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Segregation between GM and non-GM Inputs in EU Feed and Food Supply Chains: Future Scenarios

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This study used a participatory scenario development approach—more precisely, a two-day exploratory experts-based workshop—to identify the key driving forces influencing future scenarios for the segregation between GM and non-GM inputs in EU feed and food supply chains, to investigate plausible alternative scenarios, and to discuss their potential implications on supply-chain actors. Twenty supply-chain stakeholders from across Europe with key positions in associations, private companies, universities, or EU institutions took part in the workshop. A medium-term time horizon (2022) was used. The drivers resulting from the discussion were first clustered and then ranked by impact and uncertainty, allowing the identification of the two key driving forces—'regulatory framework' (more enabling or restrictive than the current regulations) and 'consumer's perception of GMOs' (more positive or negative than the present one). According to stakeholders, a stricter policy on GMOs in Europe might end up with increased segregation costs for supply-chain actors, a reduced international competitiveness of important sectors, and an uncertain long-term economic sustainability of the niche markets for certified non-GM food products.

Key words: explorative participatory approach, GM soybean, GMO regulations, scenario development, segregation.

Introduction

The European Union is a large importer of genetically modified (GM) soybean and soybean products, mainly used in the livestock sector (e.g., Tillie & Rodríguez-Cerezo, 2015). When dealing with the segregation between GM and non-GM inputs in the EU feed and food supply chains, several issues are at stake—the interests of many stakeholder groups, the economic risk due to the adventitious presence of authorized GM materials above the legal threshold, the zero-tolerance policy for unapproved GM events, the asynchronous approval process among the EU and third countries, different sources of uncertainties (e.g., inputs availability, premium price, quality standards), and the decisions to be taken either at firm or government level. Looking ahead, the future of GMOs in the European Union is not clear. At present, it is a sensitive political issue, as confirmed by the high-pitched debate around the latest moves of the European Commission (see European Commission, 2015a, 2015b) and the on-going negotiations for the Transatlantic Trade and Investment Partnership (TTIP). Changes in social, technological, economic, environmental, or political factors can have relevant implications on the future economic sustainability and governance of the EU feed and food supply chains, as well as on the markets of certified non-GM food products (Passuello, Boccaletti, & Soregaroli, 2015). Likely, the business context that feed/food supply chain actors will face in the future will be significantly different from the present one. The heterogeneous position of the EU Member States (MS) towards the cultivation of GM crops and the use of GM inputs in feed and food manufacturing could create different situations within the European Union. A set of alternative future scenarios should therefore be considered by stakeholders and policymakers as part of their strategic decision-making process.

The purpose of this study is threefold: 1) to determine and validate the key driving forces influencing future scenarios for the segregation between GM and non-GM inputs in EU feed and food supply chains; 2) to sketch alternative plausible scenarios; 3) to discuss potential implications of such scenarios for supply chain actors. Accordingly, we use a participatory scenario development approach—more precisely a two-day exploratory expert-based workshop—to draw, building on intuitive logic and experts' judgment/assessment, plausible alternative futures for GMOs segregation in Europe and investigate risks and opportunities for the main actors along the feed/food supply chains. Our ambition is to offer a framework where academics, professionals, and officials working in EU institutions

could leverage their know-how in sketching and discussing plausible alternative futures. "Bringing together different types of expertise can provide a broader perspective on complex, uncertain problems, generate new and surprising insights, and help better address relevant policy concerns in the scenario building process" (Volkery, Ribeiro, Henrichs, & Hoogeveen, 2008, p. 460). Furthermore, "the participation of different stakeholders helps enhance the credibility and legitimacy of the scenarios among potential target groups" (*Ibid*., p. 460).

The design of the research and the organization of the workshop, which was held in Brussels in Fall 2014, required several months. The reference starting point of the scenario development process was the situation of the EU feed/food market in September 2014. Experts considered Europe at large, and focused on the organizational and operational aspects linked to the management of GMO segregation along the supply chain, as well as on the potential implications for the main chain actors. To balance "the necessity to cover a sufficiently wide time horizon without introducing too much uncertainty into the scenarios" (Zanoli, Gambelli, & Vairo, 2012, p. 44), 2022 was chosen. Besides the researchers involved in the project and a general moderator, 20 feed/food supply chain stakeholders (from across Europe) having key positions in associations and private companies, universities, or EU institutions took part in the expert workshop. The drivers resulting from the discussion were first clustered and then ranked by impact and uncertainty, allowing the identification of two key driving forces, which provided the framework for the scenarios development. The use of a scenario-axes technique is considered state-of-the-art (van-Vliet & Kok, 2015).

The scenario storylines and the associated risks and opportunities are expected to be valuable for policymakers and practitioners/professionals along the EU feed and food supply chains in envisioning strategies, actions, or policy interventions that might be needed in alternative future settings. Thanks to the insights on the potential implications of the developed scenarios for different supply chain actors, this study should contribute to the on-going policy debates around the so-called "*opt-out regulations*" (European Commission, 2015a; Gryson, Eeckhout, Trouillier, Le Bail, & Soler, 2009) and the economic/technical sustainability of the markets for certified non-GM food products. The article provides some background information followed by the methodological approach used in this research and the main results and conclusions drawn.

