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## A Precautionary Approach to Technology Appraisal? – A multi-criteria mapping of genetic modification in UK agriculture

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**The prospect of genetically modified crops and foods has become a political hot potato in Britain. Food industry executives, government advisors and biotechnologists have been caught unaware of the strength and persistence of public concern. The pilot study by SPRU on multi-criteria mapping of genetically modified crop in agricultural systems in the UK shows how in such an overheated political arena highly polarized disputants can participate constructively in discussion and regulatory appraisal and create a “map” of the debate surrounding GM crops.**

### Some Key Difficulties in Technology Appraisal

The social appraisal of technological risk has always been a difficult undertaking. With diminishing public confidence in traditional expert institutions and procedures, the difficulties seem to be growing. In some quarters, there has been a tendency to see this as mere cultural fashion – reflecting the ephemeral anxieties of the “risk society” (Giddens 1991; Beck 1992; Lash et al. 1996). Under this view, the answer lies in basing the regulatory appraisal process on “sound science”, keeping it as free as possible from the messy and emotive business of politics. In this regard, aspiring “scientific” techniques, such as probabilistic risk assessment and cost-benefit analysis, are sometimes held to offer rational, robust and objective aids to “science based” decision-making.

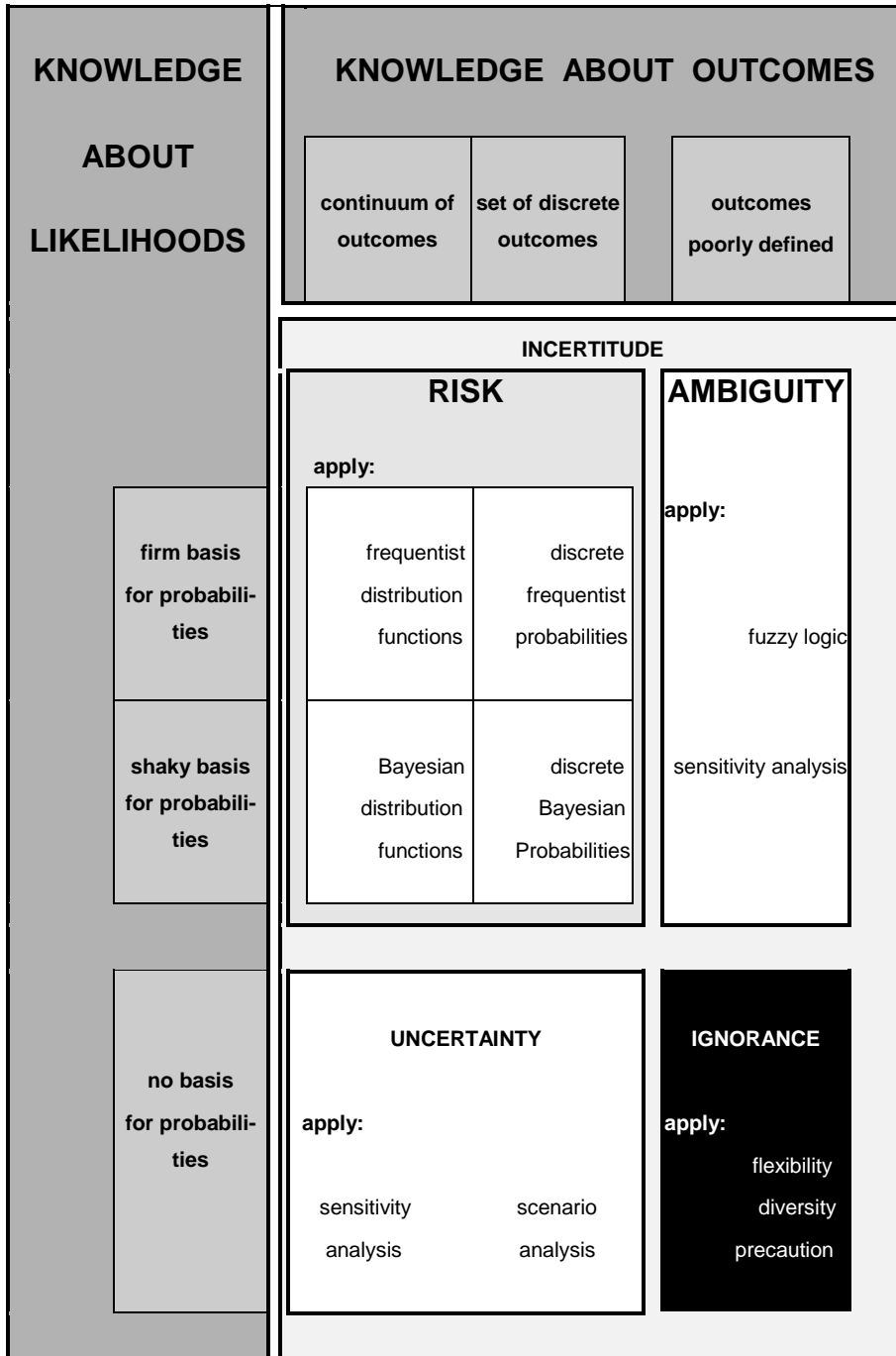
Unfortunately, the difficulties in the social appraisal of technological risk are not so easily resolved. Although the language of “sound science” remains prominent, the available methods and procedures manifestly fail to deliver on the rhetoric. This is not simply a matter of practice failing to live up to potential. Ironically, the reasons for the failure of “sound sci-

ence” as a basis for policy making are fundamental to the science of probability, risk and rational choice itself.

