Traceability and labelling of GMOs as a framework for risk management in European Regulation

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Abstract: Traceability and labelling are required by European regulation for food produced from GMOs. For this regulation one of the main advantages of traceability consists in providing information that should allow the precise withdrawal of products from the production process. This paper tests this idea. For that purpose, it seeks to establish whether the mandatory traceability will create an information set refined enough to locate GMO products in the production process. In this respect, the limits of the European regulation are pointed out. It is shown however that results are improved as soon as labelling is introduced alongside the requirement of traceability.

JEL Codes: I18, K32, Q18.

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Activities producing or using genetically modified organisms (GMOs) have to meet mandatory requirements in Europe. These requirements figure in several European rules that concern both the placing on the market of the GMOs and their traceability and labelling. GMOs traceability and labelling are specifically affected by the European Regulations 1829/2003 and 1830/2003. The aim of these Regulations is to create a harmonised community framework for the traceability and labelling of GMOs. This harmonisation is seen as a necessary condition for the free trade of GMOs on the internal market. It should also facilitate the implementation of risk management (See Robertson and Kellow 2001 for issues on international harmonisation of risk management practices).

These Regulations call for measures to ensure traceability and labelling of authorised GMOs at all stages of their placing on the market. Traceability is intended as "the ability to trace GMOs and products produced from GMOs at all stages of their placing on the market through the production and the distribution chains" (Article 3 of the European regulation 1830/2003). Concerning the labelling, the European regulation requires the use of a positive label. Indeed, the words "genetically modified" or "produced from genetically modified (name of the ingredient)" shall appear (Article 13 of the European regulation 1829/2003). Every genetically modified substance used in a processed food for example has to be identified with precise identifiers. The positive

label is therefore more precise than one that would read only "this product *may* contain GMOs". This latter kind of label indeed transmits little information (see the criticism of Runge and Jackson 2000 on this point)

Two objectives are attached to traceability and labelling by the European regulation. The first aim consists in the implementation of risk management measures like the withdrawal of products in the event of unforeseen adverse effects of GMOs on human health, animal health or the environment being established. The second aim is to ensure that accurate information is available to operators and consumers to enable them to make an informed choice of product.

The ways labelling and traceability affect markets for food have been studied in economics literature (Caswell 1998a, 1998b, Runge and Jackson 2000, Fulton and Giannakas 2004). Their consequences on the consumers' welfare have been placed at the centre of the analysis. Attention has been paid in this context to the traceability and labelling capacity to improve fair practice in the food trade and to provide consumer choice (Carter and Gruère 2003 for a criticism). In a recent paper Crespi and Marette 2003 investigated the welfare effects of the two alternative mandatory labelling systems that can be used for GMOs ("Does contain" *versus* "Does not contain" GMOs). The authors reached the conclusion that the welfare effects of the two labels are different but that neither of them should be seen as dominating the other in every circumstance. The decision to favour one rather than the other should depend on the value of the ratio of consumers reluctant to GMOs to indifferent consumers (see Noussair *et al*. 2004 for an estimation of purchasing behaviour of consumers). If this ratio is high, "Does contain GMOs" should be implemented as the mandatory labelling system.

The view considering traceability as a tool for managing risks is currently defended by the European Union in the international arena of the Codex Alimentarius. In this context European Union faces the position of the United-States that considers that traceability should only be seen as a way to differentiate products. The risk management perspective of the traceability and labelling of GMOs is therefore analysed in this paper. More specifically, the paper explores the following important question for risk management. Does the mandatory GMOs traceability provide enough information to authorities to allow the precise withdrawal of GMO products as claimed under Regulation

1830/2003? In other words, the paper seeks to establish if the demanded traceability will create a sufficiently refined information set to locate precisely GMO products in the production process and the distribution chain. In this respect, the paper points out the limits of the requirement of the Regulation 1830/2003. More specifically, the incapacity of this Regulation to necessitate a precise policy on batches and its consequences in the production of information are emphasized. The paper shows however that the results are improved as soon as the consideration of labelling is introduced along with the requirement of traceability. As a corollary of this analysis, a conclusion on the comparison of the positive and negative forms of labelling will be drawn.

What are the risks that traceability enable us to handle? Two kinds of risk can be considered. The first is the risk that a GMO is discovered to be dangerous only once its marketing has been authorized. However products could be withdrawn using GMO labelling alone, without any need of reliance on traceability. The second risk, as shown by recent affairs, is the risk that a GMO non-authorized for human consumption is mixed with an authorized GMO. In this case, labelling alone will not enable the targeted withdrawal of products, which can only be achieved if the identity of the operator who has accidentally mixed the two GMOs is singled out. This paper focuses on the second type of risk, since it clearly requires both labelling and traceability.

