

The Impact of Institutions on Innovation: The Case of Biotechnology (EW02-177)

A European Science Foundation Exploratory Workshop

Barcelona, 19-20 September 2003

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1. Executive Summary

This two-day conference provided a forum for a wide variety of methods and questions to be applied to the area of biotechnology and, as a sub-focus, agricultural biotechnology. Participants were drawn from a variety of countries and a variety of perspectives, making the discussions wide-ranging and stimulating.

The workshop was divided into three sessions, each focussing on a different aspect of the topic.

The first session comprised three papers related to spillovers and the diffusion of agricultural biotechnologies, and was chaired by Bruno Cassiman (IESE Business School, Universidad de Navarra). The following papers were presented:

- 'What Determines Technological Hits? Geography and Firm Competencies in Biotechnology vs. 'Traditional' Chemicals', Myriam Mariani (MERIT, University of Maastricht and University of Camerino)
- 'Intellectual Property Rights in Agricultural Biotechnologies and the Global Diffusion of Productivity Gains', Timo Goeschl (University of Cambridge) and Timothy Swanson (University College London)
- 'The Impact of Knowledge Base and Spillovers: Evidence from Biotechnology Patents in the Foods Sector', Myriam Carrère (INRA, France) and Mhamed-Ali El-Aroui (Institut Supérieur de Gestion de Tunis,

The second session comprised three papers on the relationships between organisation, regulation and innovation, and was chaired by Katharine Rockett (University of Essex and CEPR).

- 'Incentive Problems in the Introduction of New Technology when the Advisor is an Interested Party', Silvia Sonderegger (University of Bristol)
- 'Competition Market Structure and Innovation', Xavier Vives (INSEAD, Fontainebleau and CEPR)
- 'The UK's Stake in the Biotechnology Debate: Global Competition and Regulatory Politics', Brian Salter (University of East Anglia) and Michael Smith (University of Georgia)

In the third and final session, chaired by Dietmar Harhoff, two papers examining issues related to patent protection were presented.

- 'Estimating Probabilities of EPO Patent Oppositions in a Bayesian Semiparametric Regression Framework', Alexander Jerak (Universität München) and Stefan Wagner (Universität München)
- 'Optimal Patent Protection When Innovation is Sequential', Andreas Panagopoulos (University of Bristol)

The conclusions of the presentations can be summarised as follows. First, geographical proximity of researchers in different firms may be particularly beneficial in the field of biotechnology, while in more traditional sectors, it appears more important for researchers within a firm to be located close together. Second, the observed conservatism of larger firms in the face of technological change may be due to agency problems involving the evaluation of the quality of new technologies. Smaller firms, that suffer less from such problems, might be expected to be less conservative and hence be earlier adopters of the new technology. Some

evidence of this appears to hold in the foods sector. Third, strong intellectual property rights may have a benefit in terms of creating incentives to innovate, but there may be effects of these rights on the development of some of the least advanced countries. While these may not all be negative, they need to be taken into account. Further, strong rights may reduce the competitive incentive to innovate. Fourth, GM regulation could serve as a model for regulation in other sectors to the extent that it has been more inclusive and broad-based than previous regulatory policies. Finally, the wider reach of more recent agricultural biotechnology patents may indicate not only their increased potential profitability, but also a potential rise in patent oppositions activity.

Although all papers presented advanced results regarding the nature of innovation in biotechnology, none of the results was uncontroversial. Hence, the benefits of the conference were at the level of general theoretical advance, a wide application of novel techniques to the analysis of questions concerning biotechnology, and stimulating debate and indicating areas of future research on both biotechnology and on the analysis of technological innovation more generally. Furthermore, there are relatively few studies of the economic dimensions of the production, protection and sale of GM foods. There appears to be disagreement about how to regulate this sector, as evidenced by the distinct regulatory stances of the US and Europe, and how to grant intellectual property protection to innovations relating to this sector. More broadly, GM is an emerging major new technology. As such, the workshop brought benefits to specialists in the management and dissemination of innovations.

2. Scientific Content of the Event

The ESF and CEPR, in collaboration with IESE Business School, organised an exploratory workshop on biotechnology and innovation in Barcelona, on the 19th and 20th of September, 2003. The conference was entitled *The Impact of Institutions on Innovation: The Case of Biotechnology*, and was organized by **Bruno Cassiman** (IESE Business School, Universidad de Navarra), **Dietmar Harhoff** (Universität München and CEPR), **Pierre Régibeau** (University of Essex and CEPR), and **Katharine Rockett** (University of Essex and CEPR).