First, there’s the problem of robustness. The scientific assessment of “risk” – defined in the formal sense shown in Figure 1 below –

requires at least some basis for assigning probabilities (Neumann, Morgenstern 1949; Juce and Raiffa 1957). Under conditions of “uncertainty” and “ambiguity”, however, the novelty, idiosyncrasy or complexity of the processes involved can preclude this (Knight 1921;

**Figure 1: Risk, Uncertainty, Ambiguity and Ignorance**



Keynes 1921). Under even less tractable conditions of “ignorance”, not only the probabilities, but also some possibilities may be unknown (Loasby 1976; Smithson 1989; Wynne 1992; Stirling 1998). Even the most authoritative of experts don’t know what they don’t know! Here, as arguably already experienced with BSE, the ozone hole and endocrine-disrupting chemicals – and potentially with genetic modification technologies – we face the prospect of surprise.

The conditions of “ambiguity”, “uncertainty” and “ignorance” are fundamental to the scientific characterisation of risk. Yet, by definition, the techniques of probabilistic risk assessment fail to address these aspects of incertitude. Such techniques are therefore inapplicable to some important and pervasive aspects of environmental decision making. Far from upholding science, persistent adherence to inapplicable methods is quite simply unscientific.

Second, there’s the issue of objectivity. Although often very precisely formulated, the results obtained by risk assessment can be highly sensitive to starting assumptions. In areas ranging from energy, through transport to chemicals, the conclusions of different risk assessments often vary radically – sometimes by many orders of magnitude (Stirling 1997a). This can have profound implications for conclusions over the relative performance of different technology or policy options. Yet the choice of which assumptions to adopt are often contingent and intrinsically subjective (Royal Commission on Environmental Pollution 1998; National Research Council Committee on Risk Characterisation 1996). It is a fundamental finding in the mathematics of rational choice, that there can be no single objective resolution of divergent subjective perspectives (Bonner 1986; Bezembinder 1989). Indeed, the economist Ken Arrow was awarded a Nobel Prize in part for work that shows there can be no single definitive way to order a range of choices in a plural society (Arrow 1963; Kelly 1978). Therefore, instead of making apparently authoritative assertions over risk, a truly scientific approach lies in systematically exploring how the picture changes depending on how it is viewed.

These difficulties, among others, are recognised in the increasing international policy

profile of the “precautionary principle” in the management of technological risk. Although the details are complex and hotly contested, the overarching “precautionary approach” builds on a series of straightforward and well-established ideas: that “*prevention is better than cure*”; that “*the polluter should pay*”; that we should look for “*no regrets*” options; that alternatives should be appraised at the level of *production systems* taken as a whole; and that we should recognise the intrinsic value of non-human – as well as human – life. More specifically, a precautionary approach acknowledges the *complexity* and *variability* of the real world and embodies a certain *humility* about scientific procedures and knowledge. It implies recognition of the *vulnerability* of the natural environment and prioritises the *rights* of those who stand to be affected by an activity, rather than those who stand to benefit from it. It requires scrutiny of all available *alternatives* and an examination of *justifications* and *benefits* as well as risks and costs. In short, a precautionary approach involves the adoption of *long-term, holistic and inclusive* perspectives in environmental protection (O’Riordan, Cameron 1994; Fisher, Harding 1999; Raffensberger, Tickner 1999).

This is all very well, but to some it seems rather abstract and ambiguous – threatening to undermine science by opening the floodgates to subjectivity (Gray, Bewers 1998). Of course, it is true that – though not a panacea – the rigours of science remain essential to the process of risk management. The crucial question is, how can we combine the disciplines of science and precaution in the practical business of technology appraisal? Based on work underlying the recent European Commission Communication on Precaution (European Commission 2000; Stirling 1999), it is possible to construct a series of eight evaluative criteria against which the regulatory appraisal of risk can be assessed both in terms of its scientific rigour and its precautionary qualities. In short, these are as follows:

- *Humility*: Does appraisal fully acknowledge the many sources of uncertainty, ignorance and subjectivity in appraisal? Does it avoid claims to complete or otherwise definitive knowledge?

- *Completeness*: Is the scope of regulatory appraisal of technological risk broad enough to address cumulative, additive, complex, synergistic and indirect effects as well as more direct causal processes?
- *Benefits and Justifications*: Is there systematic consideration of the claimed benefits and justifications as well as adverse effects, in order to allow determination of “net” benefits under different contexts?
- *Comparison*: Is appraisal conducted on a comparative (rather than case-by-case) basis, including a variety of technological and policy options and the cumulative effects across different cases?
- *Participation*: Is there full engagement by all interested and affected parties, both to elicit all relevant knowledge and to include consideration of all pertinent priorities and framing assumptions?
- *Mapping*: Are appraisal results expressed, not as discrete numbers, but using sensitivity analysis systematically to “map” the consequences of different value judgements and framing assumptions?
- *Transparency*: How straightforward are the methods employed? Do they minimise the number of hidden variables and allow detailed auditing of how particular results derive from particular inputs?
- *Diversity*: Does appraisal address the way that diverse mixes of different options may help to hedge against uncertainty and ignorance and help accommodate divergent social perspectives?

