Constraints and Incentives for Agricultural Biotechnology in Brazil

Izaías de C. Borges

Faculty of PUCCAMP, Pontifícia University of Campinas NEA – Center of Agriculture and Environment Research, Institute of Economics (Unicamp), Brazil

José Maria F. J. da Silveira

Professor of the Institute of Economics (Unicamp), NEA – Center of Agriculture and Environment Research, Institute of Economics (Unicamp), Brazil

Andrea Leda R. O. Ojima

PhD candidate in Economics, Institute of Economics (Unicamp), Researcher of IEA, Institute of Agricultural Economics, Brazil

Abstract

The aim of this paper is to discuss the co-evolution between agricultural biotechnology and biosafety process, with a special focus on Brazilian case. This rapid diffusion process has occurred in parallel with a high transaction cost process of regulation, combining local, territorial, national and supranational evolution of rules and norms involving public sector, private representatives and other stakeholders. So Forth, Brazilian case is one of the most interesting biotechnology regulation process in the world, once the country is simultaneously looking forward to the promotion of agribusiness competitiveness, preserve biodiversity and avoid bio-piracy. In order to treat this complex framework, the first methodological step is to create a typology of stakeholders based on their position in the regulation process. Once a typology is defined, the second step is to identify the critical factors explaining their behavior. The multicriteria analysis is used to characterize the processes associated to the evolution of agricultural biotechnology and to the improvement of biosafety assessment methods. Finally, is the aim of the paper to define the friction and convergence zones between those groups, using clustering procedures.

Keywords: : Biosafety, Agricultural Biotechnology, Multicriteria Analysis

JEL Classification: O30, Q55, Q16

Resumo

O objetivo do trabalho é discutir o processo de co-evolução entre biotecnologia e o processo de regulação da biotecnologia, com foco especial no caso do Brasil. O rápido processo de difusão da biotecnologia ocorreu acompanhado com um elevado custo de regulação, cujas regras foram definidas em várias escalas, combinando os níveis local, territorial, nacional e internacional. Este processo envolveu tanto setor público quanto privado, definido com a participação de *stakeholders* de vários tipos. O interesse do trabalho refere-se ao fato de a regulação da biotecnologia do Brasil é marcada pela ambigüidade ao buscar a conciliação entre a promoção da competitividade do agronegócio, a preservação da biodiversidade e o objetivo de evitar a biopirataria. Com objetivo de tratar esta estrutura complexa, o primeiro passo metodológico adotado foi criar uma tipologia de stakeholder baseado em sua posição no processo regulatório. Em seguida, explicar os fatores críticos que diferenciam os agentes envolvidos no processo. A análise multicritério é então aplicada para caracterizar os processos associados à evolução da biotecnologia agrícola e na melhoria de métodos de implementação de sua regulação. Finalmente, busca-se aplicar técnicas de análise multivariada e procedimentos de formação de *clusters* para identificar zonas de convergência/divergência entre os grupos previamente definidos.

1. Introduction

Agricultural biotechnology is one of the fields of application for biotechnology that presents a wide array of possibilities, generating technological opportunities. As noted by Silveira e Borges (2007), it is not limited to genetically modified organisms (GMOs) but involves a large set of technologies, some of them intermediate (such as molecular markers), and also generates new products (e.g. new matrices, new seeds, information for bioinformatics etc). It thus permits the continuity of pre-existing technological trajectories (Silveira et alii 2007), such as those relating to pest control, but expands the technological paradigm by creating possibilities and new technological alternatives, such as viral disease control or biofortified foods. In short, it causes technological impacts and brings about changes in the economic, social and environmental organization of a broad gamut of activities that are fundamental in countries where natural resource use is increasingly intensive.

The notion that "the future is now" treats the impact of biotechnology as a mere side-effect of innovations as they are introduced. The arguments involved in the debate raise the specter of various types of impact:

(a) economic impacts, such as the crisis of agricultural productivity, the pressure of demand from emerging countries, and the pursuit of competitiveness by exporter countries in acute processes of competition;

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E-mail addresses: `icborges@hotmail.com`, `jmsilv@eco.unicamp.br`

(b) social impacts, in counterpoint with the different forms of organization of agricultural production, from small farmers producing staple foods to producers of commodities, via a critique of the effects of globalized agriculture, which among other things is responsible for meeting demand for energy products in a renewable manner;
(c) environmental impacts, which must respond simultaneously to short-, medium- and long-term demands, besides being unremittingly criticized by agroecologists in search of a model radically distinct from today's agribusiness model (Altieri 2002; Shiva 1995); and
(d) the impacts of technology, with proven effectiveness in achieving immediate results (Qaim et alii 2006; Silveira e Borges 2007; Huang et alii 2007; Pray et alii 2006), contrasting with expected lock-in phenomena of various kinds, from those relating to the cost of removing GMOs from nature [1] to the selective effects of innovation in formulating and applying biosafety rules grounded in solutions to conflicts of interest and agreements of a predominantly political nature (Zylberman 2006; Silveira e Buainain 2007).

The central point of this paper is that decision makers, whose common knowledge is responsible for the general lines of the regulatory framework for biotechnology (see Aoki 2007), [2] contribute to defining the substantive elements that make up regulation based on the perception of a large number of sub-criteria, which can be classed into three main groups: perceived current benefits, projected benefits, and risks.