The **case for the workshop** in the proposal that led to the conference pointed out that there had been few studies on the economic dimensions of the production, intellectual property protection, and sale of GM foods. Further, there was disagreement about how to regulate the sector, with different countries following different regulatory models. The proposal also pointed out that, as an emerging major new technology, the study of GM could hold great interest for specialists in the management and dissemination of innovations. Every effort was made to elicit presentation of recent and currently developing work, engage researchers from a variety of disciplines, encourage co-authorships, present information on GM that could lead to more informed work in this area, and generate new research ideas. In order to broaden the relevance of the workshop, the title was changed so to encompass biotechnology in general, rather than focussing solely on GM foods. Finally, involvement throughout Europe was also sought.

The sessions in the proposal focussed on regulatory structure, intellectual property and competition policy, patent oppositions, a comparison of GM to other areas of biotechnology, and the broader theoretical treatment of new innovation and its regulation.

As will be clear from the detailed discussion that follows, the workshop produced presentations on the range of topics that had been scheduled, focussed on recent and developing work, and covered both empirical and theoretical issues. A wide range of participants from Europe attended, coming from different approaches within Economics (institutional, theoretical, empirical, evolutionary, law and economics), and outside of Economics (business, politics, statistics). Several co-authorships have been reported to me as coming out of the workshop, discussion was lively, and overall the conference was stimulating. In this sense, it met its original **overall objectives**.

Putting the contributions of the presentations together, broad **conclusions** that could be drawn could be summarised as follows:

1. Geographical proximity of researchers (as in the case of research parks) may be particularly beneficial in biotechnology. In the case of food innovations, this may be qualified by saying that contact outside of the traditional areas of food research may be especially beneficial. In more traditional sectors, it appears more important for researchers within a firm to be located close together.
2. The frequently observed phenomenon of conservatism in the face of technological change may be due to agency problems, resulting in biased reporting by 'experts' of the quality of the newer technologies. This effect would be expected to get worse, the larger the firm, and could explain the reticence of larger firms to be leaders in the adoption of new technologies.
3. Strong intellectual property rights in biotechnology (and especially agricultural biotechnology) have pros and cons. In one sense, strong rights could be seen as creating a profit incentive to innovate. On the other side, there may be effects of these rights on the development of some of the least advanced countries. While these may not

all be negative, they need to be taken into account. Further, strong rights may reduce the competitive incentive to innovate. The optimal strength of intellectual property protection to apply might depend on the relative promise of the newer technology and hence might best be determined on a case-by-case basis.

4. A new model of regulatory control, involving a much broader base (including consumers, scientists, and many others) has been applied with some success in the UK for agricultural biotechnology. This could serve as a model for regulation in other sectors. Unfortunately, it may suffer from some fragility in the sense that minor errors in the regulatory process may magnify, rather than dampen, potentially causing significant instability in the industry.
5. The wider reach of more recent agricultural biotechnology patents may indicate not only their increased potential profitability, but also a potential rise in patent oppositions activity. Clearly, such legal hurdles should be taken into account in the research planning of the enterprises involved.

A **detailed description** of the papers presented follows.

The **first session** of the workshop, chaired by **Bruno Cassiman** (IESE Business School, Universidad de Navarra), comprised three papers related to **spillovers and the diffusion of agricultural biotechnologies**.

In the first paper of the session, entitled 'What Determines Technological Hits? Geography and Firm Competencies in Biotechnology vs. 'Traditional' Chemicals', **Myriam Mariani** (MERIT, University of Maastricht and University of Camerino) tried to put together insights from streams of work ascribing the eventual value of innovations either to firm competencies or to geographical location. Hence, her work drew heavily from the literature on Economic Geography. Using patent citations to proxy innovation value, she sought to do this, using a sample of 4,304 randomly selected European chemical patents applied for by 705 firms in the chemical and biotechnology sectors, from 1987-96.