These are the considerations that have informed the development of the “multi-criteria mapping” technique employed in the present case study (Stirling 1997b). In short, the motivation behind this approach is to seek to combine the openness and qualitative flexibility of participatory deliberation with the clarity and focus of quantitative assessment. The specific case study with which this method has been piloted concerns the hotly contested debate over the use of genetically modified crops in UK agriculture.

### The Debate over the Regulation of Genetically Modified (GM) Crops

The agricultural use of GM technologies is held by many to promise great benefits. On the other hand, others fear that the use of these technologies in agriculture may result in serious, irreversible harm. In the UK, formal regulatory appraisal of GM crops has centred on the question of whether or not they are “safe” for the environment and for human consumption. However, there is considerable scientific uncertainty over the form and magnitudes of the possible effects and, as yet (by contrast with chemical or nuclear risks), little accumulated practical experience to draw upon. This has led to the evolution of a set of controls which are intended to be precautionary in nature – where it is accepted that action to avoid harm may be taken in the absence of scientific proof – with the conduct of risk assessment being required *before* experimental or commercial use of a particular genetically modified organism is allowed.

Despite this somewhat precautionary approach to risk regulation enshrined in the European Commission’s Deliberate Release Directive (European Commission 1990) and the Novel Foods Regulation, the regulatory appraisal process has failed to gain confidence, either of Non-Governmental Organisations (NGOs), private industry (Mayer et al. 1996) or the general public (EPCAG 1997; Grove-White et al. 1997). This lack of confidence arises among other reasons: because the scope of the regulatory appraisal is still held in many quarters to be too narrow; because there is a general lack of trust in official reassurances of safety (particularly in the wake of BSE); and because justifications and benefits are not explicitly included in the evaluation process. Industry and regulators have expressed frustration, believing that the precautionary approach is being invoked in too burdensome a fashion, with unrealistic demands being made concerning absolute proof of safety.

It has also been almost impossible to gain agreement between European Member States over whether particular commercial releases of GM crops are environmentally “safe”, despite a supposedly common approach to their risk assessment (Schomberg 1998; Wynne, Mayer 1999). Disputes routinely emerge over the appropriate scope of regulatory appraisal. Even where there is agreement over the possibility that effects will occur, notions of what constitute *adverse* effects remain strongly contested.

These sorts of problems with the current regulatory appraisal of GM crops are typical of those that beset the use of conventional risk assessment and cost benefit analysis in other areas. Taken together, these characteristics of the UK and European debate over the application of GM technologies in agriculture make it a challenging candidate for a case study concerning the potential for combining the systematic quantitative rigours of science with the breadth and flexibility of precaution.

### The Multi-Criteria Mapping Pilot Study

The details of the multi-criteria mapping methodology and this particular application in the GM field in the UK are described at length elsewhere (Stirling, Mayer 1999, 2000). Only a summary will be attempted here. The study “*A pilot multi-criteria mapping of a genetically modified crop in agricultural systems in the UK*” was performed by the Science and Technology Policy Research (SPRU) unit of the University of Sussex and took place between April 1998 and September 1999. It was funded by the transnational food firm Unilever, but was entirely independent in its conception, design, implementation and reporting. The two authors come from an academic and NGO background and the project was overseen by a steering group comprising a wide range of environmental, consumer, farming and food industry representatives. The specific topic chosen for the study was the production of oilseed rape in the UK. Six “basic options” were identified in advance for the purposes of comparison (Table 1).

**Table 1: The Definitions of the “Basic Options” Appraised by all Participants**

OPTION	DEFINITION
Organic Agriculture	All farming and food production conducted under present day organic standards
Integrated Pest Management	All farming and food production conducted using systems designed to limit but not exclude chemical inputs and with greater emphasis on biological control systems than conventional systems.
Conventional Agriculture	All farming and food production conducted under present day intensive systems.
GM oilseed rape with segregation and present systems of labelling	Labelling based on the presence of foreign DNA or protein in the final product.
GM oilseed rape with post-release monitoring	Monitoring for effects (mainly environmental) conducted on an on-going basis after commercialisation.
GM oilseed rape with voluntary controls on areas of cultivation	Areas of growing of GM oilseed rape restricted on a voluntary basis to avoid unwanted effects such as gene flow and cross fertilisation of non-GM crops.
Up to six additional options to be specified by participant	Any option of participant’s choice including combinations of the above if desired

In consultation with the steering group, twelve individual high profile protagonists in the GM food debate were selected as participants. These individuals came from a variety of backgrounds, including academics and government advisers, environmental, consumer and religious organisations and representatives from the farming, food and biotechnology industries. Of course, it is impossible to claim any “statistically representative” status for such a small sample. However, care was taken that, between them, the group of participants covered a full “envelope” of specialist and socio-political perspectives – ranging, for instance, from strongly opposed to strongly in favour of the use of GM crops. Given the character of the UK GM debate at the time of the study (1998-1999), it was necessary to give undertakings of anonymity in order to secure participants’ involvement. However, the viewpoints of participants are reproduced individually, being identified by a code letter and an affiliation with one of four general groupings of perspectives:

“academic”, “NGO”, “industry” or “government” (Table 2).