Background

The EU regulatory framework on GMOs has changed alongside the development of recombinant DNA technology applied to plant biotechnology (Wesseler, 2014; Wesseler & Kalaitzandonakes, 2011). Its core principles include safety for the environment and human/animal health, freedom of choice for consumers and supply chain actors (assured by coexistence, labeling, and traceability rules), and a system of case-by-case evaluations for the approval of GM events (e.g., Lefebvre et al., 2014). A differentiation between approval for the release into the environment (i.e., GMOs cultivation) and for placing on the market (i.e., importing and processing GM inputs) exists (Wesseler, 2014; Wesseler & Kalaitzandonakes, 2011). A positive labeling system for authorized GM traits and a zero-tolerance policy for unauthorized ones are in force in the European Union. It is mandatory to label as GM any feed/food product containing more than 0.9% of adventitious presence of authorized GMOs for each ingredient. There is, however, no legal obligation to label as GM any animal product obtained from animals fed with feedstuff containing GM materials. The reason is that, so far, the use of GM feed is not technically detectable in animal products. Negative labeling is not regulated at the EU level, but it is left to Member States (Koester, 2012) or actors along agro-food value chains (Passuello et al., 2015), resulting in a variety of situations. For instance, despite the absence of legal requirements, some EU retailers decided to set and lead voluntary non-GM private standards also for products of animal origin (Gruère & Sengupta, 2009; Passuello et al., 2015). Besides influencing the share and price of non-GM inputs in the market place, the thresholds set by law impact coexistence, segregation, and distribution costs, as well as producers' and consumers' willingness to pay (WTP) and freedom of choice (Giannakas, Kalaitzandonakes, Magnier, & Mattas, 2011).

The concerns of several stakeholder groups about the potential risks of green biotechnology translated in a cautious approach in regulating the trade and industrial use of GM crops and inputs, resulting in a substantial reduction of the number of field trials and of the applications for environmental release of GM events (EuropaBio, 2011; Wesseler, 2014). The situation is further complicated by the fact that the degree of acceptance of agricultural biotechnologies is not homogeneous either across the EU MS or different stakeholder groups. Broadly speaking, MS can be grouped into *opponents* (where most stakeholders are not in favor of GMOs),

conflicted (voices in favor such as professionals working in the agriculture sector and scientists are outmatched by voices against like consumers, activists, and politicians), and *adopters* (industries and governments support the use of GM crops). The latter category includes countries that are currently cultivating MON810 corn (the only trait commercially cultivated in the EU) for animal feed and biogas production, as well as those like the Netherlands and the United Kingdom which would do so if other traits feasible for their growing conditions were approved (Lefebvre et al., 2014). The literature (e.g., Skevas, Kikulwe, Papadopoulou, Skevas, & Wesseler, 2012; Wesseler, 2014) shows that in some MS there are farmers who would like to cultivate MON810 but hesitate because of social pressure.

Until the beginning of 2015, the EU legislation offered MS limited possibilities to decide on the cultivation of authorized GM traits on their territory. Despite that, 9[1] MS out of 28 invoked the safeguard clause (Article 23 in Directive 2001/18/EC) to ban the cultivation of authorized GMOs. Several national bans were not lifted although the European Food Safety Authority deliberated that they were not justified by scientific evidence. A request to lift the bans from the Council did not solve the issue either (Wesseler, 2014; Wesseler & Kalaitzandonakes, 2011). In 2009, 13 MS asked the European Commission for more flexibility in deciding whether to cultivate GM crops in their territory. To break through, in July 2010 the Commission presented the so-called *opt-out proposal*, which contains a non-exhaustive list of reasons that MS could use to justify bans on the cultivation of approved GM traits on their territory or part of it, based on grounds different from environmental or health considerations (e.g., socio-economic reasons, land use, and town planning) and without affecting current risk-assessment and authorization systems. The proposal was discussed and amended through the years. On June 12, 2014 the Environment Council reached a political agreement (almost unanimously) on a draft directive amending Directive 2001/18/EC on the possibility for the MS to restrict or prohibit the cultivation of GMOs in their territory (Lefebvre et al., 2014). The new text (Directive [EU] 2015/412) was published in the Official Journal in March 2015. Stakeholders at different levels of the chain are rather concerned about the potential implications of this new Directive for the EU segregated feed and food market. In April 2015, the European Commission proposed to amend Regulation (EC) No. 1829/2003 in order to allow MS to restrict or prohibit the sale and use of GM feed and food in their territory, on the basis of grounds different from the aspects assessed by the European Food Safety Authority during the authorization process. This opt-out proposal has been facing fierce opposition from both main European associations representing feed/food supply chain actors, and some members of the European Parliament. Stakeholders and politicians are particularly concerned about the lack of an impact assessment, the compatibility of opt-out measures adopted by single MS with the World Trade Organization (WTO) rules and the internal market, and the possible negative consequences for agriculture and the feed/food industry. Potential consequences could include a distortion of competition and lower investments in opt-out countries, job-losses, and harsh times for livestock sectors more dependent on imported GM proteins. The practicability of the proposed legislation is questionable: if approved, it would require border controls for feedstuff and foodstuff traded between pro- and anti-GMO countries, but border controls no longer exist within the European Union (e.g., Chatain, 2015; Laaninen, 2015). The proposal was rejected by the European Parliament during the plenary session of October 28, 2015. The Commission, invited to present a new proposal, replied that the legislative text will not be withdrawn, and the issue will be discussed by the Agriculture and Fisheries Council (AGRIFISH). Stakeholders are now paying serious attention to the next moves of the Council of the European Union and of the European Commission.

