involved, the overall coordinating costs, and their incidence. Minimum distance requirements, however, may reduce the ex-post liability costs significantly. Crop interval between GM and non-GM crops impose irreversible costs to the GM adopter, since the decision to cultivate GM-crops impacts the GM-free status in the following years.

The cost of dealing with segregation measures can be reduced with written agreements among neighboring farmers on the non-application of such measures. A discrete number of countries allows for this possibility, while a few deny it. With these agreements the neighboring farmer gives up the right to claim compensation for the eventual loss of a

GM-free status, therefore also reducing the liability risk. In any case, these measures do not overcome the transaction costs of dealing with neighbors.

In general, the requirement is a written agreement among all concerned farmers. In Portugal municipalities can declare themselves GM-free only with the approval of local farmers associations. In Slovenia a municipality can declare itself GM-free, but this applies only to the land which is property of the municipality. In Italy the proposed regulation would allow a municipality to declare itself GM-free if a quorum of 50% +1 of the farmers agree.

Not all of the Member States impose segregation measures. In Spain[4] GM farmers need to adopt good agricultural practices and recommendations given by seed companies, mainly consisting in refuges areas and control of volunteers. No minimum distances are defined and the non-GM farmer has the duty to adopt segregation measures if willing to obtain a GM-free harvest. Spain also does not require prior notification to authorities and mandatory information to third parties, while only asking for record keeping. Draft measures for Spain would change the regulatory framework; however, no legal coexistence problems emerged until now. But there is also no consensus among stakeholders whether or not additional coexistence policies are needed (CEC, 2009a, p.70).

[4] In 2008, Spain had the largest GM-maize acreage in the EU: the total maize area was 79,269 ha, 22,11% of which was GM.

Even when respecting technical segregation measures, the cultivation of GM crops could cause damages to non-GM harvest. For this reason Austria (some regions), France and Luxemburg require a mandatory financial guarantee from the GM-farmer. This could consist of an insurance contract (foreseen by Austria, France, Italy and Luxemburg), although at the moment no insurance companies offer such a product since the sufficient information for a proper assessment of risk are lacking[5]. Belgium and Denmark introduce compensations funds paid by the GM-farmer. These funds protect the GM farmer from further financial loss as long as the technical ex-ante regulations are respected.

Ex-post liability

Technical segregation and financial guarantees increase the current regulatory costs, while reducing ex-post liability costs. These ex-post liability costs include the possible damages, due to admixture with GM crops, that the GM farmer has to compensate depending on the legislations, which a quite divers within the EU (Koch, 2008).

In general, the legislation refers to the civil law and, in particular, to the tort law (ECTIL, 2007). The GM-farmer can be held liable if it can be demonstrated that he was negligent or wrongdoing. Usually, in this case the GM-farmer has to compensate the damage and all other expenses. However, France and Germany adopt a strict liability regime for GM-

[5] Insurance companies do not have sufficient data to estimate the level of damage and its probability. Uncertainty on the liability regimes contributes to this lack of knowledge.

crops: in this case the GM-farmer is liable for all economic damages independently of his behavior.

For the definition of damage occurrence and its importance, in general, countries refer to the need to label as GM a product because of the adventitious admixture with GM material over the 0.9% labeling threshold[6]. The level of the damage is measured as the difference between the price of the GM-product and the price of the non-GM product. If there is no price mark-up for conventional non-GM crops economic damage will be difficult to prove and it is reasonable to expect that no compensation must be paid.

Excluding the case of strict liability, compliance with ex-ante regulations mainly protects farmers against liability claims[7]. However, ex-ante regulation expose farmers to non-compliance penalties, foreseen in most countries, that can be independent from the occurrence of a damage. For example, countries such as Czech Republic, Denmark, Hungary, or Portugal foresee regular controls to GM-fields and provide penalties for non-compliance that could be fines or, in some cases, the withdrawal of the GM growing

[6] As ECTIL (2007) underlines, it is uncertain how the different legal systems will deal with those cases where the non-GM farmer face losses originating from delivery contracts voluntarily setting higher standards of purity (less than 0.9%).

[7] To further protect non-GM farmers, many member states directly compensate economic losses caused by GM admixture using either specific compensation founds or general resources.

authorization. Other Member States do not explicitly state whether the fine for non-compliance is independent from the occurrence of an admixture.

The ex-post liability rules do not result in additional *ex-ante* costs directly, but indirectly, due to inducing adaptive behavior by GM farmers, such as the planting of windbreaks and negotiations with neighbors about possible damage settlements (Beckmann, et al., 2009).

3. A generic model assessing coexistence

The previous section has illustrated that Canada, the United States and the EU-members states do regulate the planting of transgenic crops. An interesting question is what are the economic implications of coexistence regulations and under what circumstances coexistence is preferable from an economic point of view. For being able to assess the economic implications a definition of coexistence is needed. In the economic literature coexistence issues are mainly discussed at farm level (e.g. Demont et al., 2009; Skevas and Wesseler, 2009; Munro, 2008; Beckmann and Wesseler, 2007; Beckmann et al., 2006; Belcher, 2005), while one has to note coexistence at farm level is directly linked to identity preservation as previously mentioned.

In areas with homogenous farms where profits of GM farmers equal profits of non-GM farmers but production costs of GM farmers are lower and product prices for non-GM farmers are higher efficient production is difficult to achieve without additional governmental regulations (Munro, 2008; Belcher et al., 2005). In the following a generic model will be developed discussing whether or not additional and what kind of governmental regulation is indeed needed and to what extent this depends on the property rights. As a starting point we consider a region of heterogeneous farms. The property right system is that damages to properties are regulated according to the prevailing law. The planting of GM crops is regulated in the same way as the planting of the equivalent non-GM one except for the following two different cases:

1. The property right is with the GM farmer. The non-GM farmer has to implement measures to prevent cross pollination and can not claim to the court compensation for damages through cross pollination.

2. The property right is with the non-GM farmer. The GM farmer has to implement measures to prevent cross pollination of non-GM crops and is liable for economic damages caused by his GM-crops to non-GM farmers, which the non-GM farmer can claim using the court.