The requirements of the Regulation 1830/2003 concerning GMOs traceability originate from the Regulation 178/2002 establishing the European Food Safety Authority and laying down procedures in the matter of food and feed safety. Therefore the mandatory traceability requirements of the Regulation 178/2002 and their limits when considering product withdrawal from the market are presented in section 1. In section 2, the positive label is introduced. It is shown how this label interferes with the traceability requirements, improving as a result the product withdrawal system implemented by the European regulation. Section 3 concludes.

1. The roots of the European regulation on GMOs traceability

The requirements on GMOs traceability layed down under the Regulation 1830/2003 are in accordance with general obligations on traceability of food and feed promulgated by the Regulation 178/2002. This regulation sets rules and procedures in the matter of

food safety that aim to create a harmonised food safety system for the European Communities. In this context, traceability is considered as a risk management tool required for "accurate and targeted withdrawals".

Precisions on traceability requirements in the Regulation 178/2002 are found in article 18. At all stages of production, processing and distribution, the necessity of traceability concerns food, feed, food-producing animals and any other substance intended to be, or expected to be, incorporated in food or feed. In other words, all inputs of the food production process and the considered food shall be traced. Consequently, every food and feed business operator is concerned with traceability, producers and retailers likewise.

For the Regulation 178/2002, the aim of traceability is to "ensure that food or feed business (…) can identify at least the business from which the food, feed, animal or substance that may be incorporated into a food or feed has been supplied" (Point 29 of the preamble of the Regulation 178/2002). The traceability described in article 18 of the Regulation 178/2002 emphasizes therefore that food and feed business operators shall be able to identify any person, or business client, from whom they have been supplied with a food. This system of traceability has been called "one step backward and one step forward" for that reason. The information shall be registered at each stage of production on specific documents. The time this information should be retained is not specified however. The traceability required by the Regulation 178/2002 is therefore drawn up step by step. It is never demanded that information on the content of a food, its origin etc. goes through the production process and the distribution chain towards the market. The information produced at a stage of production can be confined at this stage. The different information elements can therefore remain scattered through the stages of the production process since no more requirements are made in the Regulation 178/2002. As a consequence, the production process cannot be traced. The traceability request concerns products only and it is the transactions between the different operators of a production process that form its base.

The required traceability is therefore less demanding than a system that would organize simultaneously the production of information and the transmission of information throughout the entire production process. This latter system of traceability would be

more efficient regarding the sanitary security aim highlighted by the Regulation 178/2002 but it would be more costly as well since it would require the labelling of every product.

Little reference to the label is made in the Regulation 178/2002. Article 18 reads that "Food or feed which is placed on the market in the Community shall be adequately labelled or identified to facilitate its traceability, through relevant documentation or information in accordance with the relevant requirements of more specific provisions". The reference to the "more specific provisions" allows the Regulation not to pronounce on the goodness of the product identification and to consider this question of labelling in respect of specific sectors and of specific sanitary risks. The traceability system asked by the Regulation 178/2002, without any label or document attached with the product as complement, can only create the framework for a "treasure hunt" for the public authorities: It is up to them to discover the path of the product. Furthermore, as is pointed out in the following, this traceability system cannot discriminate goods.

To illustrate this point, three producers S_1, S_2 and *C* are considered. These producers are linked in a vertical relation as shown in figure 1. Within the production process, producer *C* is located downstream of producers S_1 and S_2. The example of a colza oil producer will be used in section 2. Producer *C* produces a processed food (colza oil) with the help of two inputs *1* and *2* (two different sort of colza) sold by producers S_1 and S_2 respectively. Both suppliers sell a batch of input to *C*: I_1 for supplier 1 and I_2 for supplier 2 respectively. Perfect substitution between the two inputs is supposed. Therefore, producer *C* can produce his output from I_1 or I_2 alone, or mixing inputs from the two batches. He sells his products on the final market and to another producer *D*.

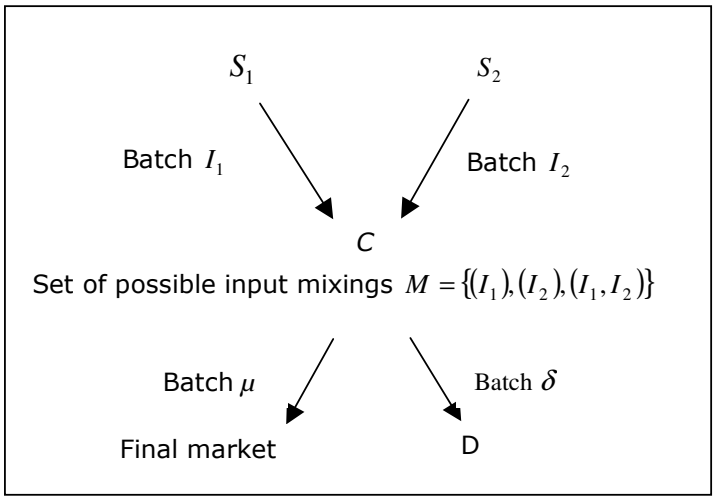

Figure 1. Identity traceability

If producer *C* only meets the traceability requirements of the Regulation 178/2002 (to be able to identify at least the businesses from which the food inputs have come and the businesses to which the food has been supplied) the information that he should register appears in figure 2. Here, for obvious economic reasons, the batches he constitutes are based on the identity of the person to whom they are sold rather than on the mixing of inputs they have originated from. For this reason this traceability is called "identity traceability" in what follows.