The paper sets out to apply a multicriteria methodology for assessing the importance of each of these dimensions according to a group of Brazilian experts, ranging from each sub-criterion to the broadest items or themes. This methodology serves as a basis for understanding what elements contribute to the formation of a vision of common knowledge on biotechnology regulation, or alternatively to maintenance and recurrent generation of the ambiguity that influences definition of the substantive themes and operational elements of the system for regulating biotechnology. The discussion is confined to the Brazilian case, which as shown by Fukuda-Parr (2007) and Silveira e Borges (2007) is one of the most interesting at present, since Brazil is widely seen as a world agribusiness leader with incomparable levels of biodiversity in cultivable species

[1] Removal is motivated by the possibility that the technology will lose value, e.g. via resistance to pests, or by premature expulsion (characteristic of the notion of a technological trajectory) of alternatives that are viable but less supported by corporations' power of diffusion (Silveira et alii 2007; Just 2006).

[2] Aoki defines processes of institutional change (or creation) based on three levels. The most general level depends on the creation of common knowledge about the rules of the game – the parameters involved in defining a regulatory apparatus – by the players (firms, scientists, formulators of R&D, and regulators, associated with government agencies and ministries with responsibilities for biotechnology). The substantive level defines the components of the regulatory process, such as the consideration of impacts on the environment or human health, and the parameters for valuing innovations. The third level, which is operational, refers to the regulation and implementation of policies, with all the difficulties that characterize this process involving costs and conflicts of interest.

(centers of genetic origin), landraces (traditional varieties) and native species that are a basis for bioprospecting (Pereira 2009).

The next section discusses the regulation of biotechnology, starting with a justification of the importance of the Brazilian case. Section 3 describes the multicriteria methodology applied to the theme of biotechnology regulation. Sections 4 and 5 present the findings and conclusions.

2. Regulation of Biotechnology

In order for genetic engineering to be a global technology used in various different places, there would have to be regulatory convergence among countries. Because a large proportion of agricultural production goes to foreign trade, the existence of different regulatory policies could in many cases prevent production of GM crops. The truth is that despite the growing acreage under GM crops, regulatory convergence, at least among the major players, is far from materializing. The difficulties of reaching agreement on the best way to regulate the use of genetic engineering in agriculture are evidenced by the negotiations that have taken place in the context of multilateral accords such as the WTO's TRIPs Agreement and the Cartagena Protocol on Biosafety (Zarilli 2005).

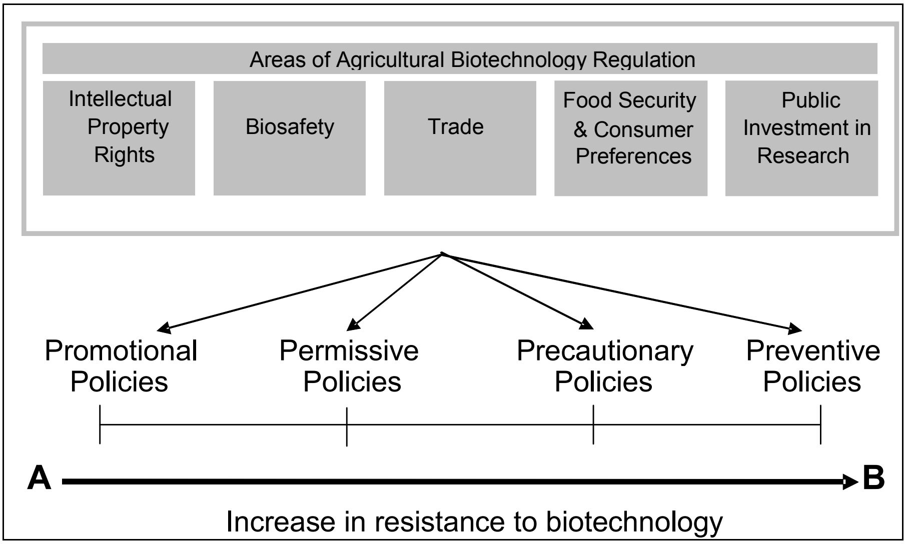
As mentioned, the difficulties of achieving agreement among countries are due to the multiple dimensions involved in the process, making the problem complex and intensifying the barriers to convergence. Defining clear rules of the game is hindered by the fact that countries do not always make their position explicit, especially because there are conflicts among stakeholders within particular countries (Hall e Martin 2005).

Based on the classification proposed by Paarlberg (2001), it is possible to distinguish four types of agricultural biotechnology policy: promotional, permissive, precautionary, and preventive. Promotional policies aim to accelerate the diffusion of GM crops within a country's borders. Permissive policies are neutral with regard to GM crop diffusion, i.e. they aim neither to accelerate nor decelerate diffusion within a country. Precautionary policies seek to decelerate diffusion of the technology without completely prohibiting its use. Finally, preventive policies aim to block diffusion of the new technology completely within a country's borders.

Governments can establish promotional, permissive, precautionary and preventive policies in five different areas of regulation: intellectual property rights, biosafety, trade, food security and consumer preference, and public investment in research, as shown in Figure 1.

The greater the resistance to agricultural biotechnology, the more restrictive a policy tends to be, up to the extreme case of total prohibition within a country. Point A corresponds to zero rejection, where the benefits perceived by stakeholders and the government greatly exceed the risks. Point B corresponds to the opposite extreme, where the degree of rejection is so great that policy becomes prohibitive.

Fig. 1. Regulatory policies for genetic engineering in agriculture



Source: Chart by the authors based on Paarlberg (2001).

The main problem is that any given country may take different positions with regard to the different areas of regulation. For example, a country's policies may be promotional in IP rights and preventive in biosafety. Conversely, another country's policies may be preventive in IP rights and promotion in biosafety.

Another source of difficulties in defining the type of regulation to be established is that a country can take different positions with regard to different crops and different attributes of GMOs. For example, it can be permissive toward soy and preventive toward corn. Or it can be permissive on insect-resistant corn and preventive on herbicide-tolerant corn. [3] Thus reaching an international agreement on GM crops is no easy task. Even within individual countries it has proved to be a tough challenge, as shown by the Brazilian case.