Consider Case 1. In this case the non-GM farmer has to invest in preventive measures by either keeping appropriate distances to the GM farmer including the use of buffer strips or other technical measures to reduce cross pollination or to talk to the GM farmer to keep a distance from his non-GM crops, whatever will be a more cost effective solution. For a given farm size and structure, the potential damage costs for the non-GM farmer will increase with the number of neighboring GM farmers. Under Case 2 the GM farmer has to keep a distance to the non-GM farmer and can do this by either locating his GM field away from the non-GM field including the use of buffer strips or other technical measures to reduce cross pollination or by talking to the non-GM neighbors. Here again, for a given farm size and structure, the costs for the GM farmer can be expected to increase with the number of non-GM neighbors.

Consider only two neighboring farms. Under Case 1 the non-GM farmer, while under Case 2 the GM farmer, has to bear the additional costs. As Coase (1960) has shown under such kind of circumstances the allocation of property rights does not affect the efficient outcome as long as neighbors are willing to negotiate and information asymmetries are negligible, but the two property rights systems have an effect on the distribution of benefits and costs.

This does not change if there are more than two neighbors. Consider one farmer is planting the non-GM crops neighboring three GM farmers. In Case 1 the non-GM farmer has either to adjust and/or talk to all three neighbors. In Case 2 the three GM farmers have to adjust and/or talk to the non-GM farmer. The number of the negotiations is the same as well as the number of adjustments. If the sum of negotiation and adjustment costs under both cases is the same an efficient outcome will be achieved.

Monroe (2008) discusses in the context of the setting of his model the possibilities of bargaining as well and concludes there are limits to achieving the social optimal level through bargaining. Our results do differ as we assume land can be reallocated to produce the same amount while in his model this possibility is not considered. The possibility of land reallocation is a realistic assumption in the EU setting as the concentration of crops in a given landscape hardly reaches more than 30% (EUROSTAT, Nuts 3 level)[8]. The study by Devos at al. (2008) at a lower regional level indicated for Belgium a concentration of less than 50% in the area with highest maize production density on cultivated land and less than 30% on total area. Ceddia et al. (2007) in their simulation study on oilseed rape conclude that if not more than 27% of an area only planted with oilseed rape is planted with GM oilseed rape the average GM content of the remaining non-GM oilseed rape will be below the 0.9% threshold level. Putting these results in the European context of oilseed rape production, oilseed rape hardly even reaches more than 25% on total land in the EU at NUTS3 level. Again, in this context coexistence should easily be achieved without minimum distance requirements and reallocation of land.

The previous papers cited indicate that achieving coexistence for maize and oilseed rape may not pose a serious problem in the EU and additional policies might not be needed. This is contrary to the ex-ante regulations and ex-post liability rules member states implement or want to implement. The conclusion is based on the 0.9% threshold level.

[8] NUTS stand for Nomenclature of Territorial Units for Statistics and subdivides the economic territory of the European Union into 97 regions at NUTS 1 level, 271 regions at NUTS 2 level and 1303 regions at NUTS 3 level.

Measuring the GM content is a difficult task (Sanvido et al., 2007; Weber et al., 2005). Studies on cross pollination indicate that the GM concentration in the harvested non-GM crop changes depending on the distance to the source (Devos et al., 2009). If the field average is taken, GM concentration rapidly decreases with field size (Weber et al, 2005). Many of the non-GM crops such as oilseed rape or grain maize are collected at regional level for further handling. If the GM concentration is measured at the elevator the concentration may further decrease. The reported evidence of GM concentration exceeding the 0.9% threshold level at some measuring points in the field does not imply the average concentration will be above the threshold level (Ceddia, 2007; Weber et al., 2007). Also Gray (2010) in her study on GM oilseed rape in Australia did conclude achieving the 0.9% threshold level for oilseed rape does not pose a problem and additional minimum distance requirements are not needed. Nevertheless, the minimum threshold level of 0.9% not necessarily has to remain the standard and it is worthwhile to investigate how the two property rights systems affect social welfare in cases where cross pollination results in adventitious presence exceeding threshold levels.

Excluding in a first stage any ex-ante regulations and ex-post liability rules for planting GM crops, the benefits for the farmer i planting one unit q of GM crops can be defined as:

$$v_{G_i} = p_{Gi} - c_{Gi} \tag{1}$$

with v_{G_i} representing the farm level value of GM (*G*) production and p_{G_i} and c_{G_i} being the respective price and variable costs for GM crops at the individual *i* farm level. The standard assumptions of the farmer being a price taker and yield per unit area *q* increases at a decreasing rate with respect to input use apply.

The benefits for the non-GM farmer planting the equivalent non-GM crops can be defined as:

$$v_{N_i} = p_{N_i} - c_{N_i} \qquad (2)$$

with v_{N_i} representing the farm level value of non-GM (*N*) production and p_{N_i} and c_{N_i} being the respective price and variable costs per unit area for the non-GM crop at the individual *i* farm level. Again the standard assumptions apply.

Assume now, that the whole group of $i = 1, \ldots, k$ 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, $vc_{N_i} = v_{N_i} - v_{G_i} > 0$; the second group $i = k - h,\ldots,k$, say group B, has a comparative advantage in GM crop production, $vc_{G_i} = v_{G_i} - v_{N_i} > 0$[9]. 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*.

[9] The GM farm has a comparative advantage in the production of GM crops as it can produce that good at a lower opportunity cost relative to the non-GM farm.

For keeping the model simple we assume each farmer *i* has only one field of equal size. The quantity of non-GM crops produced in the area, Q_N, is h and the quantity of GM crops, Q_G, is k-h.

From an economic point of view coexistence at regional level would be preferable, if

$$\sum_{i=1}^{h} v_{G_i} + \sum_{i=k-h}^{k} v_{N_i} > \sum_{i=1}^{k} v_{G_i}, \sum_{i=1}^{k} v_{N_i} \qquad (3)$$

Drawing from Beckmann and Wesseler (2007), the coexistence value (*vc*) of GM farming (non-GM farming) of farm *i*, will be denoted by $vc_{G_i}^{\ell}$ ($vc_{N_i}^{\ell}$) in case the GM farmer will be liable (*l*) for any harm caused by planting GM crops and by $vc_{G_i}^{n}$ ($vc_{N_i}^{n}$) in case the GM farmer will not be held liable (*n*). The interpretation of liability is that in the case where the GM farmer will be liable the property right is with the non-GM farmer, in the sense that the non-GM farmer has the right to produce non-GM crops and the GM farmer has to take measures to protect that right and in the case where the GM farmer is not liable he has the property right to plant GM crops and the non-GM farmer has to take appropriate measures.