4 items registered:

(1) Batch I_1 bought from S_1

(2) Batch I_2 bought from S_2

(5) Batch μ sold to the market

(6) Batch δ sold to D

Figure 2 – Information registered by C for identity traceability

The *identity traceability* does not allow precise product withdrawal from the market or from the production process. For instance, if a sanitary problem arises because of product *1* from batch I_1, both batches μ and δ (e.g. the entire production of the processed food) should be withdrawn from the market and the production process.

To track every unit of output, producer *C* should differentiate three batches I_C, I'_C and I''_C corresponding to the three different "inputs mixings" he has operated in his production. The defined batches should therefore be registered, in compliance to Regulation 178/2002, on the basis of the person to whom they are sold (figure 3). If a

production from a batch is sold to different persons, an equivalent number of batches should be defined.

The system of traceability created this way thus attaches two dimensions to the batches: their orientation in the production process (with the identification of the persons who buy them) and their nature (with their input composition). This system is called in what follows, "discriminating traceability", since it can be used to locate precisely each unit of goods in the production process. If a sanitary problem arises because of batch I_1 for instance, batches I_C and I_C'' only should be withdrawn from the market.

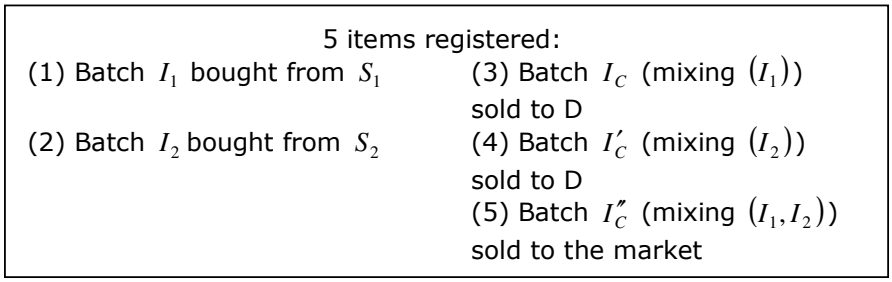

Figure 3 – *Information registered by C for discriminating traceability*

The Regulation 178/2002 however does not impose precise conditions with regard to batch. Indeed, batches are not mentioned in article 18 on traceability. They appear in article 14 and 15 to precise that where any food or feed which is unsafe is part of a batch, lot or consignment of food of the same class or description, it shall be presumed that all the food in the batch, lot or consignment is also unsafe.

All things considered the traceability system required by the Regulation 178/2002 can be seen as demanding when considering its application field (since every food product is considered) but can simultaneously be regarded as limited since it requires the identification of the suppliers and of the client businesses only. The *identity traceability* thus constructed cannot therefore be used as an information system for customers; neither does it allow precise product withdrawal from the production process or from the market. However, the demands of the regulation 178/2002 form a minimum framework that can be completed with an information system drawn up with labelling for example. Such a complement is expected in the GMOs case.

2. Traceability and GMOs labelling within European rules

The description of the implementation of traceability in the regulation on GMOs (Article 4 of the Regulation 1830/2003) conforms to the requirements of the broader regulation 178/2002. Operators are asked to set up systems and procedures to allow the holding of information on products consisting or containing GMOS (inputs and outputs) on the one hand, and on the identification of the operator by whom, and the operator to whom, the products have been made available on the other hand. The principle of "one step backward and one step forward" is therefore retained for the GMOs traceability. Furthermore, the regulation shall apply at all stages to the placing on the market of food and feed produced from GMOs. At the first stage of the placing on the market of a GMO product, operators shall ensure that the information that it contains, or that it consists of GMOs is transmitted in writing to the operator receiving the product. At all subsequent stages of the placing on the market of products operators shall ensure that the information received is transmitted in writing to the operators receiving the products. The information has to be held five years.