The EU extensively relies on international markets to satisfy the feed industry's demand for soybean and soybean meal (Backus et al., 2008). Despite recent initiatives to reduce the protein dependency from imports stimulating locally grown non-GM soybean (e.g., in the Danube region), the current potential for non-GM protein crops production in Europe is marginal if compared to the amount required by compound feed producers. A recent report from the European Commission's Joint Research Centre shows that 95% of the soybean products used in 2013 in the EU was imported from third countries, and that almost 80% of the soybean area worldwide is currently cultivated with GM traits (Tillie & Rodríguez-Cerezo, 2015). Since the authorization of importing specific GM traits, traders supplying the EU market can choose among conventional crops, certified identity-preserved (IP) non-GM commodities, and a mix of GM and conventional that can be labeled and sold as

1. *Austria, Bulgaria, France, Germany, Greece, Hungary, Italy, Poland, and Luxembourg.*

GM (Tillie & Rodríguez-Cerezo, 2015). With the growing adoption of biotechnologies around the globe, it is getting more and more difficult and expensive for livestock producers and EU companies to source non-GM IP commodities (Lefebvre et al., 2014), which are generally used to produce meat or other animal products labeled as "GM-free" or as organic. "Systems for identity preservation and product segregation hold value in the European market for certified non-GM food products" (Passuello et al., 2015, p. 2565). About 15% of the EU-27 compound feed market is indeed estimated to be non-GM IP (e.g., Martin & Boussit, 2012). Non-GM IP soybean and soybean meals are imported mainly from Brazil (Gryson et al., 2009).

Materials and Methods

Scenario development is a tool for strategic analysis, supporting systemic investigations of the main determinants of a sector or business (Zanoli et al., 2012) and enabling the consideration of plausible alternative futures by taking into account the possible interactions among driving forces. Furthermore, it allows to highlight the risks and opportunities associated with each scenario, and to reason about likely response strategies (Blanco et al., 2012). Scenario development is particularly effective when complex and controversial issues affecting the interests of many stakeholder groups are addressed, and the uncertainty about key interacting drivers in a medium- to long-term time horizon is high (Blanco et al., 2012; Volkery et al., 2008). The broad spectrum of application (e.g., business planning, political decision making, global environmental research, and local community management) led to the development of different approaches (Zanoli et al., 2012) and to a variety of scenario types, categorized by van Notten, Rotmans, Asselt, and Rothman (2003) on the basis of 14 features comprising a) *inclusion of norms*—descriptive or normative; b) *vantage point*—exploration or backcasting; c) *data collection*—desk research or participatory; and d) *data*—qualitative or quantitative (Kok, Vliet, Bärlund, Dubel, & Sendzimir, 2011). In exploratory descriptive qualitative exercises, the current situation is used as a starting point and plausible futures are sketched in the form of narratives/storylines, showing the implications of external drivers. Conversely, normative scenarios first identify a desired future situation and then use backcasting to explore different strategies to reach it, exploiting opportunities and minimizing threats.

Exploratory scenarios are often built using a participatory approach relying on intuitive logic and on the judgment/assessment of a selected group of influential experts/stakeholders who have an active role in the scenario-generation system (Zanoli et al., 2012). Experts, drawing from their knowledge and diversity of perspectives, consider hypothetical boundary conditions and imagine a set of plausible alternative futures (Blanco et al., 2012). Therefore, the scenario approach goes beyond traditional trend extrapolation. The higher the heterogeneity of the experts involved, the lower is the risk of incurring in narrow thinking, leading to only one vision of the future. "By employing participatory methods, policymakers and other stakeholders can be directly involved in assessing possible futures, and thus be better placed to help shape the future or adapt to changing conditions" (Kok et al., 2011, p. 836). Besides gaining insight into the way drivers influence each other, exploratory scenarios frequently strive for awareness raising, the stimulation of creative thinking or social learning (Kok et al., 2011). Table 1 shows further benefits and challenges of participatory scenario workshops. Scenarios "cannot be evaluated on the basis of their predictive accuracy, as the probability of a single scenario happening completely is close to zero" (van der Heijden, 1996, as cited in Zanoli et al., 2012, p. 42). The criteria generally used to evaluate scenario's effectiveness are 1) *plausibility*—it must fall within the limits of what might conceivably happen; 2) *internal consistency*—the credibility of the scenario should not be undermined by built-in inconsistencies in its logics; 3) *compelling narratives*—the storyline of how events might develop between the current situation and the chosen time-horizon should provide dynamics/logics and be convincing; and 4) *decision-making utility*—should allow stakeholders to decide policies or response strategies based on risks, opportunities, and impacts.

Cognitive diversity is required in future studies using scenario development (Franco, Meadows, & Armstrong, 2013; van-Vliet & Kok, 2015). In inviting participants to scenario workshops, it is important "to select stakeholders who are able to abstract from their background to a certain extent and are open for discussing new perspectives, but still obtain a relevant decision-making position" (Volkery et al., 2008, p. 462). Our objective was to gather 15-20 feed/food supply chain experts in addition to the 6 researchers involved in the project and a general moderator. We succeeded in bringing together 20 experts from across Europe, having key positions in associations and private companies, universities, or EU institutions. Tables 2 and 3 show experts'

Table 1. Benefits and challenges of participatory scenario workshops.