Depending on the property right system either GM farmers cause an externality on non-GM farmers (case 1) or non-GM farmers cause an externality on GM farmers (case 2). Coexistence can than be defined as

"A state described by a set of policies exogenous to the farmers that results in the planting of 'organic and/or non-organic-non-GM' and 'GM crops' at the same point in time in a pre-defined region with at least one farm i where $vc_{G_i}^{n} > vc_{N_i}^{n}$ *and one where* $vc_{G_i}^{n} < vc_{N_i}^{n}$ *under a GM-farmer property right system and at least one farm i where* $vc_{G_i}^{\ell} > vc_{N_i}^{\ell}$ *and one where* $vc_{G_i}^{\ell} < vc_{N_i}^{\ell}$ *under a non-GM-farmer property right system"*

The definitions of $vc_{G_i}^{\ell}, vc_{N_i}^{\ell}$ and $vc_{G_i}^{n}, vc_{N_i}^{n}$ are subject to the exogenous policies. In this section we only considered legal property rights to set the stage, while other polices will be discussed in section 4.

A few words are needed about the link between liability and damages. The problem with cross pollination is that the damage can not be directly observed. Only if a farmer has done some testing, adding additional costs, the level of adventitious presence will be known. Further, the knowledge that the adventitious presence will be above the threshold level does not necessarily result in immediate compensation payments. Compensation needs to be claimed, and additional costs will be generated by the court, which mechanisms seem to be more difficult than one might expect (Shleifer, 2010). The implications of different liability systems will be discussed in the following section.

4. Coexistence and Regulations

The discussion in section (3) assumes that there is no serious coexistence problem as the adventitious presence below commonly used threshold level of 0.9% can be maintained at regional level without requiring additional regulatory interventions such as minimum distance requirements or others. Now we define problems related to coexistence in more detail assuming the adventitious presence will reach the threshold level. This section draws partly on an earlier paper published by two of the authors (Beckmann and Wesseler, 2007). 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.

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, (2) the diffusion coefficient α 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. The level of adventitious presence (AP) 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 revenue difference, and the (2) quantity 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 revenue 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.

$$D = \sum_{a=1}^{h} d_a \left(\alpha_{N_a}, Q_G, T, p_{N_a}, p_{G_a}, q_{N_a} \right) \tag{4}$$

Considering damage costs only, a GM farmer will expand his GM crop production until marginal revenue equals the marginal damage, while a non-GM farmer will do the same, if he has to bear all the damages. Note, Q_G includes q_{G_b} and would reduce to q_{G_b}, if there is only one GM farmer in the neighborhood.

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:

$$\alpha_i = \alpha_i(m_i, m_{k-i}) \quad (5a)$$

$$f_i = f_i(m_i, q_{N\,i}, q_{G_i}, Q_N, Q_G) \quad (5b)$$

$$F = \sum_{i=1}^{k} f_i = \sum_{a=1}^{h} f_a + \sum_{b=k-h}^{k} f_b \quad (5c)$$

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 such as buffer zones. Equation (5a) 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 (5b) 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. Finally, the management and fencing costs in the region are the sum of the individual management and fencing costs as indicated by equation (5c). 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. Ignoring transaction costs and considering the additional costs discussed above (3) can be rewritten:

$$VC = \sum_{i=1}^{h} v_{N_i} + \sum_{i=k-h}^{k} v_{G_i} - \sum_{i=1}^{h} d_i - \sum_{i=1}^{k} f_i > V_N, V_G \quad (6)$$

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 (6) reflects the sum of the individual decisions. These individual decisions are affected by the distribution of property rights.

4.1 Liability Rights and Distribution of Costs and Benefits

In the following three different kind of transaction cost regimes will be considered. First, transaction costs of bargaining between GM and non-GM farmers are infinite, second, transaction costs are zero, and third, transaction costs are positive but not infinite. A clarification is needed about the meaning of transaction costs. In the context of coexistence we define the transaction costs as additional costs of negotiating and implementing an agreement with a neighbor. This implies both the GM and the non-GM farmer have to bear additional costs, as bargaining an arrangement includes both sides. Transaction costs are indicated by TAC. The plus and minus superscripts indicate who is taking the initiative (+) and who is responding (-).

Under each regime the two property rights cases are discussed. The benefits and costs for each case under the three transaction costs regimes are summarized in Table 2 and Table 3. In the following we simply refer to the equations. As mentioned before the farm management practices are ranked and the least cost management practice is chosen by the farmer. The fencing, damage, and compensation costs are not necessarily the same under each transaction cost scenario. The damage and fencing costs under the infinite transaction costs scenario are at least as high or higher as under the zero transaction cost scenario, while the damage, fencing, and compensation payments under the positive transaction cost scenario at least as high or higher than under the zero transaction costs scenario. Costs for claiming damages will be ignored for the meantime and discussed in the section on the symmetry of the two property rights cases.

4.1.1 Infinite Transaction Costs

In the case of infinite transaction costs (TAC) neighbors are not willing or not able to negotiate. This could be the case where neighbors may have already other neighborhood disputes or where it will be difficult to indentify who the relevant neighbor is.

Case 1: 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 neighborhood due to damages from the GM field. The co-existence value of non-GM farming will be reduced if neighboring farms plant GM crops by the expected damage d_{N_i} and/or by the costs f_{N_i} of the management and fencing practices that prevent potential damages (equation 7a). The co-existence value of GM farming, however, does not change for famers belonging to group B.

An individual farmer *i* will now choose to plant GM crops, if $vc^n_{G_i} > vc^n_{N_i}$ and vice versa. The distribution of rights and therefore costs and benefits as indicated by equation (7a) and (7b) 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. A non-GM farmer, however, has an incentive to invest in management systems that prevent damages. Cost minimizing behavior 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[10]. 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.

Case 2: 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

[10] The decision rule represented here is the result of a more complex optimization by the farmer. The variables included in equations 7a and 7b are not independent: the level of the damage and fencing costs are correlated, as well as the level of the damage and the value of coexistence, since both depend on the price difference between GM and non-GM crops. Here we only look at the optimal outcome by the farmer of fencing and damage for a given comparative advantage that, of course, depends on the prices in the input/output market.

cp_{G_i} at the rate of the damage. The damage could be caused on more than one farm.[11] 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 (see equation 8b). The value of non-GM farming will remain at v_{N_i} since the damage is fully compensated by the GM farmer (see equation 8a).