The paper's main result was that in the 'traditional' chemical sectors (organic chemicals, materials, pharmaceuticals and polymers), the probability of developing technological 'hits' critically depended on economies of scale in R&D internal to the firm, while geographically localised knowledge spillovers played no role. By contrast, in the new 'biotechnology' sector, not only were firm characteristics important, but the probability of producing technological hits also depended on geographically localised knowledge spillovers. Mariani thus argued that the centrality of firms *vis-à-vis* regions underlined a more general contrast between two different models of producing innovations. One could also view her work as providing a solid grounding for the promotion of research parks for ventures in biotechnology (and in agricultural biotechnology, in particular).

In his discussion of the paper, **Pierre Régibeau** (University of Essex and CEPR) commented that, whereas many authors insist on the importance of either geographical location, or firm competencies alone, this paper had the advantage of putting the two points of view together. Nevertheless, he also highlighted the fact that though the dataset was very rich and lent itself to a wide variety of tests, the author sometimes glossed over some variables that could have been better explained, especially when their signs or magnitudes were not as might otherwise have been expected. Interestingly, he highlighted the result that there appears to be a difference between the importance of geography in stimulating research when researchers in the *same* company are grouped geographically and when researchers in *different* companies are grouped geographically. This is an important point, as grouping researchers within the same firm is primarily a strategic management issue, whereas grouping researchers from different firms is an

issue of concern for public policy (towards research parks, for example). Hence, he concluded that this paper points to several important avenues for investigation in several literatures. In further comments, **Ramon Marimon** (CREI, Universitat Pompeu Fabra and CEPR) suggested that it might be interesting to take industry concentration into account in the analysis, a point with which the author agreed, mentioning her intention to do so.

The second paper of the first session, by **Timo Goeschl** (University of Cambridge) and **Timothy Swanson** examined from an agricultural economics and development standpoint the performance of yields in developing and developed countries for the eight most important agricultural crops over a period from 1961-99. The paper was entitled 'Intellectual Property Rights in Agricultural Biotechnologies and the Global Diffusion of Productivity Gains', and was presented by Timo Goeschl. The authors argued that while global gains in yields and productivity have been impressive in the last fifty years, these gains have not been distributed uniformly. The relative yield gap between developed and developing countries across these major crop varieties is on average about 57 percent lower in developing countries, meaning that they are operating far off the productivity frontier in the agricultural sector and participating in less of the general gains in the global agriculture. The main contribution of the paper is to show how property rights structures have added to differential rates of diffusion of technical change. In particular, the paper argues that differences in the type of intellectual property rights protection can explain the differences in relative yields across crops. Strong property rights over innovations have two clear effects: not only do they advance the rate of innovation at the frontier, but also they slow the rate at which these innovations diffuse to countries off that frontier. The results indicate that there is absolute convergence to developed country levels except for two particular crops (maize and sorghum). This can be explained by the exceptionally low rate of diffusion of innovations from developed to developing countries in these crops. In the study, hybridisation is taken as a proxy for stronger intellectual property rights, as hybrids lose much of their productivity when seeds are re-used. Hybridisation has been particularly evident in maize and sorghum. In fact, the econometric analysis indicates that the rate of diffusion is slower for hybrids than for the traditional seeds, suggesting that stronger intellectual property rights regimes might promote innovation, but inhibit diffusion in this area. Further, the rates of diffusion appear particularly slow for countries that are the least developed. This could create concerns that the promotion of stronger intellectual property rights regimes in agricultural biotechnology, in particular in recent years with the advent of GM varieties, could work against the interest of those countries that are least advanced agriculturally.

The main issue raised by **Carolin Socher** (Universität Munchen) was the need to include additional variables to control for other factors, such as different climates, subsidy policies and trade barriers. She also pointed out the need to differentiate between 'gene' and 'green' revolutions and the possibility of including a dummy variable to differentiate these two terms. **Shyama Ramani** (INRA, France) noticed that the yield gap between developed and developing countries can be seen also as an incentive problem. The country specific nature of hybrid crops obliges firms to make country-specific investments that would be taken only if firms can secure future demand sustainability. This is the main difference between hybrids and other innovations, such as AIDS medicines, which are not country specific and, once developed, can be sold all over the world. For example in India, private firms that own an agricultural technology cannot sell it directly to farmers since all contracts must pass through the central Government and local dealers. These firms usually have no incentive to make technology transfer to developing countries simply because sustainable demand may not exist or local governments may not protect the technology transfer agreements. **Dietmar Harhoff** (Universität München and CEPR) stressed once again the need to include some additional control variables. He also pointed out that, while the rate of catch up might be slower for hybrids, the rate of productivity improvement in hybrids is double that of traditional seeds. As a result, hybrids yield a much faster rate of