Benefits of participatory scenario workshops
"It can be used to consider the impact of future exogenous shocks and major structural changes in the system under analysis" (Zanoli et al., 2012, p. 42).
Scenarios "can assist with thinking about non-linear events and cause-and-effect" and "can allow uncertainty and complexity to be handled in a fresh and structured way" (Bryson et al., 2010, p. 289).
"Active involvement of the wider stakeholder community (…) provide an active learning arena for all those involved, and provide an interactive basis necessary for generating joined-up thinking" (Patel, Kok, & Rothman, 2007, p. 546).
Identification of new issues and problems which an organization may have to face in the future (Varum & Melo, 2010).
".. the outcomes of participatory processes often challenge the perceptions of those in authority -at the highest levels of government, as well as those at the local or grassroots level - in this way influencing and changing attitudes and agendas" (Patel et al., 2007, p. 549).
Challenges of participatory scenario workshops
It is a demanding methodology requiring participants to invest considerable effort, thought and creativity; it can be costly in terms of executive time.
"Diverging interests, conflicting views and possible hidden agendas of participants can lead a scenario process easily into a stalemate" (…) "participants tend to defend their positions and dismiss the legitimacy of other positions" (Volkery et al., 2008, 462).
"It is (…) necessary to engage a competent, professional facilitator who can win the trust of participants and can reveal and sort out interest conflicts in the beginning" (Toth, 2001, as cited in Volkery et al., 2008, p. 462).

Source: own elaboration

Table 2. Experts' place of work.

Place of work	# of respondents
Associations	6
Private companies	8
Universities	4
EU institutions	2

Source: own elaboration

Table 3. Years of experience in the sector of the experts.

Years of experience	# of respondents
< 5	6
5-10	1
10-15	3
15-20	2
> 20	7
Not specified	1

Source: own elaboration

place of work and years of experience in the sector; 35% and 25% of them have respectively more than 20 and between 10 and 20 years of experience. To our knowledge, very few research projects at the EU level employed such a broad participatory approach in scenario development, none of them focusing on GMOs segregation. The participation of different stakeholders enhances the credibility and legitimacy of the developed scenarios.

The STEEP[2] analysis—which is a framework for the investigation of external factors in strategic planning—is often used in participatory scenario development processes to facilitate driving forces' brainstorming (Blanco et al., 2012). Participants are generally asked to think about social, technological, economic, environmental, and political factors influencing the object of the analysis. Driving forces are then weighted by importance, i.e., by the magnitude of their potential impact and by their degree of uncertainty (Blanco et al., 2012, Parkinson, Friedman, Hacking, Cooke, & Guthrie, 2012). The two highest-ranking driving forces, i.e., the most important and uncertain ones, provide the axes of a two-dimensional matrix used to generate a set of alternative plausible scenarios, which are then developed by the invited experts (Blanco et al., 2012). Typically, three to five scenarios are developed; one very close to "business as usual" is generally included (Bryson, Piper, & Rounsevell, 2010). This "scenario-axes technique" is considered state-of-the-art (van-Vliet & Kok, 2015).

Each participant (with the exclusion of the research team, consisting of the researchers who designed the process, helped the general moderator steering it, and analyzed the results) assigned the identified driving forces to the 5 categories of the STEEP framework. A first clustering performed by the research team was discussed in plenary with the twofold aim of reaching consensus through group discussion, and obtaining high internal consistency and differentiation among clusters.

2. *Social, Technological, Economic, Environmental, and Political factors.*

Table 4. Clusters within the STEEP framework and results of the voting.

	Clusters STEEP	Very high impact (# of votes)	Very high uncertainty (# of votes)
Social	Demographics & age of population	1	0
	Consumer's perception of GMOs	***8***	***7***
	Media/communication to consumers	6	2
	Consumer awareness & science-based education	2	1
	Lobbying & NGOs	2	2
	Change in lifestyle	0	0
	Religious aspects & ethics	0	0
	Welfare & income	0	1
Technological	Testing & analysis	1	0
	Seed purity	1	1
	New technology at farm level	0	2
	Innovative traits	7	0
	Training in the supply chain	0	0
	Patents & royalties	0	1
Economic	Consumer WTP for non-GM	0	2
	Trends in international trade: S&D	3	1
	UE protein self-sufficiency	0	0
	Availability in global supply	1	4
	Premium cost of non-GM	5	0
	Supply chain risk attitude	1	0
	Market power	2	0
	Economic crisis	1	0
	Food as financial commodity	0	1
	Governance of the supply chain	0	0
	Commercial/marketing strategies	3	0
Environmental	Pest management & plant resistance	1	2
	Scarcity in natural resources	2	1
	Agronomic needs/climate change	0	0
	Biodiversity	0	0
Political	Public research	1	0
	Labeling/claims	1	0
	Regulatory framework	***4***	***8***
	EU governance	3	6
	Enforcement	0	0
	International trade agreements	1	4
	Authorization of GM plants for cultivation in the EU	3	3
	Role of Europe in long-term vision	3	5
	Impact of NGOs	0	0
	Logistics & infrastructures	0	0
	Ideology	1	2