The hypothesis used here is that the different policies established by countries result from differences between countries in terms of their natural, economic, social, political and institutional conditions and in terms of their role in the global market for agricultural commodities.

A country's role in the global market for agricultural commodities means whether it is a net exporter or importer of food and other agricultural goods. Exporter countries may specialize in raw or bulk goods or processed goods. Similarly, importer countries may predominantly import food for the domestic

[3] An obvious case is China, which imposes restrictions on GM soy varieties based on the argument that the country is a center for species biodiversity in this case, while at the same time emphatically promoting the creation and use of GM cotton varieties (Huang et alii 2007).

market or raw materials for processing and re-export. Each stakeholder group within any given country will have different perceptions of the benefits of GM crops and hence different degrees of risk tolerance with regard to those same crops. If for a particular group of stakeholders the benefits outweigh the risks, they will want public policy for GM crops to be promotional. Where benefits are not seen as outweighing risks, the stakeholder group in question will want policy to be precautionary or even preventive.

How stakeholders perceive benefits and risks depends on whether they have direct or indirect relations to the new technology. Relations are direct for stakeholders in the technology's production chain and thus directly affected by it, and indirect for stakeholders outside the innovation production chain but affected by the technology's "externalities".

Stakeholder theory classifies these two groups into: primary stakeholders, who are in the innovation production chain and take decisions on creating, using or consuming a new technology; and secondary stakeholders, who do not participate directly in the diffusion of a new technology and are affected by it only indirectly. Primary stakeholders are those who develop, produce and use new technology as well as final consumers who buy the products made using the technology in question. Secondary stakeholders are groups or organizations that for whatever reason feel threatened by the new technology.

The importance of each group may vary from one country to another. For example, in agricultural producer countries with large areas of forest, environmentalists may be more important than consumer advocates. Conversely, consumer advocacy groups tend to have more weight in the rich countries, which mostly import agricultural produce and have small remaining areas of forest. Because the different stakeholder groups have different perceptions of actual and potential benefits and risks, they advocate different policies for GM crops. The next section outlines the methodology proposed as a basis for analyzing regulation as presented.

3. Methodology

3.1. *Justification for the use of the multicriteria methodology*

The methodology of the present work has an exploratory nature which, as previously seen, is justified by the great deal of polarization-with implications for the regulatory framework-which has characterized the debate about the incorporation of GMOs into food products in Brazil since 1995 (Silveira e Borges 2007; Fukuda-Parr 2007). Hence, the use of this methodology has the goal of providing means to answer questions that must serve as basis for the application of methodologies that generate more accurate and precise results, such as those that measure the impact of segregation in grain trade (Huang et alii 2007, 2004; Moschini 2001; Silveira et alii 2007) or studies aimed at providing a model of quantitative analysis able to support decision making on whether or not to legalize GMOs (Scatasta et alii 2006).

The idea that it is possible to measure the irreversibility of the impact caused by GMOs implies questioning the pertinence of invoking the Precautionary Principle (Silveira e Buainain 2007), the "ignorance" of future impacts and also of potential benefits of the adoption of GMOs in agriculture having been one of the arguments used for adopting measures ranging from costly biosafety requirements to the adoption of a moratorium on products in several levels-from research to commercialization, depending on the product, region and circumstances involved.

Among those favoring the view contained in this work is Zylberman (2006), who recognizes the political nature of the biotechnology regulation process, which, he argues, is not solely based on economic principles. To his analysis we may add the comment that political economy dimension of GMOs surrounding the debate is related both to the presence of strong uncertainty (Dequech 2004) and ambiguity (Hall e Martin 2005; Silveira et alii 2007). In sum, the goal behind developing a multicriteria methodology for the elements that condition and contribute to the definition of biotechnology regulation is to support decision-making processes involving multiple dimensions, divided, in the case at hand, into three main levels: current benefits, potential benefits and risk perception. This is an innovation both in the field of the debate on biotechnology and in the application of the multicriteria methodology. The data-collecting instrument was generated based on a review of a broad range of literature and on the authors' firsthand experience with the debate occurring in Brazil and internationally. This instrument is, in fact, an Excel spreadsheet especially designed to compel the prioritization of sub-criteria and criteria (but leaving blank spaces for the respondent not to accept a pertinent comparison, as shall be seen ahead).

In order to improve our understanding of the various sides of this controversial issue, we searched out the opinion of experts on the risks and benefits of GM crops. Initially and roughly, it is possible to say that those advocating GM cultivation tend to prioritize its benefits and those who oppose it tend to prioritize its risks. But which benefits and risks are these, and what is behind the polarization between passionate advocates and harsh critics? Do those defending GM trials use the same types of benefits as criteria? Likewise, do those opposing them do so for the same reasons? Within a given set of benefits that experts perceive, does one type of benefit prevail among those involved in the debate, so that there might be a convergence among all of the different stakeholders? In the same vein, is there a specific type of risk that stands above all other types so that a crop that did not present it could more easily be accepted by all stakeholders?

3.2. *Brief summary of the methodology*

Drawing on the literature available on impacts of GM crops, eleven topics that have been fueling the controversy on GM plants in Brazil and abroad were selected:

- Economic risks; Environmental risks; Technological risks;
- Future economic benefits; Future social benefits; Future environmental benefits; Future technological benefits;
- Existing economic benefits; Existing social benefits; Existing environmental benefits.

Within each of these eleven themes lie a specific number of items to which they pertain, generally four, which represent a detailing, or the content, of each theme. These themes, for their part, were clustered into three larger groups: risks, potential benefits and observed benefits, which support the general viewpoints, the *common knowledge* fundamental to the creation of regulatory institutions (Aoki 2007).[4] The aim of this research was to verify the weight that each of these groups should have in the political decisions concerning OMG crops, according to the opinion of each of the experts interviewed.