If the expected compensation payments for economic damages and/or the fencing costs exceed the value of GM production, $cp_{Gi} + f_{G_i} > v_{Gi} - v_{Ni}$, GM crops will be prevented from being grown and the adoption of GM crops will be reduced.

4.1.2 Zero Transaction Costs

In this case neighbors are willing to negotiate, but the negotiation costs are zero. This may seem unrealistic but as the case study by Skevas and Wesseler (2009) shows a very likely possibility.

Case 1: GM farmer not liable

[11] 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.

Again, the GM-farmer have the unrestricted right to grow GM crops. They are not liable and do not bear any costs of cross pollination. A naïve interpretation would be that the GM farmers now have an incentive to expand GM crops until the marginal value of the comparative advantage is equal to zero. But each GM farmer will cause damage to the neighboring non-GM farmers. If the transaction costs are zero, the non-GM farmer has an incentive to negotiate and be willing to pay for the reduction of GM crops by the GM-farmer, that is compensate the investments of the GM farmer in fencing. The willingness to pay by the non GM farmer for reduced damages creates an opportunity cost for the GM-farmer. The amount of GM crops will be reduced until the marginal benefits from planting non-GM crops are equal to the marginal minimized sum of compensation payment plus damage plus fencing costs of the non-GM farmer (see equation 9a).

Case 2: GM farmer liable

In case the GM-farmer is perfectly liable for the possible damages he causes he has to pay compensation equivalent to the damage caused or he has to invest in technologies in order to reduce or even prevent damages. But under zero transaction costs he can also negotiate with his non-GM neighbor and ask him to invest in fencing as well and compensate for the additional costs. The GM farmer will minimize the sum of compensation paid plus the fencing costs and plant GM crops as long as the sum is not above the gains from GM crops.

In both cases an efficient allocation of GM and non-GM crops will be achieved considering information asymmetries are negligible, which is a reasonable assumption for neighboring farms. The situation is similar to the classic case discussed by Coase (1960). Given farm benefits of GM and non-GM crops and fencing and damage in a specific region the two property rights cases both result in the same allocation of GM and non-GM farms while the distribution of benefits will be affected.

4.1.3 Positive Transaction Costs

In the previous transaction costs regime communication between neighbors took place but at zero costs. This may not necessarily be the case. In particular if several neighbors will be involved. The inclusion of transaction costs can be considered as additional costs of the farmer. The difference to the previous case is that the costs for achieving an agreement will increase. Please note, we assume both the GM and non-GM farmer are willing to bargain, if not, the previous case with infinite transaction costs applies.

Case 1: GM farmer not liable

In the case where the property right is with the GM farmer, the benefits for planting non-GM crops decrease by the transaction costs (TAC). The plus and minus superscripts indicate who is taking the initiative (+) and who is responding (-). In this case a non-GM farmer has the possibility either to invest in fencing and/or accept some damage on his farm or to start talking to the neighboring GM farmer and negotiate with him investing in fencing on his farm. The non-GM farmer compensates for the additional costs which includes covering the transaction costs of the GM farmer (see Equation 11b). The non-GM farmer will plant non-GM crops until the marginal incremental benefits from non-GM planting are equal to the marginal damage plus fencing plus compensation plus transaction costs.

Case 2: GM farmer *liable*

Equations 12a and 12b illustrate that the costs for arranging coexistence increase if *TAC* are non-zero. The GM farmer has still an incentive to negotiate with his neighbor as long as the transaction costs are sufficiently low (see Equation 12b). The GM farmer has in comparison to the previous regime to consider that negotiations are not costless and that he also needs to compensate his neighbor for the participation in the negotiations increasing the compensation payments.

The same conclusion as under the previous regime with respect to efficiency apply only that costs may have increased. The costs will increase if more than one neighbor will be involved but this will not change the efficient outcome between the two property rights cases as long as negotiations are possible.

4.2 Spatial Implications

While in the previous section the implications of transaction costs and their implications on the value of GM and non-GM farming have been discussed spatial aspects have not been addressed explicitly. But the spatial allocation of GM and non-GM crops will be affected by the distribution of property rights and discussed in the following.

Case 1: GM farmer not liable

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. Similarly, the non-GM farmer's compensation payment 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 and the third by the transaction costs. Given these limits and, therefore, considering $d_a, f_a, TAC_{a,b}^{+,-} \geq 0$ the following three situations are possible:

$v_{N_a} - v_{G_a}^n > v_{G_b}^n - v_{N_b} - TAC_b^- < d_a + f_a + TAC_a^+$	non-GM farmer compensates GM farmer for not growing GM crops	(13a)
$v_{N_a} - v_{G_a}^n > v_{G_b}^n - v_{N_b} - TAC_b^- > d_a + f_a + TAC_a^+$	non-GM farmer accepts damages and/or undertakes fencing	(13b)
$v_{G_b}^n - v_{N_b} - TAC_b^- > v_{N_a} - v_{G_a}^n < d_a + f_a + TAC_a^+$	non-GM farmer switches to GM farming	(13c)

The situation explained in equations 13a, 13b, 13c is summarized in figure 1. 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 $d_a + f_a + TAC_a^+$. Equation (13a) 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 (13b) describes the area above the dotted line and to the right of the vertical line $d_a + f_a + TAC_a^+$. In this case there are no spatial agglomeration effects and GM and non-GM farms will coexist. Equation (13c) describes the area above the 45-degree line and to the left of the vertical line $d_a + f_a + TAC_a^+$. 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.