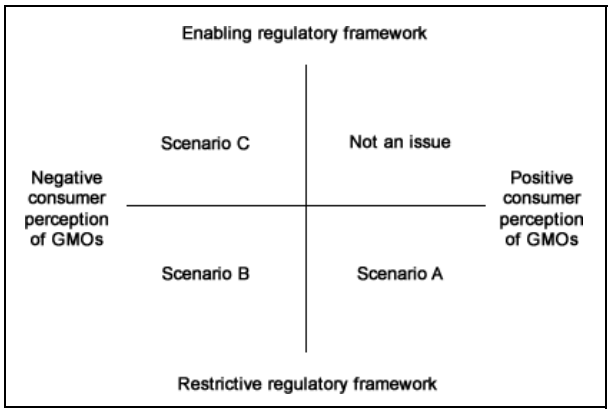

Figure 1. Matrix used for the development of the scenarios.
Source: own elaboration

Participants were then asked to pick the top three by importance and the top three by uncertainty from the clusters. After that, the research team called one-by-one the clusters, asking participants to vote raising their hands. A plenary discussion allowed to validate the resulting clusters as the axes of the scenario-matrix and to define their endpoints. The combination of individual rating and group validation assures effective results. After discarding the most implausible scenario, participants were assigned to three break-out groups, whose composition was decided in advance to maximize the diversity within each group and to cover the relevant supply chain activities. Each group—instructed to reason on the interactions among keywords (e.g., events, policy decisions, and economic situations) and driving forces/clusters, to discuss implications, challenges, and opportunities for stakeholders—worked on one scenario. Finally, each group presented the resulting storyline in a plenary session, allowing all participants to comment on and integrate the scenarios.

Driving Forces Influencing Future Scenarios

Participants suggested many social, technological, economic, environmental, and political factors influencing the future of GMO segregation in the EU and fine-tuned their clustering within the STEEP framework. The clusters and the results of the voting on their importance (magnitude of potential impact) and degree of uncertainty are reported in Table 4. *Regulatory framework* and *consumer's perception of GM agricultural and food products* were validated by group discussion as the axes of the two-dimensional matrix (Figure 1) used for the development of scenarios. The endpoints of the axes

were defined, respectively, as more enabling or restrictive than the current regulations, and more positive or negative compared to the present perception. Experts discarded the scenario characterized by 'enabling regulatory framework' and 'positive consumer's perception of GMOs,' judging it as the one having the lowest potential to stimulate a productive discussion. In the following subsection, we discuss three scenarios resulting from the analysis of experts' assessment and qualitative data. For each scenario, we first present a storyline on the key drivers and their effects on demand and supply, then focus on potential risks and opportunities for the main EU supply-chain actors.

Scenario Storylines and Implications for the Supply-chain Actors

Scenario A: Restrictive Regulatory Framework and Positive Consumer's Perception of GMOs

Storyline. We might depict alternative possible sub-scenarios depending on what aspects of the 2022 regulatory framework are more restrictive than today. Regulations might indeed set lower thresholds for labeling feed/food products as GM, prescribe specific segregation procedures along the supply chain, set stricter rules about health claims, or be more restrictive on the cultivation of GM crops and/or on the import of GM inputs for feed/food processing. In developing this scenario, the experts assumed lower thresholds for GM labels and restrictions on the import and processing of GM inputs. The majority of EU consumers show a positive perception of GMOs thanks to the concurrence of various factors, including the absence of food scares, a more neutral position by non-governmental organizations (NGOs) and the media, and the increasing public awareness that GM crops can better adapt to adverse growing conditions and have higher productivity than conventional crops. In this scenario, the large part of consumers is keen on purchasing GM foods; a segment seems to be indifferent about the GM/non-GM feature of what they eat, considering other characteristics more relevant when shopping for food. Their perception might turn fully positive with the introduction of a consumer-oriented second generation of GMOs, from which enhanced GM foods with health and nutritional benefits are obtained. If these beneficial effects were scientifically proven, consumers' WTP for GM foods may increase.

The demand is affected in two ways: 1) a generalized acceptance of GM food ingredients shifts the demand to the right, leading to an increase in the price of GM products; 2) the demand for certified non-GM foods decreases and shifts to the left, with a substantial reduction in the WTP for these products. The supply of GM crops within the EU is at risk due to the more restrictive regulatory framework, which in this scenario may reduce or even ban (on the basis of non-scientific reasons) the cultivation of authorized GM crops in Europe or in some MS. The import of GM ingredients from non-EU countries might imply significant compliance costs, which may penalize the European feed and food industries. If imported ingredients/raw materials contain approved GMOs above the legal threshold, the easiest solution to avoid trade disruptions would be to label them as GM, therefore losing the premium price linked to the certified non-GM feature.

Risks and Opportunities. The overall impact on the EU market depends on the relative effects on demand and supply, but we may expect a general increase in food prices, depending on the size of the entry barriers isolating the EU from the rest of the world. Unit segregation costs would probably exceed the price differential between GM and non-GM products, with both retailers and manufacturers progressively abandoning the certified non-GM niche market. The segment of consumers against GMOs and willing to pay an extra price for the non-GM attribute could target organic products.