productivity gain for less developed countries. Hence, even if the least advanced countries benefit least from these technological advances, they do still benefit significantly in terms of productivity. Contrary to the conclusions of the paper, this should generate a reason to *promote* strong intellectual property regimes precisely to encourage agricultural innovation to occur. Second, he emphasised that if hybrids are specialised to local conditions, their slower diffusion might mean that the technology would be more difficult to transfer because it might need additional design changes to adapt to local conditions. In this sense, the slower diffusion of hybrids may not be due to a difference in property rights regimes but may, in fact, represent beneficial 'tailoring' of the crop to local conditions so that high yields are preserved. This point, too, suggests that the policy conclusions that should be drawn from the study are unclear.

The third paper of the session, a joint contribution by **Shyama Ramani** (INRA, France), **Myriam Carrère** (INRA, France), and **Mhamed-Ali El-Aroui** (Institut Supérieur de Gestion de Tunis, Tunisia) was presented by Shyama Ramani and Myriam Carrere. The paper was entitled 'The Impact of Knowledge Base and Spillovers: Evidence from Biotechnology Patents in the Foods Sector'. The authors investigated the impact of the knowledge base of agents, intersectoral spillovers, and intrasectoral spillovers on the creation of new knowledge. The objective of the paper was to understand better the nature of the evolution of the integration of biotechnology in the foods sector and to examine the impact of knowledge spillovers versus 'feedback' from the previously acquired knowledge on the new technology creation.

The paper provided a theoretical model for new technology creation, which then was tested empirically using patent data from the foods sector. An innovative feature of the theoretical model is that firms follow routines, rather than rational profit-maximising behaviour, when setting R&D expenditures. In this sense, it is related to the evolutionary school of economic analysis and to work in the organisational behaviour literature. The model also attempts to incorporate some concepts from scientometrics on the translation of patents into a knowledge base for the firm. This latter approach leads to features of the model that two firms with the same number of patent allocations do not have the same knowledge base and even though spillovers are freely accessible, they do not benefit all firms equally. Hence, the theory is quite eclectic and novel. The empirical estimate of the model reveals that in the foods sector, intersectoral spillovers have a greater impact on new knowledge creation than feedback from previous knowledge. In fact, previous advances in food seem to have a negative impact on further innovation. This may indicate a conservatism in switching approaches within a given field (a point investigated further by the next paper, see below). On the other hand, advances in food are greatly helped by spillovers from industrial sectors where biotechnology has been incorporated, such as pharmaceuticals and chemicals. Further, the food sector receives equally significant spillovers from two fundamental scientific fields of biotechnology: genetic engineering and biocatalysis. Relating this to the results of the first paper, this could indicate a desirable mix in research park composition, as well as supporting the results obtained by the first paper on the desirability of research parks in stimulating research in the area of agricultural biotechnology.

The discussant of the paper, **Tobias Kretschmer** (London School of Economics) made several comments on the model. In particular, he pointed out that the capacity of the firm to exploit the intrasectoral spillovers, modelled in the paper as a rivalrous, in fact could be non-rival and depend on the experience of the firm in the certain field. Also, R&D activities, which in the model appear as non-competitive, could be modelled as rivalrous. He also commented on the empirical results of the paper, noting in particular that the negative impact of previous R&D on today's R&D activities (a rather surprising result) could be the effect of the US data present in the sample, or decreasing returns, or alternatively some strategic reasons. Hence, as possible ways to investigate the results in more depth, he suggested comparing the model provided in the

paper with the equilibrium model on the same data set and to examine more carefully the US data effect.

The **first session** of the second day of the exploratory workshop examined the relationships between **organisation, regulation and innovation**. Three papers related to this issue were presented, with **Katharine Rockett** (University of Essex and CEPR) chairing the session.

The first paper to be presented, by **Silvia Sonderegger** (University of Bristol), was entitled 'Incentive Problems in the Introduction of New Technology when the Advisor is an Interested Party'. In the paper, the author considered in an agency theoretic framework the incentive problems in the introduction of new technology that stem from conflicts of interest arising between an employer and her current employees. If an employer decides to adopt a new technology, she will also replace her specialist workforce. Therefore, although an employee has access to important information concerning the efficiency of an innovation, he has an incentive to hide or misreport it, so as not to lose his job.