**Table 2: The Participants**

AREA	CODE
Agriculture and food industry	B, L, H, K
Academic scientists	C, J
Government safety advisors	E, F
Religious and public interest groups	A, D, G, I

During a 2-3 hour individual interview, each participant undertook a four stage process: (i) the identification of additional options; (ii) the defining of appraisal criteria under which the options should be assessed; (iii) the scoring of the performance of each option under each criterion and (iv) the weighting of each criterion in terms of its relative importance. A straightforward “linear additive” multi-criteria procedure was employed using a simple spreadsheet model mounted on a portable computer in order to display to the participant the results of the scoring and weighting process as it developed. The process then iterated cyclically until the participant was satisfied that the results accurately reflected their own personal perspective and professional judgement on the issues at hand (Fig. 2).

One crucial feature of the scoring process was the deliberate eliciting of a range of performance scores for each option under each criterion. Rather than providing a single “best guess”, this allowed consideration of a range of optimistic and pessimistic assumptions under each perspective. The discussion of the associated issues were then carefully documented and provided an interesting reflection of the importance of technical uncertainties in the final picture of performance derived under each perspective.

In the period following the interviews, participants were each contacted and asked to consider one final aspect of appraisal. This concerned the role of deliberate diversification among options as a means to implement two crucial features of the precautionary approach discussed earlier in this paper: the desire to hedge against intractable uncertainties and ignorance and to accommodate a variety of socio-political viewpoints. For this purpose, a simple index of diversity was borrowed from mathematical ecology and information theory

in order to model different trade-offs between the value attached to the performance of individual options and the value attached to diversity in the mix of options. The details of this method are described in more detail elsewhere (Stirling, Mayer 1999, 2000). In short, participants can choose to assign a “zero”, “low”, “medium” or “high” weighting to diversity. Where this takes a zero value, then only the best-performing option is included in the favoured mix. Where higher weightings are placed on diversity, progressively greater contributions are included from lower-performing options – drawn on in proportion to their relative performance under the perspective in question. In this way, the study was able to elicit a crude notion of the importance of ignorance and pluralism under the different perspectives.

As analysis proceeded, participants were asked to review the results of a thorough sensitivity analysis conducted on their own set of weightings. Along with an invitation that participants retain the spreadsheet model and freely experiment with it at their leisure, this provided a further means to verify that the final results represented a robust reflection of the different viewpoints. Finally, all participants were invited to a concluding workshop at which the results were again confirmed and used as a basis for wider-ranging discussion.