These characteristics seem to indicate the probable implementation of the *identity traceability*, as demonstrated in section 1. This result, of course, can be seen as an important limitation in the specific context of GMOs since the *identity traceability* cannot permit precise withdrawal of the product from the production process and the distribution chain. To support this idea, one can point out that little is written into the regulation on batches of products. In particular, the traceability requirements do not evoke batches. However, the labelling requirement that appears as a complement of traceability introduces a constraint in the GMOs regulation absent from the regulation 178/2002. The obligation to identify GMOs and to transmit the information on their presence is indeed established. This information completes the information that the traceability provides concerning the identity of the operators throughout the production process. We are therefore in possession of the two ingredients necessary for the implementation of a *discriminating traceability*: the information on the nature of the product and the information on the identity of the operators. Therefore, should the conclusion be reached that the *discriminating traceability* will be implemented as soon as the traceability requirements are coupled with the labelling obligation? This question

is considered in this section with the help of cases that differ in the number of GMOs and the number of suppliers they take into account (2.1).

2.1 The implementation of GMOs traceability and labelling in five different cases

The figure of producer *C* is considered with $N+1$ suppliers S_i of inputs. To bring the traceability of producer *C* to the fore, it is supposed that every supplier implements a *discriminating traceability*. The number of different GMOs the producer *C* uses is fixed at *G*. Finally, it is supposed that only one supplier sells an input not genetically modified to producer *C*. The *N* other suppliers sell therefore genetically modified inputs. The case of a colza oil producer can be used as an illustration. This producer can use a non genetically modified colza to produce his oil as well as one or several genetically modified colza allowed by the European Directory 2001/18 (seven different genetically modified colza can be therefore used: Topas 19/2, GT 73, Liberator L62, Falcon GS 40/90, MS1 RF1, MS1 RF2, MS8 RF3).

Five cases are first distinguished based on the number of suppliers *N* and the number of GMOs *G* that are considered. Then, the comparison of theses cases will enable to assess the performance of the traceability and labelling requirements of the European regulation (2.2). In all the cases studied, producer *C* is supposed to comply with the traceability and labelling requirements of the European Regulation 1830/2003 while looking simultaneously at the minimisation of the cost of implementation. He will not therefore decide on his own to implement an expensive *discriminating traceability*, but will choose to do so if compelled to. In this respect, two information sets have to be established for traceability. The first one is an inventory of the batches received and the names of the corresponding suppliers. The second is an inventory of the batches sold and the names of the business clients to whom they have been sold. The presence of GMOs has to be labelled in both cases.

Case a: $N=2,\ G=2$ *with a one-to-one relation between the set of suppliers and the set of GMOs*

In this first situation producer *C* faces three suppliers, with two of them ($N=2$) offering different genetically modified inputs 1 and 2 ($G=2$). This situation is therefore

characterised by $G/N = 1$ and a one-to-one relation between the set of suppliers and the set of GMOs. The third supplier offers an input which is not genetically modified (noted "0").

The first information set registered by producer *C* contains therefore three elements (the exponents 1 and 2 relate to GMOs and the exponent 0 to the non GMO input):

I_1^1 that reads batch of input 1 containing GMO 1 from S_1.

I_2^2 that reads batch of input 2 containing GMO 2 from S_2.

I_3^0 that reads batch of input 0 from S_3.

This set of information is noted $I_a = \{I_1^1, I_2^2, I_3^0\}$.

Once this information is registered, producer *C* can mix the different batches in his production process. The assumption of perfect substitution between the different inputs is made. As expressed with the colza oil example, it is supposed that the output can be produced combining producer *C*'s work with one input (this hypothesis is necessary to obtain a batch of product that does not contain GMO while considering only one no GMO input), two inputs or all inputs and that all possible input mixings are realised by *C*. The set of the possible input mixings contains seven elements:

$$M_a = \{(I_1^1), (I_2^2), (I_3^0), (I_1^1, I_2^2), (I_1^1, I_3^0), (I_2^2, I_3^0), (I_1^1, I_2^2, I_3^0)\}$$

Ignoring for the moment the identity (or the market) to which the production will be offered, the labelling of the GMOs obliges producer *C* to distinguish four batches of product:

Batch 1 with the label "contain GMO 1": $P^1 = \{(I_1^1), (I_1^1, I_3^0)\}$

Batch 2 with the label "contain GMO 2": $P^2 = \{(I_2^2), (I_2^2, I_3^0)\}$

Batch 3 with the label "contain GMO 1 and GMO 2": $P^{1,2} = \{(I_1^1, I_2^2), (I_1^1, I_2^2, I_3^0)\}$

Batch 4 without any label: $P^0 = \{(I_3^0)\}$

When these batches are sold, the identities of the business clients are introduced. If an entire batch is sold to a single person, the name of this person is registered with this batch. The case is similar if the entire batch is sold on the same market. If a batch is

divided between several clients, an equivalent number of batches with the corresponding identities is created.