As mentioned, the problem was structured based on multicriteria decision models. These models employ a set of decision-making procedures more adequate to deal with complex issues, where "aspects pertinent to a given problem cannot be apprehended based on a single perspective" (Munda 2003). As seen here, the choices of policies for GM crops involve economic, social, environmental and technological dimensions. Therefore, the multicriteria analysis is more adequate in the context of this problem.

According to Gomes, the first multicriteria methods emerged in the 1970s, aimed at dealing with situations in which the decision maker, acting with rationality, had to solve a problem in which several objectives were to be reached simultaneously. According to Schmidt (1995), multicriteria techniques permit the evaluation of criteria that cannot be transformed into financial values, thereby allowing the inclusion of differences and conflicts of opinion in the process.

This work used the Analytical Hierarchy Method (AHP), a multicriteria analysis technique developed in the 1970s by Thomas L. Saaty (Saaty 1991; Gomes et alii 2004). In this type of analysis, the decision problem is divided into hierarchical levels, so as to facilitate its understanding and assessment. The AHP model has three steps: hierarchy formation, addition of experts' preferences and operationalization of the reference matrix to obtain the priority

[4] From Aoki's perspective (2007), there are three analysis levels to study change processes in institutions-in this case we considered the creation of institutions: a) the general level, of common knowledge; b) the substantive level, in which the fundamental must be defined, for example, what is necessary to compose a biosafety regime at the national and international levels; c) the level of operationality of the policies resulting from different governance designs adopted, which implies analyzing, for instance, compliance costs of the biosafety policy and its paradoxes.

vectors. The first step, therefore, is to structure the problem in a hierarchy tree, as presented in subsection 4.1.

The second step entails analyzing the impact or the importance of each element of the n-level hierarchy over the $n+1$-level hierarchy. For instance, in the choice of policies for GM crops, what should be the importance or the contribution of risks, observed benefits and potential benefits? Likewise, concerning risks, what is the importance of technological, social and environmental risks?

Once the hierarchy is built, each expert makes a comparison, pair by pair, of each element from a given hierarchy level, thereby creating a square decision matrix, called matrix A. In this matrix, each expert will represent, based on a predefined scale, his/her preference among the elements compared, with relation to the element in the level immediately superior (Saaty 1991; Gomes et alii 2004).

The scale used to represent the preferences in the matrix and in the comparison will be "Saaty's fundamental scale." Based on this scale, the factors are compared among themselves in a matrix like the one seen. The matrix on Table 1 illustrates the procedure described. Let us suppose that expert X completed the matrix according to his preferences. According to him, Potential benefits have essential or strong importance over observed benefits, hence number 5 in A_{12} square of matrix A; Potential benefits have very strong importance over risks, hence number 7 in the A_{13} square of matrix A; Observed benefits have moderate importance over risks, hence number 3 in the A_{23} square of matrix A. Matrix A is a reciprocal matrix, where element $A_{21}=1/5$, element $A_{31}=1/7$ and element $A_{32}=1/3$.

1	Same importance	Both activities equally contribute to the objective
3	Moderate importance of one over another	Experience and judgment slightly favor one activity over the other
3	Essential or strong importance	Experience and judgment strongly favor one activity over the other
7	Very strong importance	One activity is strongly favored and its dominance is demonstrated in practice
9	Extreme importance	Evidence favors one activity over the other, with the highest degree of confidence
2,4,6,8	Intermediate values	When a condition of compromise is needed between two alternatives

Based on the responses in matrix A, the next step involves obtaining a priority vector, i.e., according to the preferences laid out in matrix A, what will be the relative importance of each element in the process of choosing

Table 1
Matrix of "Grade Assignments" according to the responses obtained in each questionnaire

	Potential benefits	Observed benefits	Risks
Potential benefits	1	5	7
Observed benefits	0.2	1	3
Risks	0.14	0.333333333	1

Source: Created by the author.

policies for expert X? According to the method proposed by Saaty (1991), the priority vector is calculated based on matrix A normalized, matrix V, where each element of V is given by $V_{ij} = \frac{a_{ij}}{\sum a_{ij}}$.

Table 2
Illustrative picture of the construction of indicators (scores) based on the AHP methodology

Potential benefits	Observed benefits	Risks	Priority vectors	
Potential benefits	0.74	0.79	0.64	0.72
Observed benefits	0.15	0.16	0.27	0.19
Risks	0.11	0.05	0.09	0.08

Source: Created by the author.

Thus, applying the formula, we have matrix V. The priority vector of each element will be the weighed sum corresponding to each element in matrix V. For example, according to the answers given by expert X in Table 2, potential benefits should have a weight of 72%, observed benefits of 19% and risks only 8% in the process of deciding policies for GM crops.

4. Results and Discussion

4.1. *Group results according to criteria*

As previously, mentioned, the Analytical Hierarchy Process (AHP) is a multiple-criteria decision analysis tool well suited to study problems involving complex choices, where decisions rely upon the opinions of various individuals regarding a large number of evaluation criteria.

To fulfill the goal of analyzing the importance that the agents who participate in the decision process ascribe to the evaluation criteria, a total of 135 questionnaires were sent out to various types of agents working in the field of agricultural biotechnology in Brazil. Of the 135 questionnaires, 57 were answered and compose the database whose main results are presented in this section.