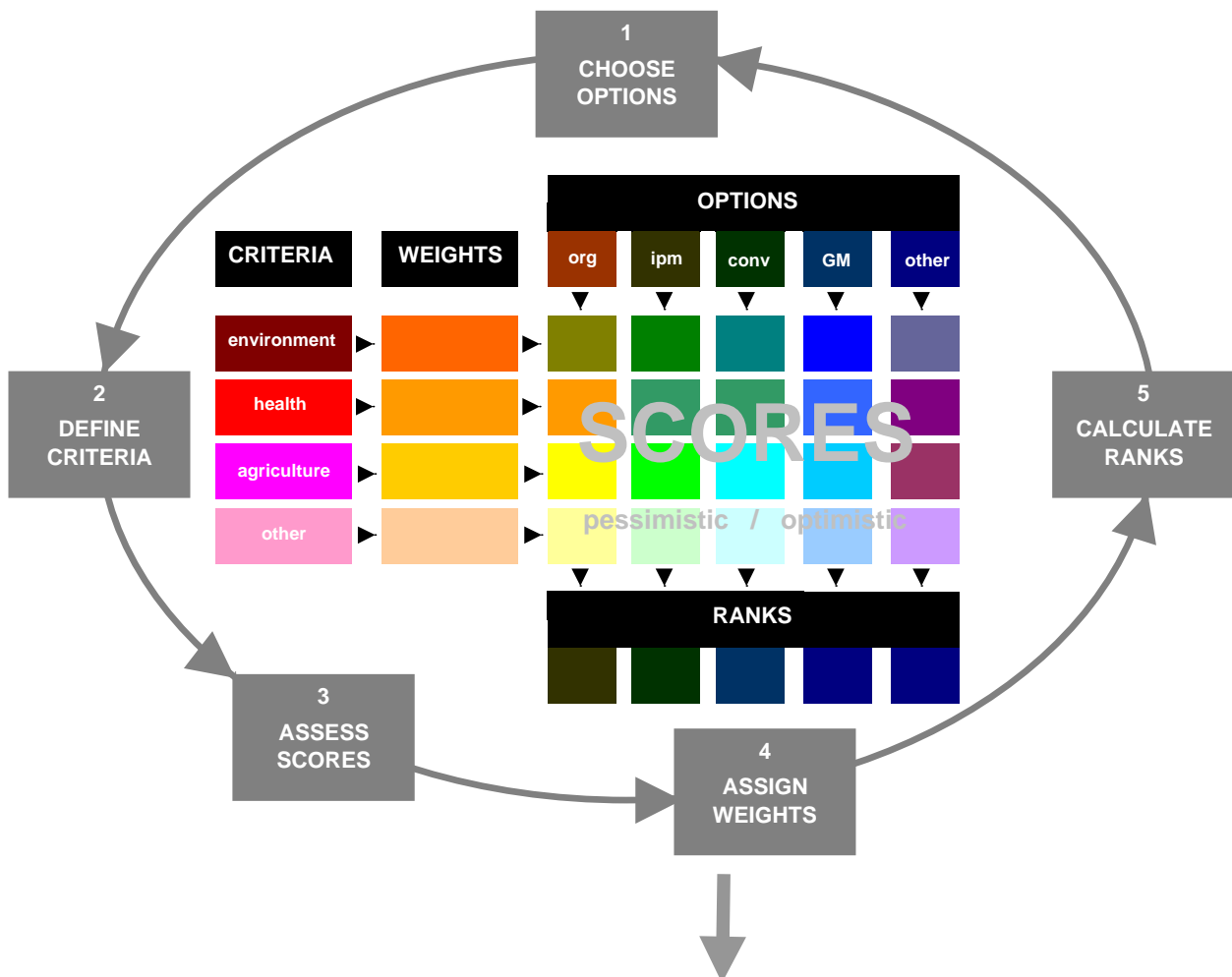
## Findings

The procedure summarised above generated a rich body of empirical material, reflecting a very wide range of issues bearing on the regulatory appraisal of GM technologies in agriculture. The key points will be summarised here.

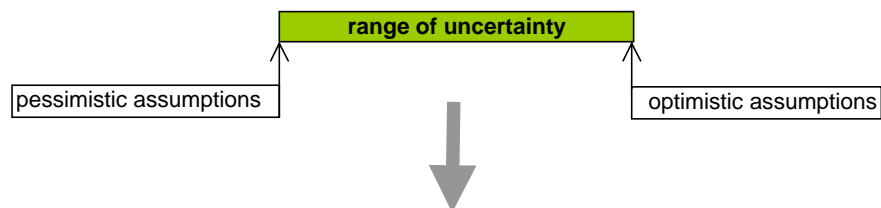
### Options

In addition to the six “basic options” a further 18 alternative agricultural strategies were identified and evaluated by participants. These included many different labelling and control regimes and the application of a series of different regulatory assessment procedures and criteria. They also involved a variety of different agricultural strategies, including a focus on hypothetical strategies using GM technologies

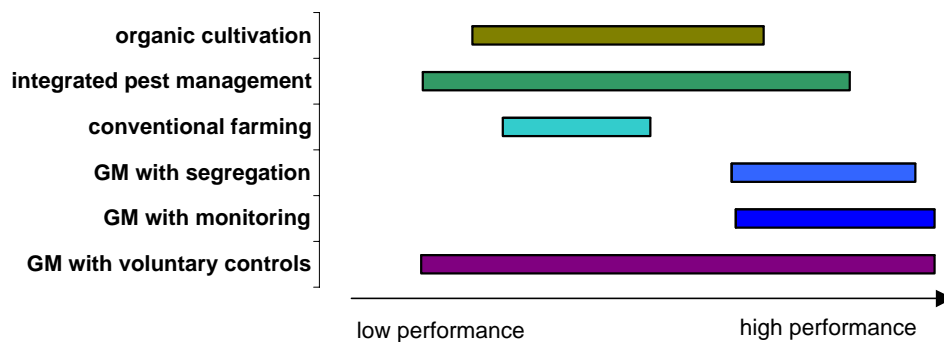
Figure 2: The Multi-Criteria Mapping Process



EACH OPTION RANK IS EXPRESSED AS A RANGE



AN OVERALL RANKING ORDER IS GENERATED FOR EACH PERSPECTIVE



under an organic farming regime. Interestingly these tended to perform relatively well under the perspectives of participants from both sides of the GM debate (Table 3).

**Table 3: Additional Options Defined by Participants**

<b>Labelling and/or other controls</b>	GM crops with segregation, full labelling and post-release monitoring and legally binding growing contracts	A
	GM crops with segregation, current labelling and post-release monitoring	F
	GM crops with segregation, full labelling and post release monitoring	H
	GM crops with segregation and labelling according to means of production and source of gene, plus post-release monitoring	G
	GM crops with segregation, comprehensive labelling based on process and generic restrictions on some classes e.g. in centre of origin	I
	GM crops within controlled sectors (compulsory control)	A
	GM crops with legally binding threshold for gene transfer to non-GM stream	A
<b>Agricultural system</b>	GM crops, IPM system	G
	GM crops, IPM system	J
	No GM crops – conventional and organic as now	K
	GM crops in conventional and organic systems	K
	GM crops, organic agricultural system, plus segregation, labelling and other regulations as required	J
<b>Assessment criteria</b>	GM crops with quality	B
	GM crops with assessment of indirect agricultural impact and assessment of need	I
<b>Other</b>	GM crops only in USA	A
	No GM commodity crops	A
	Complete public control over choice	C