The model identifies the conditions under which no renegotiation-proof contract exists, which induces employees to truthfully reveal the information. In this way, the model predicts that agency problems may result in excessive conservatism, and resistance to change. The implication of this result is that, when it comes to the efficient adoption of radical new technologies, larger firms, where ownership and expertise are often separated, are disadvantaged with respect to smaller entrepreneurial firms.

Claudes Crampes (IDEI) in the discussion of the paper pointed out that the model was presented as a moral hazard problem, but it could be viewed as an adverse selection problem as well, where the employee could be bad or good at evaluating new technology or at convincing the principal. Further, the model assumes that standard tools to correct such a moral hazard problem are not available to the firms in this model. For example, the firms cannot organise workers into a 'tournament' whereby those biasing their assessment of the benefits of the new technology would be punished. Neither can the firm make commitments not to lay workers off in the face of new technology. Both modifications could correct the conservative bias of the firm. **Bruno Cassiman** (IESE Business School, Universidad de Navarra) noticed that innovation as it is modelled in the paper was external to the firm, whereas the empirical evidence of inertia in firms is often due to the 'not-invented-here' syndrome. In this case, internal researchers typically do reveal a lot of information about their innovations but managers are the ones who reject them. In fact, this appears to be true in the case study that was presented to motivate the paper.

The second paper of the session by **Xavier Vives** (INSEAD, Fontainebleau and CEPR) was entitled 'Competition, Market Structure, and Innovation'. In what is still an early version of the paper, Vives studies the impact of competitive pressure on innovation, seeking results that are more robust than those obtained in the literature on innovation incentives in oligopoly to date. This is a very ambitious task, as this literature is extremely large and has no clear conclusions in terms of how innovation incentives relate to the competitiveness of a sector. Clearly, this is important as competition law potentially changes the degree competitiveness in the economy. The paper, which uses the tools of industrial organisation analysis, characterises competitive pressure in terms of the number of firms, degree of product substitutability, and market size, varying these parameters to investigate their impact on innovation, represented by R&D expenditure. The model itself assumes there is no 'tournament' contest with respect to innovation, and that there are no strategic effects or spillovers.

The paper breaks down the effects of increased competition in an industry into two basic effects. First, as competition increases, the elasticity of demand faced by any single supplier increases as well (all else equal). This tends to encourage firms to invent, as this 'elasticity effect' means that they face tougher price competition in the absence of innovation. Second, as competition

increases, the demand faced by any individual firm shifts in (again, all else equal and assuming that all firms act symmetrically). This tends to discourage firms from inventing, as this 'demand' effect means that they face a smaller market for their output. These two effects go in opposite directions, and their interplay depends crucially on other assumptions of market structure (such as whether competition occurs in prices or quantities, the degree of product differentiation and so on).

The author indicated his intention to develop the study further by investigating how robust the results would be to the presence of spillovers, strategic effects, symmetric markets, and alternative ways of characterising competitive pressure. He also intends to move later on from a positive to a normative approach, investigating the welfare implications of the model.

Commenting on the paper, **Tommaso Valetti** (Imperial College, London and CEPR) emphasised the paper's interest but raised the question of which industries it could be applied to, given the 'no tournament' assumption, which implies no competition for innovation. He also highlighted the fact that for the next stage focusing on policy and welfare implications, it would be important to specify what ought to be the policy-makers' goals: whether to maximise R&D per firm, average R&D in the economy, R&D by the most innovative firm, or some other objective. In addition, Valetti suggested that the paper could be useful for raising the degree of awareness among policy-makers of the possibility of over-investment in innovation. **Bruno Cassiman** (IESE Business School, Universidad de Navarra) on the other hand, drew attention to the importance of the strategic effect in real life situations, as shown in work by other authors. He argued that it is difficult for work based on large samples to pick this out, and that such work was therefore biased towards underestimating its importance. The author agreed with this, commenting that this first attempt, by assuming the absence of strategic effects, could actually highlight their importance by contrasting the model's outcomes with and without their presence.

The final paper of the session was entitled 'The UK's Stake in the Biotechnology Debate: Global Competition and Regulatory Politics'. Co-authored by **Brian Salter** (University of East Anglia) and **Michael Smith** (University of Georgia), it was presented by Brian Salter. This paper was of a completely different nature, focussing on the political characteristics of GM food regulation, and using a political model.