The precise description of the other cases is given in annex for convenience. Case (b) demarks from case (a) relaxing the one-to-one relation between the set of suppliers and the set of GMOS. Case (c) introduces a fourth supplier selling GMO 2, while supplier 1 and supplier 2 are supposed to deliver GMO 1 and GMO 2 respectively. In case (d), a third GMO is introduced whereas the number of GMOs suppliers is kept unchanged (supplier 1 is supposed to deliver both GMOs 1 and 3). Finally, case (d) is similar to situation (a) but with three different GMOs and three different suppliers. Table 1 reviews the results obtained:

Cases	**Case *a***	**Case *b***	**Case *c***	**Case *d***	**Case *e***
GMOs suppliers	$N = 2$	$N = 2$	$N = 3,$	$N = 2,$	$N = 3,$
Number of GMOs	$G = 2$	$G = 2$	$G = 2$	$G = 3$	$G = 3$
One-to-one relation	*yes*	*no*	*no*	*no*	*yes*
Card I	3	4	4	4	4
Card M	7	15	15	15	15
Labelled batches	3	3	3	7	7
Unlabelled batch	1	1	1	1	1

Table 1: the five considered cases of traceability and labelling

2.2 Comments and comparison of the cases

2.2.1 General comments

In the preceding examples, the different sets of possible input mixings, noted *M*, are comparable to state spaces of the theory of information. The implementation of the labelling requirements creates a partition of those spaces. The different partitions obtained, clearly show that the labelling obligation creates information. Therefore, to continue with the information theory analogy, labelling constraint generates information sets. A *discriminating traceability* is not nevertheless reached. In situation (a) for example, the partition of M_a that arises with the use of the positive label is:

$$\left\{\left[\left(I_1^1\right),\left(I_1^1, I_3^0\right)\right],\left[\left(I_2^2\right),\left(I_2^2, I_3^0\right)\right],\left[\left(I_1^1, I_2^2\right),\left(I_1^1, I_2^2, I_3^0\right)\right],\left[\left(I_3^0\right)\right]\right\}.$$

The implementation of a *discriminating traceability* would require the following partition (the finest one) of the set of the possible input mixings:

$$\left\{\left[\left(I_1^1\right)\right],\left[\left(I_2^2\right)\right],\left[\left(I_3^0\right)\right],\left[\left(I_1^1, I_2^2\right)\right],\left[\left(I_1^1, I_3^0\right)\right],\left[\left(I_2^2, I_3^0\right)\right],\left[\left(I_1^1, I_2^2, I_3^0\right)\right]\right\}$$

This partition of M_a is the finest that can be constructed. Its main property is to isolate each possible input mixing. Such a partition of the set of possible input mixings is never realized in the analysed cases.

Furthermore, it is interesting to note that, in every analysed case, if a sanitary problem arises because of I_3^0, the non GMO input, the entire production of producer *C* should be withdrawn from the market. This clearly underlines that the labelling requirement will only produce information for GMOs and that the traceability of non GMO inputs, is not improved.

The evaluation of the negative label can be carried out. In every described situation this form of label would produce the same kind of result: a partition of the sets *M* into two subsets. The first subset would correspond to a batch with the label "does not contain GMO", that would contain the element $\left(I_3^0\right)$ only. The second subset would correspond to a batch without any label, which would gather all the remaining elements (every input mixing containing GMOs). It is therefore straightforward that the use of the negative label would not implement a *discriminating traceability*, on the one hand, and that the positive label provides better results in all the five considered cases, on the other hand. If a sanitary problem arises because of one of the considered GMOs, the entire production of producer *C*, except for the part produced with the only I_3^0, should be withdrawn from the market.

It is interesting to note that the same kind of result would have been achieved if the positive label that reads "*may* contain GMOs" had been chosen in the regulation. A producer that seeks to minimize the traceability implementation costs would distinguish two batches: one, with no label, that would contain the element $\left(I_3^0\right)$ only, and another, labelled "*may* contain GMOs" that would gather all the remaining elements.

Before turning to the comparison of the five described cases, an important outcome of the requirements of the European regulation 1830/2003 can be carried out. The "one step backward and one step forward" property of the mandatory traceability system isolates each producer of a production process and is unable to consider every producer simultaneously. As a consequence, if in a production process every producer ideally implements a discriminating traceability (regardless its cost) a producer operating downhill has the capacity, while compelling with the regulation, to scramble the information produced up to there, with the implementation of an identity traceability and GMOs labelling.

2.2.2 The five cases in perspective

A difficulty emerges as soon as one tries to compare the five given situations. Indeed, the criterion of the refinement of the partitions of the set of possible input mixings cannot be used since different sets are at stake. However, information concerning the size of the set of batches producer *C* received, the size of the set of possible input mixings and the number of batches he creates to satisfy labelling obligation, can be used to compare the various situations and to draw conclusions on important aspects of the traceability and labelling of GMOs.