### Criteria

A total of 117 appraisal criteria were defined by different participants. Although some of these are apparently closely related, all embody important differences of emphasis or framing. It is interesting that criteria typically reflect issues not only of consumer choice but also of citizenship and wider questions of participation and agency. Collectively they cover a very wide range of considerations, including envi-

ronmental, agricultural, health, economic, social and ethical issues. Most of these issues are very remote from the factors included in orthodox risk assessment. Indeed, for no participant was it true that the full range of their concerns is fully addressed by existing regulatory appraisal procedures in the UK (Table 4)

### Performance Scores

The pattern displayed by the performance scores assigned by participants under the various groups of criteria shows that the differences between perspectives are not simply due to variations in the weighting placed on different criteria. Participants adopt a variety of different “framing assumptions”, resulting in significant differences in the scores assigned by different participants under the same criteria. This has implications for conventional multi-criteria analysis, in which scoring is often conducted by a separate body of experts, with an assumption that different value judgements can be captured simply in the weightings. Despite these differences, however, the patterns evident in the scoring do allow certain general conclusions. For instance, under all perspectives the organic option tends to perform well under environmental criteria. Also, the evident divergence between the patterns of performance under health and environmental criteria challenge conventional assumptions that these aspects of performance will *necessarily* be well correlated.

### Weightings

Notwithstanding the complications raised with respect to scoring above, the patterns evident in the weightings do illuminate some interesting, if rather unsurprising, features. Perspectives drawn from the biotechnology industry and food supply chain are conspicuous in their relative under-emphasis of the social and/or environmental and safety considerations which are prominent under all other perspectives. The perspectives adopted by government advisers have the distinctive characteristic of being at the same time relatively narrow in scope whilst emphasising environmental and safety considerations. The perspectives expressed by the non-industry participants share a markedly lower emphasis on economic or agricultural considerations.

**Table 4: Broad Groupings of Criteria Defined by Participants**

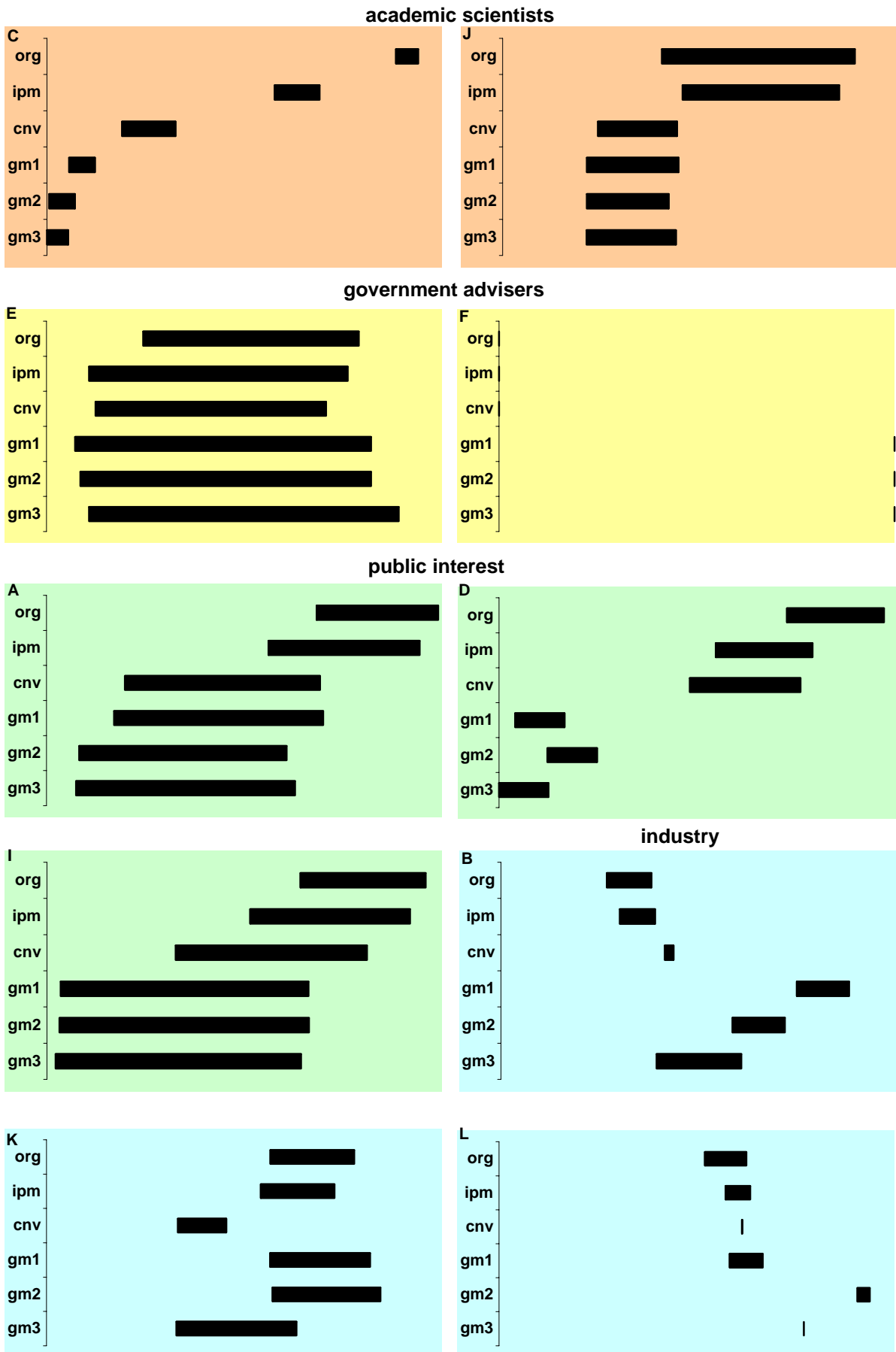
ENVIRONMENT	Biodiversity	<i>eg: field boundary ecology, other environmental risks</i>
	Chemical use	<i>eg: reduction in use of existing herbicide sprays, benefits of contact herbicides versus soil acting residuals, longer term pollution of air and water</i>
	Genetic pollution	<i>eg: gene flow to other crops and native flora</i>
	Wildlife effects	<i>eg: Impact of enhanced weed control efficiency on wildlife, other practices affecting wildlife value of agricultural systems</i>
	Unexpected effects	<i>eg: potential for effects not foresee under this scheme</i>
	Visual	<i>eg: amenity impacts]</i>
	Aesthetics	<i>eg: feelings about environment</i>
HEALTH	Allergenicity	<i>eg: from food consumption</i>
	Toxicity	<i>eg: human or animal health</i>
	Nutrition	<i>eg: to consumers</i>
	Unexpected effects	<i>eg: unexpected interactions between ingredients, stability of genetic insert</i>
	Ability to manage	<i>eg: traceability and ease of recall</i>
AGRICULTURE	Weed control	<i>eg: invasive volunteers and weedy relatives</i>
	Food supply stability	<i>eg: sustainability, tendency to monocultures, global food security</i>
	Agricultural practice	<i>eg: farmers' rights, choice and quality of life, land requirements</i>
ECONOMY	Consumer benefit	<i>eg: retail price</i>
	Producers benefit	<i>eg: shorter term costs, yield or longer term value added</i>
	Benefit to processor	<i>eg: profitability</i>
	Socio-economic impact	<i>eg: welfare of small farmers, substitutions for developing countries</i>
SOCIETY	Individual impacts	<i>eg: consumer choice, transparency, accessibility, participation, pluralism</i>
	Institutional impacts	<i>eg: concentration of power, institutional trust, regulatory complexity</i>
	Social needs	<i>eg: new opportunities, opportunity costs, misuse of science, employment, quality of life</i>
ETHICS	Fundamental principles	<i>eg: animal welfare, taking care of nature</i>
	Knowledge base	<i>eg: hubris about scientific knowledge</i>