Case 2: GM farmer liable

If the GM farmer is liable for possible damages, he will only consider planting GM-crops as long as the incremental value is positive and above the compensation payment and/or fencing investments. The farmer's decision can be illustrated in the following three arrangements[12]:

$v^{\ell}_{G_b} - v_{N_b} > v_{N_a} - v^{\ell}_{G_a} - TAC^{-}_{a} < cp_{G_b} + f_b + TAC^{+}_{b}$	GM farmer will compensate non-GM farmer for not growing non-GM	(14a)
$v^{\ell}_{G_b} - v_{N_b} > v_{N_a} - v^{\ell}_{G_a} - TAC^{-}_{a} > cp_{G_b} + f_b + TAC^{+}_{b}$	GM farmer compensates damages to the non-GM farmer and/or undertakes fencing	(14b)
$v^{\ell}_{G_b} - v_{N_b} < cp_{G_b} + f_b + TAC^{+}_{b} < v_{N_a} - v^{\ell}_{G_a} - TAC^{-}_{a}$	GM farmer will switch to non-GM crops	(14c)

The situation explained in equations 14a, 14b, 14c is summarized in figure 2. Now, the damage and fencing costs are introduced by the horizontal line $cp_b + f_b + TAC^{+}_{b}$. Equation (14a) 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 (14b) describes the area to the right of the dotted line and above the $cp_b + f_b + TAC^{+}_{b}$ 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 (14c) describes the area below the 45-degree and $cp_b + f_b + TAC^{+}_{b}$ line. In this area the GM farmer will switch to non-GM crops as the

[12] Please note, that equations 13a 13b, 13c and 14a, 14b, 14c imply a negative attitude of farmers towards GM crops.

damage costs are higher than incremental benefits from GM crops resulting in a spatial agglomeration of non-GM farms.

In both cases, with and without liability, incentives for spatial agglomeration exist. If fencing, damage, and transaction 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 d 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 13a, 13b, 13c and equations 14a, 14b, and 14c 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 neighboring fields, incentives for non-GM farmers to cooperate and organize GM free zones exist. Collaboration with neighboring 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. 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.

4.3 Symmetry of the property rights systems

While having discussed the benefits and costs of the two property rights systems under different assumptions with respect to transaction costs, implications for the symmetry of the two property rights systems follow. If the transaction costs are infinite under Case 1 it can be expected that more GM crops will be planted while under Case 2 more non-GM crops as costs for the two groups of farmers differ. While efficiency at farm level can be achieved[13] this not necessarily maximizes social welfare. Among heterogeneous farms, this will depend on the relative advantage of one production system over the other. In cases where the incremental benefits of a GM farmer are positive, $v_{G_i} - v_{N_i} > 0$, but less than the damage costs caused a property right system where the GM farmer is liable is preferable. In case where the incremental benefits of a non-GM farmer are positive, $v_{N_i} - v_{G_i} > 0$, but less than the damage costs a property right system where the GM farmer is not liable is preferable.

[13] Marginal farmer *i* decides efficiently whether to plant GM or non GM crops.

Considering the additional costs of claiming damage, a property rights system under infinite transaction costs where the GM farmer is liable increases the total costs over a system where the GM farmer is not liable. The later one would be preferable from a social welfare point of view as the costs of using the court system would be lower. Considering this, we can conclude the implications of the two property rights systems under infinite transaction costs are not symmetric and the case where the GM farmer is not liable preferable from a social welfare point of view.

The two property rights systems will be symmetric under zero (15a) and positive (15b) transaction costs as long as costs caused on the non-GM farm under Case 1 are equal to the costs caused on the GM farm under Case 2, that is

$$\min\left(d_{N_i} + f_{N_i} + cp_{N_i}\right) = \min\left(cp_{G_i} + f_{G_i}\right) \tag{15a}$$

$$\min\left(d_{N_i} + f_{N_i} + cp_{N_i} + TAC^{+}_{N_i}\right) = \min\left(cp_{G_i} + f_{G_i} + TAC^{+}_{G_i}\right) \tag{15b}$$

The joint profits in both cases will be the same. A closer look on equation 15a and 15b implies transaction costs to be symmetric, $TCA^{+}_{N} = TCA^{+}_{G}$, $TCA^{-}_{N} = TCA^{-}_{G}$. GM and non-GM farmers face the same transaction costs when they need to start bargaining. Differences may appear if there are systematic differences between GM and non-GM farmers, which could be found in personal differences affecting their bargaining capabilities. But it is difficult to believe that bargaining capabilities are affected differently if the same person has to bargain with a GM or a non-GM farmer. Also the damage and fencing costs can be expected to be the same as the compensation payments, even so fencing costs may differ. Some empirical studies imply that buffer strips are more effective on non-GM than on GM fields (Ceddia, 2009). But in this case the cost minimizing strategy implies that in Case 2 the compensation payments will include fencing costs such as buffer strips for the non-GM farmer and again symmetry holds.

Symmetry also applies for situations as mentioned under 13a, 13c and 14a, 14c. For the Case 1 property right system consider equation 13c. The non-GM farmer will become a GM farmer. Assuming the same costs but under the Case 2 property right system, equation 14a, the non-GM farmer will become a GM farmer. The opposite applies for the comparison of 13a and 14c. If one of the situations as describes under 13a, 13c, 14a and 14c will be observed in a specific region either only GM or only non-GM crops will be grown and coexistence not be possible.[14] While from an economic point of view the outcome is the same independend on the property right system, the two different property rights systems have distributional implications. Comparing 13b and 14b already illustrates the distributional effects. Under Case 1 the GM-farmer will be better of than the non-GM farmer while under Case 2 the GM-farmer has to bear additional costs. This will have long-term effects while under Case 1 the comparative advantage of the GM-farmer will be supported and the GM farmer be more competitive while under Case 2 the comparative advantage of the non-GM farmer will be improved and the non-GM farmer

[14] While this is a strong result from a theoretical point of view but as discussed in section 3 this will hardly be the case in reality for the reasons mentioned.

be more competitive. Depending on where the two different kinds of farming will be located under the two different property rights systems in Figure 1 and Figure 2 either one or the other has better possibilities to outcompete the other. If the comparison between GM-farmer and non-GM farmer is located above the 45°-line in Figure 1 the GM farmer will have a comparative advantage over the non-GM farmer and be able to outcompete the non-GM farmer in the longer run and it can be expected GM-farms will become the dominant form of agriculture in the region under consideration. In case the benefits from GM farming are moderate and the comparison between GM and non-GM farmer results in a point below the 45°-line in Figure 1 the non-GM farm has a comparative advantage, can outcompete the GM-farm and in the long-run non-GM farming will become the dominant form of agriculture.[15]

Despite the implications of the differences in comparative advantage, in case where the GM farmer is liable additional costs for claiming damages arise under each of the three transaction costs regimes discussed. The costs of using the legal system can be substantial even in countries with well developed rules (Shavell, 2010). This creates a bias against the case where GM farmers are liable and from a social welfare point of view non-liability of GM farmers is preferable in all three cases, while it is most preferable in case of infinite transaction cost, followed by positive transaction costs, followed by zero transaction costs as the costs of using the legal system to claim damage compensation do decline.