The consequence of losing the one-to-one relation between G and N

To estimate the consequences of the loss of the one-to-one relation between *G* and *N*, case (a) is compared with case (b). These two cases consider the same number of suppliers and the same number of GMOs. In case (b) however the one-to-one relation between *G* and *N* is not verified. The first statement that can be made consists in the increase of the amount of information that producer *C* receives (we pass from three to four). The direct effect of this is to make the size of the set *M* grow (we pass from seven input mixings to fifteen input mixings). Producer *C* however continues to distinguish four batches, among which three are labelled. A deterioration of the traceability is therefore led by the loss of the one-to-one relation between *G* and *N*: the partitions of the two sets *M* have the same number of sub-sets (identically labelled) whereas the size of the number of possible input mixings has grown. The mean size of the batches grows therefore (it pass from 1,75 in case (a) to 3,75 in case (b)). In other words, the increase

of the number of suppliers, while the number of GMOs remains the same, distorts the capacity to distinguish of the GMOs traceability.

The consequence of the reduction of the G/N ratio because of an increase in the number of GMOs suppliers

To estimate the consequences of the reduction of the G/N ratio caused by an increase in the number of GMOs suppliers, case (c) is compared with case (a). The introduction of supplier 4, offering GMO 2 besides supplier 2, increases the amount of information producer *C* receives (we pass from three to four input mixings). The consequence is to make the set of possible input mixings grow (we pass from seven to fifteen elements). Since the labelling requirements are the same in both cases, the number of batches producer *C* distinguishes is the same (four batches). The increased size of the set *M* is not therefore considered by the traceability. As a result, the capacity of traceability to discriminate is distorted. This result is interesting because we could have thought the the increase in the number of suppliers would strengthen the identity traceability. The number of registered information concerning the suppliers increases indeed as a result. However this information is scrambled afterwards because no attention is paid to the inputs mixings.

The consequence of the reduction of the G/N ratio because of the reduction of the number of GMOs

To estimate the consequences of the reduction of the G/N ratio caused by the decrease in the number of GMOs, case (e) is compared with case (c). The number of suppliers offering GMOs remains at three but the number of different GMOs decreases from three in case (e) to two in case (c). This change has no effect on the amount of information received by producer *C* (this number is four in both cases). The two sets of possible input mixings have therefore the same size (fifteen elements). However, the labelling requirements become less constraining as the number of GMOs decreases. Producer *C* is compelled to distinguish four batches in the latter case (c) instead of eight in the former (case (e)). As a result, the mean size of the batches is smaller in case (e) than in case (c) (1,875 compared to 3,75). This forms a paradoxical effect of the number of GMOs on the information production (called *GMOs effect* in what follows). Its

reduction does not improve the traceability, but distorts the capacity of the latter to discriminate.

The consequence of the increase of the G/N ratio above 1 because of an increase in the number of GMOs

To estimate the consequences of the increase of the G/N ratio caused by an increase in the number of GMOs, case (d) is compared with case (a). If the number of GMOs suppliers is the same in both cases (two), the number of GMOs passes from two in case (a) to three in case (d). This change produces an increase in the amount of information producer *C* receives (we pass from three to four). Consequently the size of the sets *M* of the possible input mixings grows (from seven we pass to fifteen elements). However, since the requirements of labelling become more constraining with the increase in the number of GMOs, the partition of the set M_d has more elements than the partition of the set M_a. Indeed, producer *C* has to distinguish eight batches in case (d) instead of four in case (a). This forms a positive *GMOs effect* on the production of information.

The consequence of the increase of the G/N ratio above 1 because of a decrease in the number of GMO suppliers

To estimate the consequences of the increase of the G/N ratio caused by a decrease in the number of GMO suppliers, case (d) is compared with case (e). If the number of GMOs is the same in both cases (three), the number of GMO suppliers passes from three in case (e) to two in case (d). The amount of information received by producer *C* and the size of the two sets *M* are the same in both cases. Furthermore, since identical labels are used in the two cases, the number of elements of the two partitions created is the same. Therefore, decrease in the number of producers has no effect on the traceability capacity to discriminate.

3. Conclusion

Traceability and labelling are required by European regulation for food and feed produced from GMOs. For the European regulator one of the main advantages of traceability consists in providing information that should allow the precise withdrawal of products from the production process and the distribution chain. Traceability is

therefore considered as a tool for managing risk. The purpose of this paper was to test this idea with respect to GMOs products. Its capacity to provide information for precise product withdrawal from the production process and the distribution chain has been analysed. For this the figure of a producer who tries to minimize the cost of the implementation of the mandatory traceability has been retained. This demarche should permit to isolate the "performance" of traceability: if the product withdrawal is possible, this result would be the consequence of the specifications of the regulation rather than of an ideal behaviour of the producers.