The development of a second generation of GMOs (with R&D investments and activities delocalized probably outside Europe due to the restrictive regulatory framework) would give biotech companies more bargaining power and the leadership of the entire supply chain. High entry barriers for new/small biotech companies willing to produce second-generation GMOs are expected. The market may require a new type of segregation among different GM traits, as well as the introduction of private certification standards set by biotech companies. Firms developing the new GM traits would put pressure on the other actors along the value chain in order to find a cost-minimizing governance form for segregation able to increase supply chain efficiency and the overall performance. The extra cost of segregation is passed through to final prices and covered by those consumers willing to pay higher prices for the enhanced GM products. Retailers, on the other hand, could be able to apply differentiation strategies based on the different GM traits. This situation would clash with the restrictions at the EU borders: a block of imports or a very slow approval system would result in fewer second-generation trait approvals, with negative consequences for

the EU feed and food industry. The beneficial effects of the consumer's increasingly positive attitude towards GMOs might be completely annihilated by the restrictive regulatory framework. In particular, farmers pass up the opportunity offered by highly profitable GM crops, the feed and food industries experience serious difficulties in getting GM ingredients—now well accepted by consumers—both from the domestic and world markets, retailers are not in a position to differentiate their products on the basis of the non-GM attribute anymore, and lose leadership of the supply chain. Europe might even end up importing enhanced GM products rather than the ingredients and raw materials necessary to produce them, with a negative impact on different food industry sectors.

Supply chain actors seem to be unhappy with the emerging situation. Could this scenario represent a transitory phase towards a more enabling regulatory framework able to accommodate the demand for and the supply of second-generation enhanced GM products? Regulators—under increasing pressure from consumers, farmers, feed/crushing/food industries, and maybe the WTO—could move towards more enabling regulations on GMOs. However, we may expect a lagged adaptation influenced by the role of Europe in a long term view.

The most relevant risks and opportunities for EU farmers, feed/food industries, and retailers are presented in Table 5.

Scenario B: Restrictive Regulatory Framework and Negative Consumer's Perception of GMOs

Storyline. This scenario represents a sharpening of the present situation. On the demand side, consumers are still skeptical of GM foods; exogenous factors such as scandals or new scientific evidence could have played a role in exacerbating the situation. The negative perception translates into a higher WTP for non-GM foods. Only enhanced GM products having direct benefits for the consumer (second generation of GMOs) could positively impact the consumer's acceptance and WTP for GM foods. The more restrictive regulatory framework is in line with the scarce confidence in GM foods of EU consumers. This may entail stricter coexistence requirements (e.g., larger buffer zones) and liabilities for non-compliance, requirements for non-GM claims, or mandatory labeling for products obtained from animals fed with GM feed. On the supply side, the zero-tolerance policy on unapproved traits together with the slow approval process makes cultivation of GM crops in the EU very difficult, if not impossible. Even past approvals could be under scrutiny. Imports suffer as well: the fulfillment of the new regulations increases import prices for GM products. Regarding non-GM food products, the strong EU demand and the high WTP makes world producers/exporters eager to supply non-GM crops, in particular soy and its derived products. The fulfilment of stricter regulations, such as lower thresholds for the labeling of foods as GM, may impact segregation costs, thus eroding margins in the long run. The future expansion or contraction of non-GM food markets within the EU will depend on the balance between these two effects—the increasing WTP on the one hand and the increasing segregation costs on the other.

Risks and Opportunities. Different from Scenario A, the isolation of the EU market is sustained by the consumers' negative perception of GMOs. Although farmers are not able to exploit the potential benefits from GM crops (e.g., higher productivity, lower need of agrochemical products or water), the strong demand for and appreciation of non-GM crops would push prices up. We may also observe an increase in non-GM domestic crop production, with a reallocation of the land among different crops and cross effects on prices (less cereals in favor of protein crops). European feed and food industries producing non-GM products would face a more favorable domestic market, but large producers may lose competitiveness in the world market. For instance, this scenario could determine a decrease in oilseed imports with important impacts on the industry's processing capacity. Even if it doubled, the domestic production would not be able to replace imports and the crushing industry may be forced to move part of its capacity outside Europe, being otherwise unable to work at full capacity and exploit economies of scale. As a consequence of the relocation in third countries, more protein meal will have to be imported to compensate for the production previously obtained from the crushing activity in the EU. Compared to GM traits, non-GM crops generally require more agrochemical products. The biotech industry would differentiate its business providing new agrochemical products for non-GM crops to EU farmers, and new GM traits to third countries open to GMOs. R&D of new GM traits and field trials are conducted outside Europe, causing the decentralization of some core activities. European food producers may decide to directly import final products such as meat rather than producing them in the EU, circumventing the problem of trade disruptions (GMOs are not detectable in animal products). However, this could have negative consequences: some countries could lose

Table 5. Scenario A: Risks and opportunities for EU farmers, feed/food industries, and retailers.