The manipulation of genetic material to serve human needs represents a new industrial revolution with an extraordinary potential, but with profound implications for public policy and ethics. Accordingly, there is a growing demand at different levels for greater regulation of all activities related to biotechnology. The development of regulatory frameworks for the biotech sector in Western Europe has faced several challenges. On the one hand, there is a competitive pressure in the biotechnology field hastened by United States and Japan. On the other hand, there is a strong domestic opposition to the manipulation of genetic materials supported by food scares, public health crises and concerns about protecting the environment and the heritage of farmers. The objective of the paper was to study the nature of the political problem behind the biotechnology debate and the government response to it. According to the authors, thanks to the special role of the UK as both a leading innovator and regulator of biotechnology, its study can offer important insights into the relationship between global competitiveness, technological innovation, regulatory policy, and the protection of societal interests at the domestic, regional, and international levels.

The ability of the UK to compete effectively in the global biotechnology market is influenced by the emerging regulation in the EU, the nature of the advantages enjoyed by its competitors and the policies it puts in place to support the industry. However, with regulatory issues now moving out of the hands of technocrats and into the more open public arena of EU politics, policies hostile to the UK's economic interest might be more likely to emerge. Another important side of

the problem lies in public trust and consumer confidence in biotechnology, GM products and their regulation: without this trust, there will never exist a competitive European biotechnology industry. The paper concludes by suggesting that the implementation of European directives on GMOs in the UK has used a new model of regulation, which is much more inclusive and open than traditional regulatory methods. The paper suggests that this is a way forward for UK regulation more generally.

The discussant, **Paul Grout** (CMPO, University of Bristol) stressed the fact that the biotechnology debate has been politicised and there is a regulatory limbo which is value destroying. As a consequence, the political intervention in market related issues could have a profound impact on the future performance of economic entities and privatised firms. In fact, a more formal model presented by the discussant showed that small political mistakes in the regulatory process could be magnified into conditions that could cause a failure of an entire industry under certain conditions. From this viewpoint, the details of the governance of GMOs take on more importance than they might appear to under more traditional models of regulation because the effects of small mistakes are not necessarily dampened over time. **Shyama Ramani** (INRA, France) asked Brian Salter how it might be possible to coordinate a common EU policy so as to get out of this regulatory limbo with a general direction. He replied by emphasising EU cooperation, and by showing that the general public interests are taken into account in the policy discussions. **John Beath** (University of St Andrews) pointed out that the regulatory model of the Food Standards Agency (FSA) has not created the expected level of legitimacy for the general public.

Dietmar Harhoff (Universität München and CEPR) chaired the **final session** of the workshop. The session had two papers examining various issues related to **patent protection**.

The first paper of the session, by **Alexander Jerak** (Universität München) and **Stefan Wagner** (Universität München), took statistical analysis to patent oppositions data. The paper introduced a new methodology to study patent data, based on a semiparametric approach, to analyse the determinants and effects of the patent oppositions in Europe for biotechnology and pharmaceutical patents, and for semiconductor and computer software patents. Entitled 'Estimating Probabilities of EPO Patent Oppositions in a Bayesian Semiparametric Regression Framework', and presented by Stefan Wagner, the paper presented a fully Bayesian method and made use of Markov Chain Monte Carlo simulation techniques for estimation purposes. The opposition probability turned out to increase with increasing number of designated states, number of EPO patent claims and number of EPO forward citations, but, unlike previous researchers, the paper shows that this increase was clearly non-linear by incorporating the effects of these metrical covariates in form of smooth regression functions instead of simple linear terms.

The discussant, **Katharine Rockett** (University of Essex and CEPR), highlighted the importance of this paper given the high number of oppositions in the GM industry. She pointed out that the economic significance of the paper's results depends on the reasons for the non-linearity, and suggested a general intuition for them. Her hypothesis, which is testable with the author's data, was that the non-linearity is the result of a difference in oppositions strategy between 'run-of-the-mill' innovations and 'drastic' innovations. If this is the case, it suggests that the high degree of patent oppositions for GM may be due to the novelty of the field and so to the more important nature of the patents that have so far been filed. This could be important in explaining a striking empirical regularity. **Timo Goeschl** (University of Cambridge) criticised the lack of theoretical framework on why patent oppositions behave non-linearly. Without this theoretical support, he claimed it was impossible to draw conclusions and policy implications from the paper. Finally **John Beath** (University of St Andrews) commented on the statistical benefits of the methodology used.