This paper shows that the principle of "one step backward and one step forward" retained by the European regulation for traceability cannot permit the precise withdrawal of products. If the traceability capacity in this perspective is improved by the joint use of positive label for GMOs, a *discriminating traceability* that allows to track precisely the inputs entering into the production process of a food is never however fully attained. Nevertheless, the analysis shows a *GMOs effect* in this context: as the number of GMOs increases, the labelling becomes more constraining and produces more information *via* GMOs traceability. This supplement of information is not important enough for the traceability to become discriminating. Discriminating traceability requires stronger obligations on batches than the European regulation 1830/2003 provides. Such provisions, however, would have made the regulation more constraining and more costly to implement as well. Of course the operators of a production process can choose to implement a stronger traceability than the mandatory one. But this situation would raise however a coordination problem. Indeed, if in a production process all producers (ideally) implement a discriminating traceability, a producer operating downhill has the capacity, while compelling with the regulation, to scramble the information produced up to there.

Annexe

Case b: $N = 2,\ G = 2$ *without the one-to-one relation between the set of suppliers and the set of GMOs*

In this situation $N = G = 2$ so that $G/N = 1$ like in case (a). The first supplier, however, is supposed to offer two batches of inputs containing respectively the first and the

second GMO whereas the second supplier offers a single batch containing GMO 2. The first set of information producer *C* has to establish contains four elements:

$$I_b = \left\{I_1^1, I_1^2, I_2^2, I_3^0\right\}$$

Fifteen different input mixings are therefore possible in this situation:

$$M_b = \{(I_1^1), (I_1^2), (I_2^2), (I_3^0), (I_1^1, I_1^2), (I_1^1, I_2^2), (I_1^1, I_3^0), (I_1^2, I_2^2), (I_1^2, I_3^0), ...$$
$$...(I_2^2, I_3^0), (I_1^1, I_1^2, I_2^2), (I_1^1, I_1^2, I_3^0), (I_1^2, I_2^2, I_3^0), (I_1^1, I_2^2, I_3^0), (I_1^1, I_1^2, I_2^2, I_3^0)\}$$

To implement the GMOs labelling requirements four batches of the processed food are created:

$P^1 = \{(I_1^1), (I_1^1, I_3^0)\}$ with the label "contain GMO 1"

$P^2 = \{(I_1^2), (I_2^2), (I_1^2, I_2^2), (I_1^2, I_3^0), (I_2^2, I_3^0), (I_1^2, I_2^2, I_3^0)\}$ with the label "contain GMO 2"

$P^{1,2} = \{(I_1^1, I_1^2), (I_1^1, I_2^2), (I_1^1, I_1^2, I_3^0), (I_1^1, I_1^2, I_2^2), (I_1^1, I_2^2, I_3^0), (I_1^1, I_1^2, I_2^2, I_3^0)\}$ with the label "contain GMO 1 and GMO 2"

$P^0 = \{(I_3^0)\}$ without any label

Case c: $N = 3$, $G = 2$

This third situation considers the same number of GMOs as in situation (a) but introduces a fourth supplier selling GMO 2, while supplier 1 and supplier 2 are supposed to deliver GMO 1 and GMO 2 respectively. The set of information concerning the suppliers producer *C* has to establish contains therefore four elements:

$$I_c = \left\{I_1^1, I_2^2, I_3^0, I_4^2\right\}$$

The set of all possible mixings contains on this basis fifteen elements:

$$M_c = \{(I_1^1), (I_2^2), (I_3^0), (I_4^2), (I_1^1, I_2^2), (I_1^1, I_3^0), (I_1^1, I_4^2), (I_2^2, I_3^0), (I_2^2, I_4^2), ...$$
$$...(I_3^0, I_4^2), (I_1^1, I_2^2, I_3^0), (I_1^1, I_2^2, I_4^2), (I_1^1, I_3^0, I_4^2), (I_2^2, I_3^0, I_4^2), (I_1^1, I_2^2, I_3^0, I_4^2)\}$$

To implement the GMOs labelling requirements four batches of the processed food are created:

$P^1 = \{(I_1^1), (I_1^1, I_3^0)\}$ with the label "contain GMO 1"

$P^2 = \{(I_2^2), (I_4^2), (I_2^2, I_4^2), (I_2^2, I_3^0), (I_4^2, I_3^0), (I_2^2, I_4^2, I_3^0)\}$ with the label "contain GMO 2"

$P^{1,2} = \left\{\left(I_1^1, I_2^2\right), \left(I_1^1, I_4^2\right), \left(I_1^1, I_2^2, I_3^0\right), \left(I_1^1, I_4^2, I_3^0\right), \left(I_1^1, I_2^2, I_4^2\right), \left(I_1^1, I_2^2, I_3^0, I_4^2\right)\right\}$ with the label "contain GMO 1 and GMO 2"

$P^0 = \left\{\left(I_3^0\right)\right\}$ without any label

Case d: $N = 2,\ G = 3$

This situation introduces a third GMO supplied to producer *C* but without raising the number of suppliers considered in situation (a). Indeed, supplier 1 is supposed to deliver both GMOs 1 and 3 in two different batches. The set of information concerning the suppliers producer *C* has to establish contains therefore four elements:

$I_d = \left\{I_1^1, I_1^3, I_2^2, I_3^0\right\}$

The set of all possible mixings contains on this basis fifteen elements:

$$M_d = \left\{\left(I_1^1\right), \left(I_2^2\right), \left(I_3^0\right), \left(I_1^3\right), \left(I_1^1, I_2^2\right), \left(I_1^1, I_3^0\right), \left(I_1^1, I_1^3\right), \left(I_2^2, I_3^0\right), \left(I_2^2, I_1^3\right), \ldots\right.$$
$$\left.\ldots\left(I_3^0, I_1^3\right), \left(I_1^1, I_2^2, I_1^3\right), \left(I_1^1, I_2^2, I_3^0\right), \left(I_2^2, I_3^0, I_1^3\right), \left(I_1^1, I_3^0, I_1^3\right), \left(I_1^1, I_2^2, I_3^0, I_1^3\right)\right\}$$

To implement the GMOs labelling requirements eight batches are created:

$P^1 = \left\{\left(I_1^1\right), \left(I_1^1, I_3^0\right)\right\}$ with the label "contain GMO 1"

$P^2 = \left\{\left(I_2^2\right), \left(I_2^2, I_3^0\right)\right\}$ with the label "contain GMO 2"

$P^3 = \left\{\left(I_3^3\right), \left(I_1^3, I_3^0\right)\right\}$ with the label "contain GMO 3"

$P^{1,2} = \left\{\left(I_1^1, I_2^2\right), \left(I_1^1, I_2^2, I_3^0\right)\right\}$ with the label "contain GMO 1 and GMO 2"

$P^{1,3} = \left\{\left(I_1^1, I_1^3\right), \left(I_1^1, I_1^3, I_3^0\right)\right\}$ with the label "contain GMO 1 and GMO 3"

$P^{2,3} = \left\{\left(I_2^2, I_1^3\right), \left(I_2^2, I_1^3, I_3^0\right)\right\}$ with the label "contain GMO 2 and GMO 3"

$P^{1,2,3} = \left\{\left(I_1^1, I_2^2, I_1^3\right), \left(I_1^1, I_2^2, I_1^3, I_3^0\right)\right\}$ with the label "contains GMO 1, GMO 2 and GMO 3"

$P^0 = \left\{\left(I_3^0\right)\right\}$ without any label

Case e: $N = 3,\ G = 3$

This situation is similar to situation (a) but with three different GMOs and three different suppliers. The first set of information contains therefore four elements:

$$I_e = \left\{I_1^1, I_2^2, I_3^0, I_4^3\right\}$$

On this basis the set of all possible input mixings contains fifteen elements:

$$M_e = \left\{\left(I_1^1\right), \left(I_2^2\right), \left(I_3^0\right), \left(I_4^3\right), \left(I_1^1, I_2^2\right), \left(I_1^1, I_3^0\right), \left(I_1^1, I_4^3\right), \left(I_2^2, I_3^0\right), \left(I_2^2, I_4^3\right), \ldots \right.$$
$$\left. \ldots \left(I_3^0, I_4^3\right), \left(I_1^1, I_2^2, I_3^3\right), \left(I_1^1, I_2^2, I_4^3\right), \left(I_2^2, I_3^0, I_4^3\right), \left(I_1^1, I_3^0, I_4^3\right), \left(I_1^1, I_2^2, I_3^0, I_4^3\right)\right\}$$

To implement the GMOs labelling requirements eight batches are created:

$P^1 = \left\{\left(I_1^1\right), \left(I_1^1, I_3^0\right)\right\}$ with the label "contain GMO 1"

$P^2 = \left\{\left(I_2^2\right), \left(I_2^2, I_3^0\right)\right\}$ with the label "contain GMO 2"

$P^3 = \left\{\left(I_4^3\right), \left(I_4^3, I_3^0\right)\right\}$ with the label "contain GMO 3"

$P^{1,2} = \left\{\left(I_1^1, I_2^2\right), \left(I_1^1, I_2^2, I_3^0\right)\right\}$ with the label "contain GMO 1 and GMO 2"

$P^{1,3} = \left\{\left(I_1^1, I_4^3\right), \left(I_1^1, I_4^3, I_3^0\right)\right\}$ with the label "contain GMO 1 and GMO 3"

$P^{2,3} = \left\{\left(I_2^2, I_4^3\right), \left(I_2^2, I_4^3, I_3^0\right)\right\}$ with the label "contains GMO 2 and GMO 3"

$P^{1,2,3} = \left\{\left(I_1^1, I_2^2, I_4^3\right), \left(I_1^1, I_2^2, I_4^3, I_3^0\right)\right\}$ with the label "contains GMO 1, GMO 2 and GMO 3"

$P^0 = \left\{\left(I_3^0\right)\right\}$ without any label

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