The figures presented in Figure 2 represent the average of the 57 individual answers in levels 2 and 3 of the themes' detailing.[5] For this group of experts, potential benefits (38.4%) should have priority over observed benefits (31.7%) and over risks (29.9%). Figure 2 also shows the weight of each of the eleven criteria within its respective group, which we shall call local weight. Within the group "Potential Benefits," environmental benefits obtained the greatest weight (28.2%) and Technological Benefits obtained the least weight (22.2%). As for the "Observed Benefits" group, economic benefits were deemed the most important, with a weight of 43.1%, whereas environmental benefits obtained the least weight (26.1%).

The difference between both groups indicates a perception that in the long run, technology will also have to present benefits beyond economic gain. To some extent, the results shown in Figure 2 indicate a perception that non-economic dimensions such as the social and the environmental will bear greater weight in future decision-making processes. With regard to risks, these dimensions obtained the least weight (29.9%), but quite near the weight of Observed Benefits. Within this group, environmental risks are seen as the most important of all, indicating that biosafety and possible impacts of GMO crops is the most concerning issue.

The analysis of the results according the criteria grouping[6] provides a roadmap of themes that deserve greater or lesser attention from experts. Nevertheless, in complex and ambiguous situations (Silveira et alii 2007; Hall e Martin 2005), like those characterizing the construction of a regulatory body in biotechnology, an alignment of extreme positions around general criteria often occurs (Silveira e Borges 2007; Ferment et alii 2009; Pelaez e Albergoni 2004; Pelaez 2006).

The classification of the respondents into professional activities allowed observing the existence of contrasts which alter the main conclusion namely, that despite the weight that the respondents place on the dissemination of GMOs, there is greater concern about potential benefits, which beats out the concern about various types of risks. The next subsection presents the results for the 4 groups identified in the study, and the following subsection seeks to locate both the stakeholder concerned with risk and the main contrasts between the items analyzed, based on the application of multivariate analysis to its principle components.

[5] For space reasons, the results obtained for the "fourth" level, concerning the items composing each criteria (for example, technological risk related to neglected types of cultivation; or economic risk represented by non-tariff barriers) will be analyzed in a brief and separated manner. However, as can be seen in Cremonezze (2009), difficulties lie in the details.

[6] It is worth emphasizing that the respondents start completing the questionnaire from the lowest level of aggregation, i.e., level 4, the most detailed one.

Fig. 2. Characterization of The Levels and Average of the Answers ($n = 57$)

Level 1 - Objective	Level 2 - Criteria	Level 3 – Sub Criteria
Objective: choose the politics for agricultural biotechnology in Brazil	Potential Benefits – 0,384	Economic – 0,249
		Social – 0,248
		Environmental – 0,282
		Technological – 0,222
	Observed Benefits – 0,317	Economic – 0,431
		Social – 0,309
		Environmental – 0,261
	Risks – 0,299	Economic – 0,234
		Social – 0,266
		Environmental – 0,303
		Technological – 0,197

Source: Created by the authors.

4.2. *Results from expert groups*

The results presented in Figure 3, refer to the average of weights obtained for groups of experts, divided into four groups, according to professional activities.

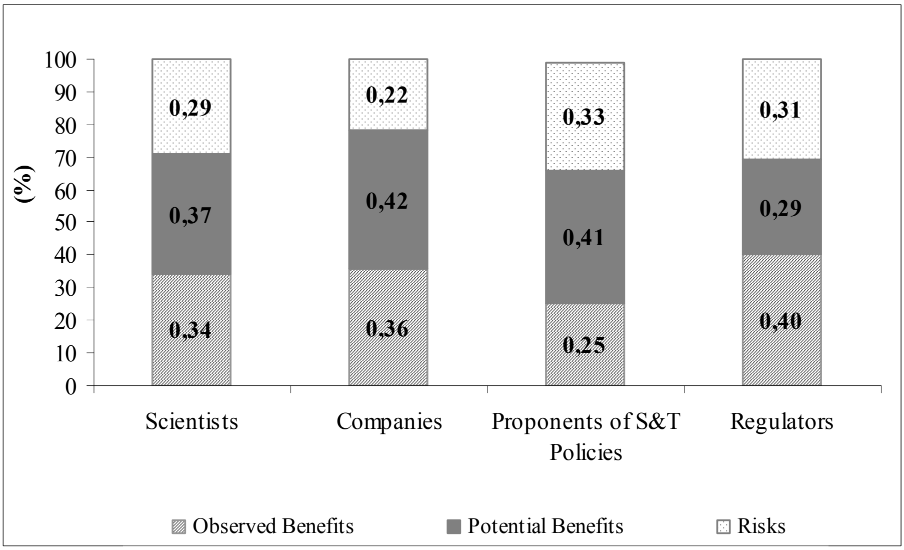
- Group 1: SCIENTISTS: includes scientists (biologists, agronomists, engineers and other professionals with a high degree of scientific specializations) working in various fields of biotechnology;
- Group 2: COMPANIES: includes executives, media advisors, technicians with higher education and researchers from private biotechnological companies;
- Group 3: PROPONENTS OF S&T POLICIES: includes professionals (economists, agronomists and social scientists) working to develop policies in science and technology;
- Group 4: REGULATORS: includes professionals with higher education working in government agencies involved in the regulation or monitoring of GMOs.

With regard to the three main criteria, potential benefits obtained the highest weigh, except within the group of regulators, in which observed benefits were deemed the most important. The results presented in Table 3 show that three groups trend away from the global average:

i. The group of regulators, which is the only group in which observed benefits have priority over the other criteria; it is also the group in which Observed Benefits have the least weight;
ii. The group of experts in scientific and technological policies (strategists), which prioritizes Potential Benefits and attributes a low weight to observed benefits. Of all groups, this one attributes the least weight to observed benefits;
iii. The group of representatives of private companies, which gives a low weight to risk. Indeed, of all groups, this one attributes the least weight to risk.