[15] This assumes that the GM trait under consideration would provide a benefit in the entire region, which is a reasonable expectation for herbicide tolerant crops but less for pest resistant crops.

However, liability systems can influence the likelihood of damage occurrence and the compensation payments a single GM-farmer needs to pay. For example, in a strict liability regime the GM-farmer has a greater chance to be held liable with respect to the case where negligence or wrongdoing needs to be demonstrated. This would influence the expected compensation payments by the GM farmer and, therefore, the value of coexistence for GM cultivation, resulting in a reduced GM adoption. Differently, a joint and several liability regime could increase the number of GM farmers involved in compensation, increasing the probability of being held liable while reducing the amount of compensation to be paid for an individual farmer being held liable in case only strict liability applies. The implementation of joint and several liability does not increase the compensation payment to the non-GM farmer but increases the total costs as additional transaction costs arise for the one farmer being held liable to share the compensation payment with the other GM farmer (Koch, 2008).

One issue that has received substantial attention in the literature on transaction costs and property rights is the role of information. Throughout the discussion we so far assumed implicitly symmetric information. While asymmetries in information are important for analyzing vertical integration (Schmitz, 2006) they also may affect outcomes in the case of negotiations and compensation payment discussed in the context of coexistence. We argue information asymmetries are less relevant as we have a setting where farmers grow the same crop in the same region and familiarity with production costs and benefits under different circumstances can be expected.

5. The implications of ex-ante regulations

The previous discussions assumed the only governmental intervention is defining the property rights and the final outcome is left to the "market". As the review in section 3 has shown a number of EU countries have implemented or consider to implement a number of mandatory ex-ante regulations including reporting, informing neighbors as well as minimum distance requirements. The previous discussion has shown an efficient allocation of resources will result independent of the distribution of the property rights under non-infinite transaction costs and zero costs for claiming damage compensation. Nevertheless, a number of EU member states use or discuss to use policy instruments to regulate coexistence. One of the most discussed and debated issue is the use of minimum distance requirements (Demont et al., 2009; Desquilbert and Bullock, 2010). If the minimum distance requirements become mandatory for the GM farmer they may create a bias and reduce overall welfare. This can easily be illustrated by considering equation 13b. If the minimum distance requirement costs result in $f_b > cp_b$ a cost effective adaption is prevented and if $f_b < cp_b$ the GM farmer will adapt by keeping a distance if in that case this is the best fencing strategy and mandatory minimum distance requirements would not be needed. An additional aspect of minimum distance requirements is the negative affect they have on adoption with respect to farm size. As Soregaroli and Wesseler (2005) have shown mandatory minimum distance requirements increase the minimum farm size needed for compliance with the regulation and as a consequence discriminate against smaller farms. This observation has been confirmed by Consmüller et al. (2009b) for the adoption of Bt corn in the Federal State of Brandenburg, Germany.

As mentioned in section 2.3, compliance with ex-ante regulations can protect farmers against liability claims in some countries. This implies that the expected $cp_b = 0$ even when damage occurs. If the ex-ante regulation sets the fencing costs at a level where $f_b < d_a + f_a$, that is, at a level that does not fully compensate the damage and fencing costs for the non-GM farmer, there would be a situation where the non-GM farmer could have an incentive to collaborate and ask the GM-farmer to keep higher fencing. However, if the additonal benefit of the non-GM farmer is lower than the additioanl fencing cost of the GM-famer, there is no incentive for the GM-farmer to collaborate, virtually imposing infinite transaction costs.

Some countries use as a coexistence policy instrument a compensation fund. Compensation funds have the advantage that they are almost property rights neutral. In case where the GM farmer is liable, payments into the fund can be collected via a price mark-up on the seeds such as in Portugal and be similar to charging damages according to marginal average damage costs. The non-GM farmer would need to proof adventitious presence beyond the threshold level and in this case be compensated for the damage. Testing costs can be part of the compensation payment, even one may consider all non-

GM sells be tested and testing costs paid out of the compensation fund. A draw back is that a compensation fund has the disadvantage of reducing the incentive of the non-GM farmer to adjust. In case the GM farmer is not liable, contributions to compensation funds would be paid by the non-GM farmer and the same reasoning as before applies.

Another possibility to promote coexistence would be through reducing transaction costs. A public registrar has the advantage of identifying GM and non-GM neighbors and reducing the search costs, while it has the obvious disadvantage of also reducing the search costs of militant opponents, which may now find it easier to locate fields for destruction.

One obstacle with the GM farmer liability regime is to claim compensation payments in case there are no compensation funds. Joint and several liability has the advantage of easing the compensation claims by non-GM farmers but generates extra burden to the specific GM farmer being held liable as he needs to claim damage payments back from the other GM farmers. This adds the legal difficulty of regionally defining other GM farmers having to contribute. Here the problem of information arises as this requires the GM farmer knows all the other GM farmers. A public registration system of GM farmers as already mentioned may help to reduce this problem. Additionally, the GM farmers that fall under the joint and several liability case need to be defined adding additional transaction costs.

6. Conclusions

Regulating coexistence has emerged lately as an important topic within the debate on GM crops. Two distinct property rights regimes have emerged: one, where the property right of planting GM crops is with the GM farmer as in Canada and the United States and one where the property right is with the non-GM farmer as in the EU. The possibility for coexistence largely depends on when an agricultural product has to be considered GM which depends on the threshold level for labeling. The threshold level for labeling in the EU is 0.9%. As studies at field level as well as simulation models show meeting the 0.9% threshold level to achieve coexistence does not cause a problem at regional level and minimum distance standards are not needed. The 0.9% standard does only apply for GM crops approved for planting or import to EU. A zero tolerance level for not approved GM crops applies. Through this EU regulation farmers in non EU countries are affected to maintain lower threshold levels. The GM policy within the EU has implications for countries exporting to the EU. Given the aforementioned property rights systems the question whether or not the two systems are symmetric with respect to the social welfare effects becomes relevant. An important aspect for comparing the two property rights cases are transaction cost, defined in the context of this analysis as the costs of arranging an agreement with neighbors. Three transaction cost regimes have been distinguished: infinite, positive and zero transaction costs. Under infinite transaction costs the property right regimes are not symmetric. If the incremental benefits of growing GM crops (non-GM crops) are less than the damage costs a property right system where the GM farmer (non-GM farmer) is liable is preferable from a social welfare point of view.