### Rankings

Perhaps the most important output of the multi-criteria mapping procedure are the patterns in the final rankings obtained under the various participant's perspectives. Indeed, it is this picture which constitutes the "map" referred to in the name of the technique, reflecting the way that final results vary with starting assumptions. Figure 3 displays the results obtained in the present exercise for the ten participants from whom it was possible to elicit all the necessary quantitative inputs (the remaining two –

G and H – expressed difficulties either in the scoring or weighting process). Each chart represents the rankings elicited from a single participant. The sequence of basic options is the same in each case, running top to bottom from organic farming, through integrated pest management and conventional intensive agriculture to GM crops with (respectively) segregation and labelling, monitoring and voluntary controls. The extension of the horizontal bars to the right reflects the overall performance of the option under that perspective – the further to

Figure 3: Final Rankings for the Basic Options under the Perspectives of Individual Participants



the right, the better the performance. The scale is in arbitrary subjective linear units of performance. The length of the bars shows the difference between the performance under optimistic and pessimistic assumptions under each perspective, providing a useful indication of the relative importance of uncertainties.

A number of features can be distinguished in this picture. First, it is clear that there exist profound differences between the practical implications of the perspectives adopted by different participants. In an orthodox regulatory appraisal procedure (such as risk assessment) such variability would typically be concealed by the emphasis on a single aggregated position. In the present analysis, on the other hand, the idiosyncrasies of each individual position are clearly displayed. Second, the pervasive importance of uncertainty is shown by the overlap between the bars. However, it can be seen that the differences between ranking orders obtained under optimistic and pessimistic scores are generally rather small compared to the differences between perspectives. This suggests that it is not generally the technical dimensions of uncertainty which are the key issue, but rather more intangible qualitative aspects concerning the divergent interests, values and framing assumptions adopted by different participants. Third, despite the variability in the evaluations of different participants, there emerge a series of consistencies. With only a few exceptions, the organic option tends to perform relatively well. Conventional intensive agriculture tends to perform uniformly badly. The voluntary controls regime for GM crops is regarded rather poorly by industry, academic and NGO participants alike, being viewed favourably only by the government advisers.