The final paper, by **Andreas Panagopoulos** (University of Bristol) and entitled 'Optimal Patent Protection When Innovation is Sequential', examined in a macroeconomic model of economic growth the optimal design of patent protection when innovation is sequential (in other words, when innovations build on prior innovation). This paper examines the choice of how to allocate research effort between a technology that is well-understood and not very risky and another, risky but potentially beneficial technology. Such a choice might be faced by firms choosing between pursuing traditional hybridisation techniques and GM techniques in developing new seed varieties, for example. In particular, the paper looks at how this choice varies with the degree of intellectual property protection. The results depend on the interplay of two effects. First, there is a 'profit incentive' to pursue new technologies when intellectual property protection is strong. This tends to argue for strong patent protection in order to induce investment in new technologies. The second effect is a 'competition incentive' to pursue new technologies in order to escape competition. The intuition is that a firm might pursue riskier technologies in order to 'leap forward' and escape competition. This second effect would argue for weak patent protection in order to induce investment in new technologies. The interplay of these effects depends, then, on the degree of competition and the risk and return characteristics of the technologies under consideration by the firm. As a result, patent protection should be case specific.

John Beath's (University of St Andrews) analysis of the paper showed it to be interesting and rich in implications, highlighting the author's distinction between two types of innovation, which he denominated 'deterministic' and 'experimental'. He related the emphasis on 'risky' innovation to investments that have been made in Scotland with a view to fostering a more entrepreneurial orientation among Scots. The issues raised by the paper renewed his hope in the long-term fruitfulness of these investments. At the same time, both Beath and **Dietmar Harhoff** (Universität München and CEPR) pointed out that, by linking the paper's analysis to terms actually used in patent offices, the paper's conclusions could be made more readily available to data analysis. The discussion also attempted to link the paper's conclusions to the older literature on the incentives to invent in models of patent races. This paper clearly has similarities to the older literature, but is built using the new quality ladder technique.

3. Assessment of the Results, and Contribution to the Future Direction of the Field

The conference provided a wide variety of approaches to a similarly wide-ranging set of issues involving the institutional context of biotechnology and, as a sub-focus, agricultural biotechnology. Biotechnology and, in particular, agricultural biotechnology, is a case where researchers interested in new technologies can study a significant innovation as it is still in the process of unfolding. For this reason, it yields an important set of information that can be used to test and make more precise earlier results on innovation. The papers presented at this conference could be seen in this light, as representing a broader interest in technological innovation, applied in this case for agricultural biotechnology, but providing insights to the design of systems of innovation more generally. Within this focus, systems of innovation were studied from a wide variety of perspectives including industrial structure, regulatory structure, spillovers, and stage of development.

The results obtained, and summarised above, are important at several levels. First, some of the papers contributed significantly to our understanding of the broader theory of innovation. At this level, the conference is clearly a step forward. Second, at the level of tools to be used in the analysis of innovation, the conference gave participants a wide exposure to techniques of analysis that could be applied to this field. These techniques ranged through a wide variety of economic analyses as well as political, statistical, and scientometric methods. These tools should help to equip participants with the means to analyse developments in this area. Third, and more closely tied to biotechnology and agricultural biotechnology, the conference informed participants of the institutional context in which this innovation is occurring and analysed the interaction of the institutional and regulatory structure with the innovation's development. Here, the main benefits were in advancing tentative conclusions and in indicating future areas of research, as none of the papers' specific conclusions were uncontroversial. In particular, the benefits of analysing more closely the economic geography of this innovation were emphasised. It was also clear that the regulatory structure of this innovation is a relatively unexplored and very fertile area of research. Finally, a sub-text of many of the papers was a comparative approach to analysis of innovation in this area, looking to a comparison of the US and Europe for ideas on how to design optimal innovation policy. Here, the results were more suggestive than conclusive, indicating that further work in this area is necessary. As a final comment, the papers presented were all potentially publishable for wide audiences, allowing dissemination of the results well beyond those who actually attended.