Farmers
Opportunities
No coexistence needed before the introduction of the second-generation of GMOs.
Creation of cooperatives of producers to increase bargaining power in dealing with seed industry and other supply-chain actors.
Cultivation contracts with seed producers/biotech companies → spatial organization of production areas + certainty of selling the harvest at an agreed price, higher than what farmers could get cultivating conventional or without contracts.
Creation of long-term relations with seed producers and the downstream supply chain.
Risks
Cultivation contracts imposing what they have to cultivate + very high liabilities if contracts are not respected.
The price of conventional crops goes down.
Exclusion of certain production areas to assure coexistence and efficient segregation among different GM-traits (buffer zones). This would allow seed companies to preserve the purity of their most valuable GM traits.
Feed and food industry
Opportunities
No segregation needed before the introduction on the market of the second-generation GMOs.
In case of lower thresholds for labeling feed/food products as GM, no trade disruptions nor difficult times for the EU feed/crushing/ livestock sectors provided that imported inputs are labeled as GM.
Increase in cattle and pig farming (less dependent on soybean than poultry).
Research on alternative protein sources to feed animals.
Risks
Having to import final products instead of ingredients if it were not possible to integrate domestic production with imports.
Meat processing companies having to dismiss non-GM lines due to too high segregation costs and low demand.
Asynchronous approval of new second-generation traits among markets and potential trade disruptions.
Costly private research to prove health claims for products derived from second-generation GMOs; different regulations in different markets might call for standardization.
Having to label non-GM/organic inputs as GM because of adventitious presence above thresholds or traces of unauthorized traits leads to loss in money.
Retailers
Opportunities
New market for second-generation GMOs—growing demand, actual WTP, differentiation on new improved products to win over competitors.
Entering in biotech companies' private standards to have enhanced GM products with private benefits on health on their shelves.
Reduced segregation costs thanks to more integrated and efficient supply chains led by biotech companies.
Extra costs for segregation are covered by the premium price that consumers are willing to pay for enhanced GM products.
Risks
Might have to dismiss non-GM private label lines due to too high segregation costs and low demand.
They are not the chain leaders anymore.

Source: own elaboration based on experts' assessments

part of their processing capacity, with social implications in terms of employment. In response to the strong demand for non-GM labeled foods, retailers may decide to extend their non-GM policy to all the private-label products on their shelves, although the stricter segregation practices and the higher segregation costs may increase retail prices. Whether consumers' WTP for certified non-GM products would cover the higher prices is a big issue under this scenario.

The most relevant risks and opportunities for EU farmers, feed/food industries, and retailers are presented in Table 6.

Scenario C: Enabling Regulatory Framework and Negative Consumer's Perception of GMOs

Storyline. Politicians and regulators adopted a more enabling regulatory framework towards GMOs pushed

Table 6. Scenario B: Risks and opportunities for EU farmers, feed/food industries, and retailers.

Farmers
Opportunities
EU farmers could benefit from higher prices on the domestic market for their non-GM produce.
Sustainable intensification—incentives to increase domestic EU protein crop production.
Risks
Crop production in the EU is not competitive with the rest of the world who adopts GM traits.
An increase in domestic protein crop production would be at detriments of soil allocated to other crops. This trade-off could affect domestic prices, consumers' choices, and even diets in the long run.
Feed and food industry
Opportunities
Stricter segregation means stronger differentiation between GM and non-GM supply chains. This is at the basis of the market segmentation of some feed and food processors, and it is an opportunity as long as consumers have WTP for the non-GM.
The EU industry could export its certified non-GM products to third countries. This export might have to face the trade imbalance on the input side, with possible retaliation by input-supplier countries.
Substitutes of soybean could benefit from a stricter policy.
Non-GM labeled products could strengthen their position in the market. Experts do not see the "non-GM" as an independent trademark, but as an attribute within an overall quality strategy.
Risks
As the rest of the world is moving towards GMOs, segregation along supply chains will be more and more complicated and costly.
As the EU will be more isolated from the rest of the world, import of crops will decrease and the EU feed industry will suffer.
Restriction to non-GM inputs will reduce the processing capacity of the EU industry. Larger producers will be the most impacted, as they need big volumes to be competitive in targeting the mass market.
Europe cannot just close frontiers to imports and think to keep exporting value-added products. The imbalance on international trade could negatively affect different sectors of the EU industry and could complicate the negotiation of international trade agreements.
Food processors having diseconomies of scales in their inputs will face competition from imported processed food products. The impact will vary depending on the market and product. For instance, it might be difficult to replace fresh meat with imported frozen meat, as the two products are very different to consumers. Consumers will have to bear the higher costs of fresh meat produced in the EU or change consumption habits.
The WTP for non-GM products produced in the EU might not be sufficient to give profitability to the industry.
Retailers
Opportunities
Certified non-GM private-label products could strengthen their position in the market. The "non-GM" need to be an attribute within an overall quality strategy.
Retailers could better exploit the potential of niche and local markets.
Some retailers could start sourcing meat outside the EU if domestic prices are not competitive.
Risks
As the rest of the world is moving towards GMOs, segregation along supply chains will be more and more complicated and costly.
Segregation costs could increase to the point that retailers are forced to switch off the non-GM policy on mass market products. Consequences on brand equity?