#### *Diversity*

The final issue concerns the merits of diversification as a precautionary response to uncertainty, ignorance and divergent values. Diverse mixes of agricultural strategies were favoured by each of the seven participants who were able to respond to this part of the analysis. Each individual option relates to some arbitrary measure of importance, such as “share of output” or “share of land in production”. For present purposes, the details do not affect the

broad-brush conclusions. What is interesting is that six of these participants – drawn from all sides of the debate – favour the deliberate pursuit of some degree of diversity. The remaining participant – a senior UK government safety adviser – displays a uniquely high degree of confidence in the validity and robustness of their own perspective. Together with the idiosyncrasies evident in the rankings displayed in Figure 3, this is, in itself, an informative result. Taken as a whole, this part of the multi-criteria mapping analysis might be taken to raise questions over the extent to which R&D and regulatory policy making should be geared towards active encouragement of a variety of techniques rather than assuming or emphasising a single particular trajectory. Given the broad support expressed from all sides of the debate for the principle of diversity, questions might also be raised over how to treat options that display characteristics that militate against diversity.

In summary, then, this pilot multi-criteria mapping exercise permits a series of quite subtle and specific observations to be made concerning the character of the debate and the positions of the different protagonists. However, it also provides a basis for some general normative conclusions concerning the options under appraisal. These findings are all the more robust, for being set firmly in the context of systematic exploration and acknowledgement of the underlying variability and dissent. In particular, in the present case, the picture is quite unequivocal with respect to the relatively negative performance of conventional intensive farming and voluntary controls on the use of GM crops. If equal attention is paid to each perspective, then it is clear that the organic farming and integrated pest management options tend to perform significantly better overall.

#### **Conclusions**

This paper began with the identification of a set of eight criteria which might be held to combine key characteristics of both science and precaution. Although only a single pilot study, the present exercise does offer a basis for some conclusions over the practical efficacy of these criteria in the regulatory appraisal of technological risk.

The results of this exercise are more *complete* than orthodox risk assessment, in that they embody consideration of an unlimited array of issues. They also include consideration of a wide range of different *strategic alternatives* to the use of GM technologies. Equal attention is given to the *justifications and benefits*, as to the impacts and costs associated with the various options. The appraisal is inherently *participatory*, in that the results fully reflect the perspectives of a wide range of different socio-economic and cultural interests. The relative simplicity and auditability of the weighting and scoring approach retains a high degree of *transparency*. A central feature is the focus on the systematic *mapping* of the way in which specific results relate to specific assumptions in appraisal. This, together with the explicit attention given to more *diverse* mixes of options, embodies a greater degree of *humility* in the face of ignorance and pluralism than is normally displayed in risk assessment.

In this way, it may be concluded that there seems no reason in principle why conventional regulatory appraisal might not be adapted to better address the imperatives both of science and precaution. The present pilot exercise was not prohibitive in scale, being conducted by two researchers working part-time over a period of eighteen months. Though necessarily provisional, the consistencies displayed in the results show that it is possible – despite the breadth of the process – to draw some quite robust conclusions over the relative performance of options such as organic farming, conventional intensive agriculture and voluntary control regimes for the use of GM crops. Although the techniques of risk assessment continue to offer useful tools in addressing certain specific aspects, there seems to be no compelling theoretical, methodological or practical reasons for persisting in basing the entire business of regulatory appraisal on these inherently constrained and limited methods.

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## Innovation, Unsicherheit und Öffentlichkeitsbeteiligung\*

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**Die Gestaltung der technologischen Entwicklung ist eine schwierige gesellschaftliche Aufgabe bei der Zukunftssicherung unter Unsicherheit. Der Beitrag macht deutlich, dass es vor allem darum geht, unsicheres Wissen qualifiziert zu bewerten. Am Beispiel der Biotechnologie wird dargestellt, wie ein Modell zur Evidenzbewertung mit dem Ziel der Entscheidungsunterstützung aufgebaut werden kann und wie dabei gesellschaftliche Akteure einzubeziehen sind.**

### Neue Schlüsseltechnologien

Mit dem Wechsel zum 21. Jahrhundert wird ein grundlegender Wandel von Produktions- und Lebensprozessen erwartet. Es ist von einer dritten industriellen Revolution die Rede (Thurrow 1999). Im Mittelpunkt stehen dabei die Entwicklungen in der Biotechnologie, der Mikroelektronik, den neuen Materialwissenschaften, der Telekommunikation, der Robotik sowie in den Computerwissenschaften.

Die hohen Erwartungen an die neuen Technologien sind jedoch nicht ungeteilt. Alles nur übertriebene Aufregung und leuchtende Seifenblasen, wie der Materialforscher Rustum Roy (Schnabel 2000) kritisch einwendet? Oder werden sogar neue Risikopotenziale in die Welt gesetzt?

Bei der Bewertung solcher Technologien sind alle Möglichkeiten zu prüfen. Denn Chancen dürfen nicht verpasst und Risiken nicht übersehen werden. In einer offenen Zivilgesellschaft hat dies unter Einbeziehung unterschiedlicher gesellschaftlicher Gruppen zu erfolgen. Insbesondere sind diejenigen zu berücksichtigen, die die Konsequenzen von Entscheidungen mitzutragen haben.

Für eine solche Bewertung braucht die Gesellschaft ein umfassendes Bewertungssystem. Dabei hat das Leitbild der Nachhaltigen Entwicklung zunehmend an Bedeutung gewonnen. Wir gehen bei der Chancen- und Risi-