Concerning the "Potential Benefits" criterion, the results show no significant discrepancies between the professional categories, as illustrated in Table 3. For all groups, potential environmental benefits have the greatest weight, excepting the group of experts in S&T policies, which attributes practically the same weight for all types of Potential Benefits. Regarding the "Observed Benefits" criterion, results show a discrepancy concerning the economic benefit criterion, between regulators and the other specialist groups. Observed economic benefits have the greatest weight for the groups, with the exception of the regulators group. With regard to Observed Benefits for the regulators group, environmental benefits have the greatest weight, whereas economic benefits have the least weight. Regarding the risk criteria, the study shows a discrepancy among groups with respect to economic and environmental risks. Two groups-regulators and experts in S&T policies-attribute greater importance to environmental risks; scientists attribute more weight to economic risks; and companies attribute more weight to social risks.

Fig. 3. Balance between benefits and risks, by professional category



Source: Created by the authors.

Another way to analyze the results mentioned is to calculate the global weight of each of the eleven criteria in level 3 of the hierarchy over level 1 or the problem's objectives. The global weight is calculated by multiplying the local weight by the weight in the superior hierarchical level. For instance, the global weight of potential economic benefit is its local weight, 0.249 multiplied by 0.384, which is the weight of the potential benefits in relation to goals.

Figure 4 presents the weighed sum of the global weights to the evaluation criteria, calculated based on the weights of 57 experts. Based on these results,

Table 3
Sub-criteria level (level 3), by professional category

Criteria	Scientists	Companies	Proponents of S&T policies	Regulators
Observed benefits				
Economics	0.42	0.48	0.48	0.27
Enviromental	0.38	0.28	0.25	0.41
Social	0.20	0.24	0.27	0.33
Potential benefits				
Economics	0.27	0.27	0.25	0.20
Enviromental	0.30	0.30	0.24	0.34
Social	0.19	0.23	0.26	0.28
Technological	0.24	0.19	0.24	0.18
Risks				
Economics	0.33	0.25	0.20	0.21
Enviromental	0.23	0.27	0.34	0.33
Social	0.21	0.31	0.27	0.27
Technological	0.23	0.18	0.20	0.19

Source: Created by the authors.

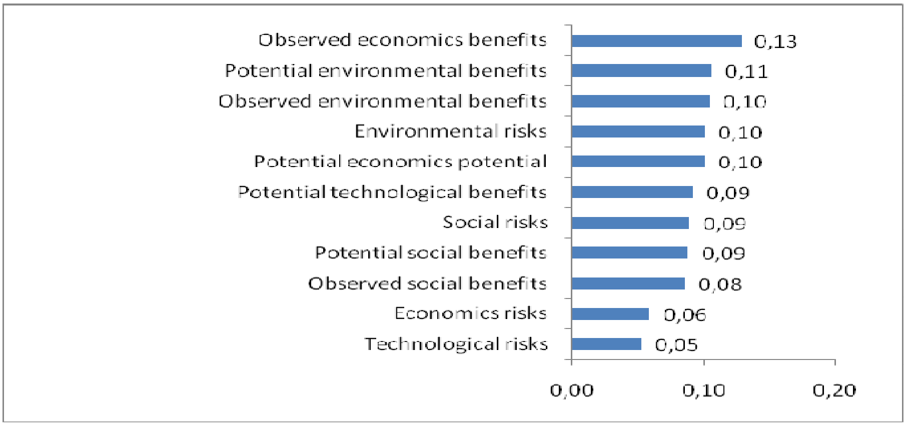
observed economic benefits and potential or future environmental benefits would be the criteria with the greatest global weight, whereas technological and economic risks would be the least important criteria.

Although the observed economic risk criterion has a higher weight, the environmental dimension of the problem seems to carry great importance for the experts, given the fact that potential environmental benefits, observed environmental benefits and environmental risks are among the four most important criteria. Together, these criteria have a global weight of 31% in the final objective, thereby overcoming the economic dimension, which has global weight of 29%. Table 4 presents a detailed results by professional category.

The group of proponents of S&T policies was excluded from this table because this group contained a very wide spectrum of positions, partly due to a greater distance from the decision-making process (a point we will revisit).

The analysis of the global weights of the evaluation criteria by category reveals discrepancies among the categories concerning economic and environmental dimensions. Whereas for scientists, company representatives and experts in S&T policies, economic benefits have a greater weight, for regulators the environmental benefits have a greater weight, and economic benefits rank

Fig. 4. Weighed sum of global evaluation criteria



Source: Created by the authors.

fifth in terms of importance.

4.3. *Results of the evaluation of subcriteria*

The evaluation criteria shown in level 3 of Figure 3 were split into subcriteria, and the weighed sum of each is presented in Table 5.

The subcriteria, ranked according with the greatest weight were:

- Technological Risks: external technological dependence and privatization of basic knowledge;
- Environmental risks: decrease in biodiversity and effect on target organisms;
- Social risks: hazardous effects on human health and farmers' increased dependence;
- Economics risks: trade barriers to GM crops; Potential Technological benefits: development of cultivars for tropical regions;
- Potential Environmental benefits: water savings in agricultural production;
- Potential Social benefits: production of cheaper foods; Potential Economics benefits: stronger competitiveness in external market and strengthening of the agro industry;
- Observed environmental benefits: reduction in environmental contamination by pesticides;
- Observed social benefits: less exposure of farmers to pesticides;
- Observed economic benefits: decrease in production costs and higher yield per hectare.