Source: own elaboration based on experts' assessments

by problems with the supply of protein inputs for feed and food processing on the EU market; disputes within the WTO due to the asynchronous approval of GM traits and its potentially disruptive impacts on the international trade; and the increasing public awareness of the scarcity of natural resources such as water, soil, and energy. The society distrusts science, the regulatory framework in place, and large US biotech companies. Distrust is fueled by a lack of transparency along the supply chain and complex industry operations and processes. The consumer's negative perception is further reinforced by the adverse communication from the media (especially through the internet and social networks) focusing on GMOs' potential negative effects on biodiversity. Benefits such as the reduced use of water or agrochemical products are disregarded. NGOs keep

stressing the lack of clear benefits from GMOs for consumers. Food products labeled as GM and non-GM are both available on the market. Price keeps having a significant weight in consumer buying behavior, and the attitude-behavior gap dealing with credence attributes contributes to reduce the sales of non-GM labeled foods.

Risks and Opportunities. Investments in life sciences could positively impact public research in Europe and persuade companies to not decentralize in third countries the R&D of new traits and agrochemical products, seed production, crushing, and feed processing. This could create new job opportunities and have positive spillover effects on other sectors of the bio-economy beyond feed and food. All in all, this could potentially reduce consumers' distrust in science and in the biotech sector. As a consequence of consumers' negative perception of GMOs and of the presence of GM foods on the market, there is room for non-GM voluntary private standards and alliances among supply-chain players. Under this scenario, consumers' WTP for the non-GM feature, non-GM crops availability, and segregation costs are important factors for the viability and economic sustainability of segregated non-GM supply chains.

Conclusions

We used an explorative participatory approach building on intuitive logic and experts' judgment/assessment to identify the main determinants, investigate plausible alternative futures, and highlight the associated risks and opportunities for the main actors along the EU feed and food supply chains. The different points of view of the relevant stakeholder groups along the chain were expressed and discussed. The involvement of such a high number of high-profile participants assured a blend of different expertise, which provided a far-reaching perspective on the complex issues investigated. This allowed us to address the relevant managerial and policy concerns. Furthermore, it enhances the results' legitimacy and credibility.

Experts identified *regulatory framework* and *consumer's perception of GMOs* as the key drivers for future GMO segregation scenarios. Their polar outcomes were defined, respectively, as more enabling/restrictive and positive/negative. Three scenarios were first discussed during the two-day workshop and then developed and analyzed afterwards. The analysis of the scenarios allowed for identifying risks and opportunities for the different players along the supply chain. The overall satisfaction of participants about the methodology adopted and the results obtained were both measured handing out a questionnaire at the end of the workshop. Further evidence of appreciation comes from the participants' interest in receiving the results of the research and from their positive feedback.

A very sensitive issue that was identified across all scenarios is the asynchronous approval of GM traits which, in combination with the zero-tolerance policy for unapproved events, could potentially result in substantial trade disruptions and price increases, causing problems to European crushers, feed manufacturers, livestock farmers, and meat processors. A diffuse concern among many stakeholders is that a stricter policy on GMOs—besides increasing segregation costs—might substantially reduce the international competitiveness of the European feed and food industry. The economic risks caused by asynchronous approvals are a relevant issue also in the negotiations of the Transatlantic Trade and Investment Partnership (TTIP) with the United States.

The cost of the non-GM strategy emerged across scenarios as a challenge for the EU feed and food supply chains. According to the experts, the long-term economic sustainability of the niche market for certified non-GM food products is at risk due to increasing segregation costs, cultivation choices of third countries moving more and more towards GMOs, consumers' WTP for the non-GM attribute, and the unsolved attitude-behavior gap for credence attributes. A recent study (Fernandez-Cornejo, Wechsler, Livingston, & Mitchell, 2014) confirmed that consumer acceptance of GM food is not homogeneous; it indeed varies with product characteristics, geographical areas, and the information to which consumers are exposed. Similarly, consumers' WTP for non-GM food products is generally found to be higher in Europe than, for instance, in the United States. Coherently with the results of some studies finding that consumers are willing to try GM food with enhanced characteristics and even to pay a premium for them (see Fernandez-Cornejo et al., 2014, for a review of the literature), Scenario A shows how GM traits with direct benefits for consumers could positively modify EU consumers' perception towards GMOs in food. We believe there is a concrete possibility that in the future, biotech companies will increasingly invest in R&D for second-generation GM traits for feed and food uses.

At present, the future of GMOs in Europe is a sensitive political issue, as demonstrated by the high-pitched debate around the proposal tabled by the European Commission of giving any Member State the possibility

to opt-out from the use of GM feed and food already authorized at the EU-level. Feed/food supply chain actors, the European Parliament, and many delegations of MS at the Council of the European Union are very concerned about its potentially dramatic direct implications for EU agriculture and the livestock sector in particular, in case the opt-out proposal was not rejected by the Agriculture and Fisheries Council. A non-scientifically motivated opt-out measure would probably be not compatible with the functioning of the internal market and even more so with international trade agreements.

This study is expected to help decision makers and stakeholders assess the technical and economic sustainability of a segregated market, as well as the potential implications of changes in the EU-level regulations on GMOs. Furthermore, this research offers a contribution addressing the key pitfall of the recent opt-out proposal tabled by the European Commission—the lack of an impact assessment on supply-chain actors.

Further research might consider the response strategies of different players involved in segregated supply chains for certified non-GM products to the delineated alternative future scenarios. Following this line of research, we recently investigated the possible response strategies of a large Italian food retailer adopting a strict policy on GMOs in food to a sketchy version of the future scenarios discussed in this study (Passuello & Boccaletti, 2016).

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