The results further show the definition of property rights with respect to GM crops under zero or positive transaction costs regimes can be considered as almost symmetric as long as there are no additional costs of using courts to settle compensation payments. While generally getting compensation payments is not cost free, a property rights system where the GM farmer is not liable is preferable from a social welfare point of view as the number of compensation payments and, thus, the costs of using the court under such kind of system are lower. This result is in line with the reasoning of Moschini (2008).

The definition of property rights has distributional implications which can either improve the competitive advantage of the GM farmer, in the case where the GM farmer is not liable or the competitive advantage of the non-GM farmer in the case where the GM farmer is liable. In the longer run the type of farming with a competitive advantage can outcompete the other one and become the dominant form of agriculture. Considering the long run effects the two property rights cases discussed may not be symmetric anymore. This aspect has not yet been investigated in detail and would be a fruitful future research, but the approach we have presented provides a starting point.

The claim for damage compensation is one important cost component favoring a property rights system where the GM farmer is not liable. Compensation funds can reduce the costs for compensation payments and in this case the advantage of that kind of property rights system.

The two different property rights systems also provide incentive for farmer to reduce transaction costs. Depending on the property right system either the GM farmer, in case they are liable, or the non-GM famer, in case the non-GM farmer is not liable have an incentive to reduce transaction costs. Building a group with common interest is one way of reducing transaction costs as discussed by Furtan et al. (2007). Alternatively farmers may use existing groups such as producer cooperatives or other forms of cooperatives to reduce transaction costs.

Mandatory minimum distance requirements while commonly used among EU member states are the worst performing regulatory instrument for achieving coexistence as they exclude the option for more cost effective solutions such as negotiations with neighbors or other technical solution such as buffer strips. As Demont el al. (2008) and Munro (2008) have shown they can have strong implications for the regional efficient allocation of GM and non-GM crops.

While the two cases of property rights have been compared given the agricultural structure, the question whether or not the property rights may matter comparing different agricultural structures needs to be addressed. In case where the average field size is large the likelihood of meeting the threshold level at non-GM farm level will be less, while the likelihood will be higher if the average field size is smaller as edge effects increase (Munro, 2008). This may increase the compensation payments as the number of compensation payments to be handled by one farm may increase resulting in an increase in the transaction costs. At regional level also the number of tests among non-GM farms will increase increasing the compensation payments by the GM farmer if he is liable or the damage costs of the non-GM farmer in case the GM farmer is not liable. In regions with on average smaller field sizes the costs for maintaining coexistence will increase, but this is independent of the property right system and can directly be explained by the higher damage costs caused by an increase in tests and the increase in transaction costs caused by an increase in the number of negotiations. But again, in a region with on average smaller farms a property right system where the GM farmer is not liable is preferable considering the costs of claiming compensation and even more desirable in comparison to the same region but with on average larger field sizes as the number of compensation claims increase.

One issue we have not discussed is the negative environmental externality effect of planting non-GM crops where alternative input reducing traits are available such as in the case of herbicide tolerant crops. Considering such kind of social benefits (see Scatasta and Wesseler, this volume) would further increase the social welfare of planting GM crops and further support the argument for a GM farmer based property rights system.

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Table 1. Ex-Ante regulations and ex-post liability rules governing coexistence at the farm level among European Union Member States

Policy	EU Member States	
	Apply	intend to apply
ex-ante regulations		
Prohibition and approval procedures		
prohibition of planting GM-crops in specific areas	AT, CY, FI, HU, LV, RO	IT, LT, PL
GM and/or non-GM area on a voluntary base	BE, ES, FR, HU, PT, SV	IT, SI
case by case approval for each field by local authorities	AT*, HU,	CY, IR
compulsory training of farmers planting GM-crops to be paid by the GM farmer	DK, HU, LT, LV, PT, SK	EE, FI, IR, IT, NL, SI

consent from landowner needed	AT, LT, LU, LV	IT
consent from neighbors needed	AT*, BE[a], HU[a], LV, SI[a]	IR[a]
Registration and information duties		
registration of areas in publicly available database (no information on individual locations and/or restricted access)	CZ, DE, PT, RO, SK, SV	BE, ES, IR
registration of areas in publicly available database (information on individual locations is released)	AT*, DK, FR, HU, LT, LU, NL,	BE, CY, EE, FI, IT, SI
informing authorities on the intention to cultivate GM crops prior to cultivation	AT, CZ, HU, LT, LU, LV, PT, SK	BE, ES, IR, SI
informing authorities on the intention to cultivate GM crops prior to cultivation and at a fixed dates of the year	DK, FI, NL, RO	IT

no obligation on informing authorities on the intention to cultivate GM prior to cultivation	ES, FR, SV	
informing neighboring farmers and/or landowners	AT*, BE, CZ, DE, DK, EE, FI, LT, LV, NL, PT, RO, SK, SV	ES, FR, IR, IT, SI
record keeping	BE, CZ, DE, DK, ES, FI, HU, LT, LV, PT, RO, SI, SK	EE, IR
Technical segregation measures		
minimum distance requirements	CZ, DE, DK, HU, LT, LU, LV, NL, PT, RO, SI, SK, SV	EE, ES, FI, FR, IR, IT
buffer zones	CZ, HU, LT, LV, PT, RO, SI, SK	EE, ES, IT
plant cycles	HU, PT, RO, SK	ES

rotation intervals	DK, HU, LT, SK	EE, ES, FI, SI
farmer to farmer agreements for not applying segregation measures are allowed	BE, DE, DK, HU, LT, LV, PT, SI, SV	EE, ES, FI
Insurance measures		
compensation fund paid by GM-farmers (levy on GM crops) plus support from the central government	BE, DK	
GM farmers need to provide a financial guarantee or a private insurance against damages	AT*, FR, LU	IT
ex-post liability		
Legal liability for damages		
liability based on civil law (usually fault based)	AT*, BE, CY, CZ, ES, HU, LT,	FI, IT

	LU, LV, NL, PL, RO, SI, SV	
strict liability for GM-farmers	DE, FR	
Penalties		
fines for non-compliance with ex-ante regulations	AT, BE, CZ, DK, EE, FR, HU, LT, LU, LV, NL, PT, SK,	FI, IT, SI

Source: authors' elaboration based on CEC (2009a).