4. Final Programme

The Impact of Institutions on Innovation: The Case of Biotechnology

A European Science Foundation Exploratory Workshop

Barcelona, 19/20 September 2003

Programme

Friday, 19 September

14:15 Registration

Session 1: Spillovers and Diffusion of Agricultural Biotechnologies

Chair: Bruno Cassiman (IESE Business School, Universidad de Navarra)

14:30 – 15:30 **What Determines Technological Hits? Geography and Firm Competencies in Biotechnology vs. “Traditional” Chemicals**
Myriam Mariani (MERIT, University of Maastricht and University of Camerino)

Discussant: Pierre Régibeau (University of Essex and CEPR)

15:30 – 16:30 **Intellectual Property Rights in Agricultural Biotechnologies and the Global Diffusion of Productivity Gains**
*Timo Goeschl (University of Cambridge)
Timothy Swanson (University College London)

Discussant: Carolin Socher (Universität München)

16:30 – 17:00 Coffee

17:00 – 18:00 **The Impact of Knowledge Base and Spillovers: Evidence from Biotechnology Patents in the Foods Sector**
Myriam Carrère (INRA, France)
Mhamed-Ali El-Aroui (Institut Supérieur de Gestion de Tunis,
Tunisie)

*Shyama Ramani (INRA, France)

Discussant: Tobias Kretschmer (London School of Economics)

18:00 – 18:15 Speech by Workshop Funder – European Science Foundation
Nathalie Schueller (European Science Foundation)

20:30 Dinner

Saturday, 20 September

Session 2: Organisation, Regulation and Innovation

Chair: Katharine Rockett (University of Essex and CEPR)

09:00 – 10:00 **Incentive Problems in the Introduction of New Technology
when the Advisor is an Interested Party**
Silvia Sonderegger (University of Bristol)

Discussant: Claudes Crampes (IDEI, Université des Sciences Sociales de
Toulouse)

10:00 – 11:00 **Competition Market Structure and Innovation**
Xavier Vives (INSEAD, Fontainebleau and CEPR)

Discussant: Tommaso Valetti (Imperial College, London and CEPR)

11:00 – 11:30 Coffee

11:30 – 12:30 **The UK's Stake in the Biotechnology Debate: Global
Competition and Regulatory Politics**
*Brian Salter (University of East Anglia)
Michael Smith (University of Georgia)

Discussant: Paul Grout (CMPO, University of Bristol)

Session 3: Patent Protection

Chair: Dietmar Harhoff (Universität München and CEPR)

12:30 – 13:30 **Estimating Probabilities of EPO Patent Oppositions in a
Bayesian Semiparametric Regression Framework**
Alexander Jerak (Universität München)
*Stefan Wagner (Universität München)

Discussant: Katharine Rockett (University of Essex and CEPR)

13:30 – 15:00 Lunch

15:00 – 16:00 **Optimal Patent Protection When Innovation is Sequential**
Andreas Panagopoulos (University of Bristol)

Discussant: John Beath (University of St Andrews)

* Denotes presenter

Organizers: Bruno Cassiman (IESE Business School, Universidad de Navarra)

Dietmar Harhoff (Universität München and CEPR)

Pierre Régibeau (University of Essex and CEPR)

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6. Statistical Information on Participants

Name	Year of Birth	Gender	Country of Origin
Derek Albone		Male	UK
Tunji Adegbesan	1975	Male	Spain
John Beath	1944	Male	UK
Isabel Busom		Female	Spain
Myriam Carrère		Female	France
Bruno Cassiman	1968	Male	Spain
Claude Crampes		Male	France
Timo Goeschl	1970	Male	UK
Elena Golovko		Female	Spain
Raul Gonzalez		Male	Spain
Paul A Grout		Male	UK
Dietmar Harhoff	1958	Male	Germany
Claude Henry		Male	France
Tobias Kretschmer	1971	Male	UK
Myriam Mariani	1970	Female	Italy
Ramon Marimon	1953	Male	Spain
Andreas Panagopoulos	1967	Male	UK
Shyama Ramani		Female	France
Pierre Régibeau	1957	Male	UK
Katharine Rockett	1958	Female	UK
Brian Salter		Male	UK
Nathalie Schueller		Female	France
Carolyn Socher	1976	Female	Germany
Silvia Sonderegger		Female	UK

Tommaso Valletti	1968	Male	UK
Xavier Vives	1955	Male	France
Stefan Wagner	1976	Male	Germany