Table 4
Global weight of the evaluation criteria by professional category

Scientists	Global score	Companies	Global score	Regulators	Global score
Observed environmental benefits	0.145	Observed economic benefits	0.173	Observed environmental benefits	0.159
Observed economic benefits	0.131	Potential environmental benefits	0.139	Observed social benefits	0.137
Observed technological benefits	0.109	Potential economic benefits	0.107	Environmental risks	0.114
Potential economic benefits	0.096	Observed environmental benefits	0.102	Observed economic benefits	0.108
Potential environmental benefits	0.095	Potential social benefits	0.094	Potential environmental benefits	0.091
Economic risks	0.094	Potential technological benefits	0.083	Social risks	0.090
Environmental risks	0.086	Observed social benefits	0.082	Potential social benefits	0.073
Observed social benefits	0.068	Social risks	0.072	Potential technological benefits	0.064
Potential social benefits	0.067	Environmental risks	0.068	Potential economic benefits	0.062
Social risks	0.058	Economic risks	0.043	Economic risks	0.052
Technological risks	0.050	Technological risks	0.038	Technological risks	0.051

Source: Created by the authors.

4.4. *Results of the multivariate analysis*

The results shown in Picture 2, referring to the answers about the criteria (level 2 in Figure 3) show that 33% of the respondents do not have an opinion or prefer not to answer when asked about which criteria are more important. At first sight, the result may seem frustrating, but when we move on to level 3 of the analysis (subcriteria qualifying the themes, for example, existing economic

Table 5
Results of multicriteria analysis: Average indices of subcriteria

Criteria 1	Criteria 2	Subcriteria	Average	Stand dev
Risks	Technological Risks	Orphan crops	0.238132	0.149145
		External technological dependence	0.268854	0.161294
		Privatization of basic knowledge	0.249144	0.149790
		Sub-investment in alternative technologies	0.243870	0.143990
	Environmental	Appearance of super plagues	0.204585	0.133082
		Effects on no-target organisms	0.215000	0.112673
		Effects on soil ecosystem	0.176237	0.078113
		Biodiversity reduction	0.242351	0.102073
		Genetic pollution	0.161826	0.079349
	Social risks	Harmful effects on human health	0.327916	0.227444
		Unemployment in agriculture	0.211877	0.111653
		Increase in land ownership concentration	0.208253	0.139561
		Intensification of farmers' dependence	0.251954	0.160582
	Economic risks	Increase in production costs	0.296202	0.173830
		Fall in production	0.254520	0.185062
		Trade barriers to GM crops	0.449279	0.249197
Potencial benefits	Technological benefits	Reduction of external technological dependence	0.236106	0.165607
		Development of technologies for sustainable use of biodiversity	0.372099	0.198983
		Development of cultivars for tropical regions	0.391795	0.202466
	Environmental benefits	Use of GM plants for bioremediation	0.197950	0.140425
		Slower rate of deforestation	0.226562	0.137937
		Water savings in agriculture	0.296252	0.132174
		Reduction of contamination by inorganic fertilizers	0.279236	0.137860
	Social benefits	Production of foods with therapeutical properties	0.185776	0.148657
		Production of cheaper foods	0.289680	0.153644
		Reduction of rural poverty	0.244218	0.141418
		Reduction of the number of diseases caused by agrochemical	0.280325	0.143912
	Economic benefits	Stronger competitiveness in external market	0.265530	0.161140
		Strengthening of agro- industry	0.264962	0.141641
		Production diversification	0.221697	0.134949
		Higher stability of agricultural production	0.247811	0.136532
Observed benefits	Environmental benefits	Carbon sequestration and emission reduction	0.165798	0.117916
		Reduction in environmental contamination by pesticides	0.408773	0.141759
		Higher retention of water in soils	0.208752	0.085528
		Reduction in soil erosion	0.216676	0.104204
	Social benefits	Foods with a lesser degree of toxins	0.219389	0.134063
		Increased levels of nutrients in foods	0.184194	0.097660
		Reduced farmers' exposure to pesticides	0.362813	0.140589
		Increase in small farmers' income	0.233604	0.133978
	Economic benefits	Reduction in production costs	0.304825	0.145268
		Higher yield per hectare	0.306909	0.139482
		Higher operational flexibility	0.237835	0.129596
		More time for other activities	0.150430	0.108351

Source: Created by the authors.

benefits, potential social benefits, etc) only 12% remain neutral.

The application of the multivariate analysis (according to the methodology proposed by Crisvisky (1993) and Escofier e Pagés (1989) of starting by an Factorial Analysis of Major Components, and then structure a hierarchy tree of groups of respondents and form partitions or clusters) allowed the analysis pf which subcriteria (from level 3, in Figure 3) most contributed to discriminate respondents and which individuals from each cluster formed, in a partition of 5 clusters, most identified with the meaning of the cluster to which he belongs. [7]

Results are presented in Table 6 and Table 7.

Table 6
Main factorial analyses: Characterizing the 3 main factorial Axes

Factorial Axes	Label	Positive values	Negative values (opposition)
1	Risks concerns	Environmental and social risks	Potential economic benefits
2	Practical reasons: Regulators need to have some answers right now	Observed social and environmental benefits	Potential economic and tech benefits
3	Building bridges to the future	Potential environmental and social impacts	Observed economic benefits

Source: By the authors.

Table 6 summarizes the result o of the factorial analysis, represented over the three most important factorial planes, resulting from the selection of five axes representing 80% of total variance (the three first planes represent 62% of total variance).