[a] Only within isolation distance.

AT-Austria, AT*- specific regions of Austria only, BE-Belgium, CY-Cyprus, CZ-Czech Republic, DE-Germany, DK-Denmark, EE-Greece, EL-Estonia, ES-Spain, FI-Finland, FR-France, HU-Hungary, IR-Ireland, IT-Italy, LT-Lithuania, LU-Luxemburg, LV-Latvia, MT-Malta, NL-The Netherlands, PL-Poland, PT-Portugal, SV-Sweden, SI-Slovenia, SK-Slovak Republic, UK-United Kingdom.

Table 2. Farm level coexistence values under different transaction cost regimes when the GM farmer is not liable.

Transaction Costs	Property Right Case 1: GM Farmer Not liable — Farm level coexistence value		Equation Number*
	Non GM Farmer, vc_N^n	GM Farmer, vc_G^n	
Infinite	$v_{N_i} - \min\left(d_{N_i} + f_{N_i}\right)$	v_{G_i}	7a, 7b
Zero	$v_{N_i} - \min\left(d_{N_i} + f_{N_i} + cp_{N_i}\right)$	$v_{G_i} - f_{G_i} + cp_{N_i}$, with $cp_{N_i} = f_{G_i}$	9a, 9b
Positive	$v_{N_i} - \min\left(d_{N_i} + f_{N_i} + cp_{N_i} + TAC_{N_i}^{+}\right)$	$v_{G_i} - f_{G_i} - TAC_{G_i}^{-} + cp_{N_i}$, with $cp_{N_i} = f_{G_i} + TAC_{G_i}^{-}$	11a, 11b

Note: equation numbers with an *a* refer to column Non GM farmer and equation numbers with a b refer to GM Farmer

Table 3. Farm level coexistence values under different transaction cost regimes when the GM farmer is liable.

Transaction Costs	Property Right Case 2: GM Farmer Liable — Farm level coexistence value		Equation Number*
	Non GM Farmer, vc_N^{ℓ}	GM Farmer, vc_G^{ℓ}	
Infinite	$v_{N_i} - d_{N_i} + cp_{G_i}$, with $cp_{G_i} = d_{N_i}$	$v_{G_i} - \min\left(cp_{G_i} + f_{G_i}\right)$	8a, 8b
Zero	$v_{N_i} - d_{N_i} - f_{N_i} + cp_{G_i}$, with $cp_{G_i} = d_{N_i} + f_{N_i}$	$v_{G_i} - \min\left(cp_{G_i} + f_{G_i}\right)$	10a, 10b
Positive	$v_{N_i} - d_{N_i} - f_{N_i} - TAC_{N_i}^{-} + cp_{G_i}$, with $cp_{G_i} = d_{N_i} + f_{N_i} + TAC_{N_i}^{-}$	$v_{G_i} - \min\left(cp_{G_i} + f_{G_i} + TAC_{G_i}^{+}\right)$	12a, 12b

Note: equation numbers with an *a* refer to column Non GM farmer and equation numbers with a b refer to GM Farmer

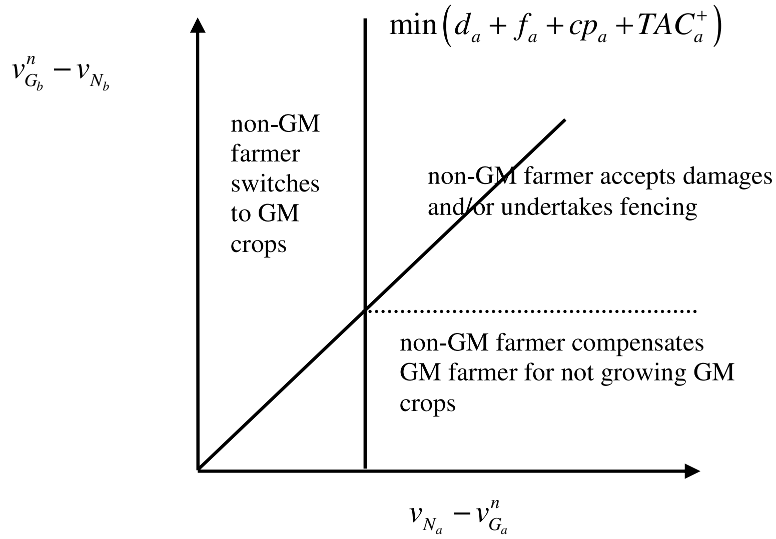

Figure 1: Allocation of Farms Considering GM farmer not liable.

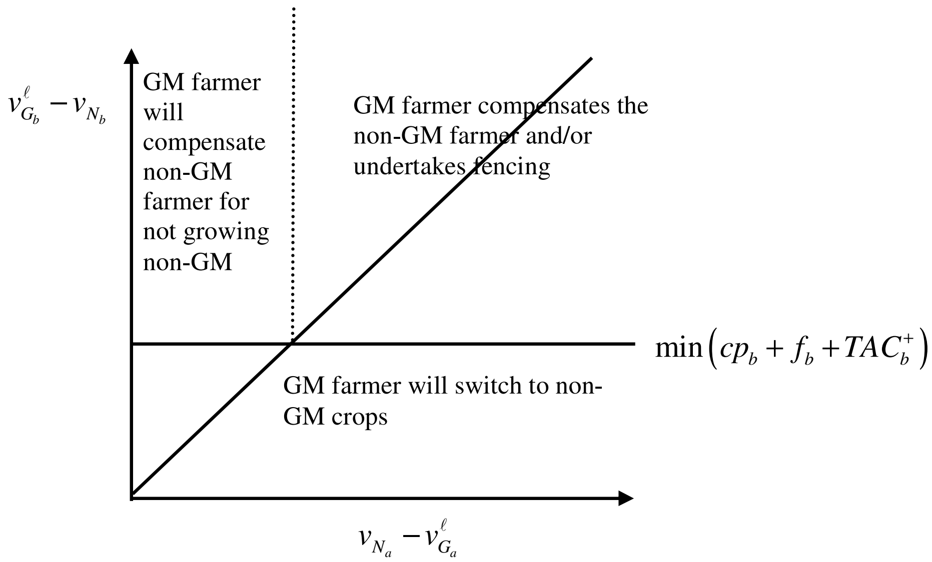

Figure 2: Allocation of Farms Considering GM farmer liable.