Picture 4 summarizes the results of the factorial analysis and the formation of clusters based on the weights of the multicriteria analysis in level in level 3 (see Figure 3). Let us start by analyzing the first factorial plane, the most important. It can be seen that in the first plane, the second quadrant localizes the factors related to strong concerns with environmental and social risks and also existing social and environmental benefits arising from GMOs. The regulators are positioned in this quadrant, who, however, ascribe more weight to existing social and environmental benefits (cluster 4). Still in planes 1 and 2, in the second quadrant, there is a cluster formed by only 11% of the respondents

[7] The formation of 5 clusters was chosen, with over 65% of explanation of total variance, because it was possible to create interesting labels for them. Obviously, the size of the sample limits the conclusions, a problem to be solved in future version of this work, once there are still questionnaires to be incorporated to the data base of the study within the acceptable period of six months to send the answer.

who clearly prioritize environmental and social risks of GMOs. The group essentially comprises those who formulate S&T policies (cluster5).

In the fourth quadrant, nearer to the second axis, are those who do not place any importance on existing benefits, and oppose to short-termed justifications of social and environmental benefits of GMO. Opposing those who privilege the importance of benefits already observed in the social and environmental field are those who observe the potential technological and economic benefits, who argue that the impacts are just beginning and that the technology is powerful (cluster 2). However, these respondents do not do so in the sense implied by Sacastra, Just (2006), when they apply method of real options. It is not about expecting the value of technological contributions overcome the problem caused by irreversible damage, but visualizing the importance of technological development as of today, given its economic and technological potentials.

Table 7
Main factorial analysis: Distribution of group of stakeholder in factorial plans

	Factorial Plans							
	1 and 2				2 and 3			
	I	II	III	IV	I	II	III	IV
Groups of stakeholders	Companies	Regulators	S&T policies			Companies		
Cluster	3	4 and 5				3	4	2

Source: Created by the authors.

The need to introduce a new factorial axis is explained by the bad representation of the potential environmental and social benefits in the first factorial plan. Forming plans 2 and 3, it is possible to verify, on account of the structure of the method, the orthogonal structure made of two components: existing social and environmental benefits with economic benefits. That is a consequence of the method. However, the opposition in factorial axis 3 between economic benefits and potential environmental and social benefits is important.

In the factorial plans 1 and 3, in the first quadrant, the clear position of entrepreneurs appears (cluster 3), defined as the category of potential environmental and social benefits. Along the first factorial axis – the axis formed by those who are concerned with environmental risks – and which places them, along the first factor in clear opposition to the cluster of environmentalists (primarily formed by those who formulate S&T policies and only one representative of the entrepreneurial sector, who is a journalist and not an executive).

Still observing Plans 1 and 3, there is a cluster formed by those who more attentively observe economic aspects as existing economic benefits and also who concern about potential economic and technological benefits (of little importance, as the results shoed in the previous section). This is the first cluster

(Cluster 1), which encompasses the largest group (as seen in Picture Y). It is possible to state that it is not well defined. Only a few of its representatives have a clear notion of their preferences.

In conclusion, in emphasizing contrasts, the multivariate analysis brings information that the simple analysis of the average sum of the weights, conducted in subsections 3.1 and 3.2, does not allow observing. First, there is indeed some consensus that GMOs bring economic benefits. That is denied by few respondents, possibly from the group of the environmentalists, predominantly formed by those who formulate S&T policies.

The vision of the future is presented in a segmented manner: entrepreneurs emphasize potential social and environmental benefits of GMOs, whereas regulators observe existing environmental and social benefits, with no concerns about arguments associated with future GM events. The emphasis on economic and technological potential is more a concern of S&T policy formulators who do not have an environmental profile, generally economists, scientism involved in biosafety issues mad professionals specialized in S&T policies.

5. Conclusions

The present work was motivated by the need to capture criteria and subcriteria involving the current debate on the regulation of genetically modified organisms in Brazil, to involve more than the simple verification that there is a polarization between entrepreneurs and environmentalists. To that end, a questionnaire was created in the multicriteria analysis framework, an innovative procedure, insofar as it forces respondents to have a position about the most polemic issues collected in the literature referring to the dimensions of the impact of GMO crops on the society, economy, technology and environment. The methodological framework also made it possible to capture the relative importance that respondents place on the temporal dimension, represented by existing and potential benefits and also risks.

A total of 57 questionnaires were responded, leading to the formation of four basic groups: Scientists (involved in agricultural biotechnology), Regulators (government member involved in regulatory affairs and monitoring), Entrepreneurs and S&T policy Formulators, being the latter group roughly divided into those more concerned about environmental issues (generally with technical education in this field) and those concerned about biosafety and economic issues. The work also included observing at a more detailed level (Level 4) which specific issues are the focus of a debate on the construction of the GMO regulatory process in Brazil.

The main conclusions are:

- Regarding the second level (themes), there is significative percentage of respondents (1/3) that decide to keep a neutral position, it means, do not assuming any preference between potential benefits, present benefits and risks. It is coherent with the aim of the paper to show the importance to deal regulatory issues in a less aggregate level;

- Analyzing the results of the third level, it means, based on the subcriteria, the main conclusion is that polarization between the vision of entrepreneurs and a sub set of Proponents of S&T policies makers group with an environmental wing;
- The latter group has concerns on social and environmental risk, in spite of the fact they recognize the importance of present economic benefits from the diffusion of GMO. The first group points out the potential social and environmental benefits of GMO, also accepting the importance of present economics benefits;
- The results also show that the group of scientists is not clearly placed on the debate and regulators, on the contrary, have practical concerns, revealed by the weight they give to present social and environmental benefits of GMO. It could not be interpreted as being an approval of GMO without any criticism, but as showing their concerns with broader impacts of the technology, from social and environmental point of view.

For a further exploration of the results, to be presented in another paper, it would be interesting to apply structural regression methods on the third and fourth levels of analysis, in the aim to understand the relation them. The preliminary analysis of the results show that experts points more clearly their preferences in the fourth level, confirming the initial proposition of the paper that polices decision need to be based on a framework capable to capture the different aspects of the building of a regulation on biotechnology.

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