Introduction: Global actors, markets and rules driving the diffusion of genetically modified (GM) crops in developing countries

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Abstract: The theme of this special issue – genetically modified (GM) crops – goes to the heart of the process of globalisation, technology and development. This introductory essay explains how this new technology is being driven by the actors (multinational corporations), markets (large global markets) and rules (intellectual property) of globalisation. But it is also shaped by the other national and global actors (farmers, research scientists, anti-globalisation and environmental NGOs), markets (national priorities) and rules (national biosafety). The papers in this issue address some policy questions for developing countries: markets that are too small for corporate sector, or to be kept GM free, or dominated by monopoly products; the rules of intellectual property rights and the enforcement of biosafety regulation. Developing countries need to develop policy approaches that are specific to its own unique set of circumstances.

Keywords: GMOs; private sector; intellectual property rights; small scale farmers; public private partnerships; philanthropy; liability.

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1 Introduction

In the foreword to the inaugural issue of this journal, its editors Archibugi and Juma (2004) argue that technology and globalisation interact in two ways. First, innovations are facilitating the process of globalisation as 'technologies of globalisation'. The most obvious example is the advances in information telecommunication technology that is making possible global interactions such as the integration of financial markets. Second, scientific research and product innovations are now located in a global space, a process of "globalisation of the scientific and technological communities". They challenge contributors to this new journal to explore these two kinds of interactions.

The generation, transmission, and diffusion of new knowledge are increasingly affected by the global economy. New trends are evident: the growing role of global markets and the pressures to tighten intellectual property rights as part of an open trade regime; the growing role of multinational corporations in technological innovation and the benefits and costs to host countries; and the increasing importance of inter-firm and inter-institutional cooperation in the transmission of knowledge. These and other new trends are generating lively debates that are relevant for public policy. Of particular concern is whether innovations are within reach of all; as Archibugi and Juma note,

> "Too often, it has been assumed that it is enough to produce knowledge for everyone to benefit from it. This is far from true, and the diffusion of vital innovation depends on the willingness of the community of researchers and engineers as much as on institutions devoted to implementing this agenda." (Archibugi and Juma, 2004. p.4)

2 Agricultural biotechnology and globalisation: actors, markets and rules

The theme of this special issue – agricultural biotechnology in developing countries – goes to the heart of the interplay between globalisation and technology. The creation and commercial diffusion of genetically modified (GM) crops is arguably the most significant technological innovation in agriculture of the last couple of decades. It is a major scientific advance that has taken the science of crop improvement from conventional plant breeding following Mendelian principles to the application of molecular biology. But the innovation is not only scientific but institutional. Globalisation is a process that is driven by new technologies, multilateral rules and global actors integrating global markets (UNDP, 2001). In contrast to the public sector institutions that drove the Green Revolution, the emergence of GM crops is driven by the actors, rules and markets of the global age:

- *actors*: multinational corporations such as Monsanto
- *rules*: rules of intellectual property rights (IPR) embedded in the multilateral trade agreement, TRIPS
- *markets*: large global markets in soybean, maize, cotton and canola.

And shaping the diffusion to developing countries is the response to these forces by local actors, rules and markets:

- *actors*: national scientists, farmers, and national environmental and anti-globalisation social movements of NGOs, globally networked with corresponding international groups
- *rules*: new national biosafety and IPR regimes, conforming to globally regimes
- *markets*: local and export markets, and demand for local GM-free markets.

Over the 1980s and 1990s, a sea change occurred in the environment for agricultural research that created powerful new incentives for private multinational corporations to invest heavily in crop breeding and improvement. This was a new trend, for until then, research and development in crop breeding and improvement had been primarily a public sector activity.

Private sector seed companies have been involved in the commercialisation of improved varieties but crop improvement was an activity mostly confined to the public sector in both the developing and developed country contexts. There are some exceptions to this general trend, notably Pioneer-Hybrid (now DuPont-Pioneer) which was founded, to develop and commercialise hybridised corn to small and medium sized farmers.[1] But in general, private sector did not invest in improving germplasma (Osgood, 2005). The simple reason for this was weak market incentives. Private sector research in agriculture in industrialised countries was relatively small and was focused on agro-chemicals, machinery, post-harvest food storage and processing which are areas that had a commercial incentive. In developing countries of Latin America, Asia, Africa and the Middle East, there has been virtually no significant private sector agricultural research activity while it has been an important responsibility of the public sector. (Pardey and Beintema, 2001; Pardy and Wright, 2006) This is not surprising in view of the importance of agriculture in these countries' GDP, exports, employment, and rural livelihoods, and to the goals of food security and poverty reduction.

The new environment of globalisation shifted incentive structures for the private sector. First, scientific advances in molecular biology and introduction of transgenics, combined with changes in US legislation on intellectual property gave incentives for US private sector to invest heavily in the life sciences as explained by Wright and Pardy (2006). Furthermore, the large seed markets in the USA for maize, soy, canola and cotton provided incentives to develop commercial transgenic varieties. Second, market liberalisation created new incentives to diffuse these varieties to countries across the globe where there was agronomic potential for these crops. Argentina for example liberalised its economy significantly at this time. Third, the new rules of globalisation made this feasible since the TRIPS agreement resulted in the tightening of intellectual property rights regimes on a global scale, as explained in the paper by Pardy and Wright (this volume). Among the most significant provisions of the Marrakech Agreement of 1994 was the agreement on trade-related intellectual property rights (TRIPS) that required adoption of tighter intellectual property rights regime in all WTO member countries. Together with the emergence of the new tools of transgenics made possible the diffusion of new GM crops which could be protected under intellectual property legislation that would be introduced around the world.

From the very start, the emergence of plant biotechnology raised acute concerns about the risks of irreversible loss of biodiversity, harm to human health, and a threat to traditional farming practices. By the 1990s, civil society became organised into a powerful anti-GM advocacy campaign. Opposition to technological innovation and the potential for social dislocation is nothing new, but the anti-GM movement has been unprecedented as a globally networked movement that captured a broad range of agendas of environmental, anti-globalisation movements, and linked national and global NGOs (Osgood, 2001). These movements advocated more restrictive policies include more rigorous health and environmental testing but also labelling which makes possible the development of GM-free consumer markets.

The strength of these movements and the opposition from the consumer public at large had significant effect on putting in place stronger regulatory frameworks governing the approval of GM products for commercial sale, and in retarding approval of varieties for commercial planting. This goes a long way to explain the differences in national legislation across countries from ‘permissive’ to ‘precautionary’.[2] In 1992, the USA introduced legislation which simplified the approval process for GM crops and testing standards reduced to the same level as for non GM products. The anti-GM movement voiced objections but were not effective in forcing a policy shift. European Union countries took the other extreme approach, and applying the precautionary principle, placed a de facto moratorium in 1998, which was replaced in 2004. Still, many European countries are maintaining GM free consumer markets by imposing labelling. This in turn has been a factor that encouraged countries interested in European export markets to maintain a GM free producer status.

These forces of global trade, global social resistance, and national regulation explain much about the pattern of generation and diffusion of GM crops. In the first decade since the first Bt maize was approved for commercialisation in the USA in 1995, global areas under production has grown steadily by over 10% annually and has reached about 81 million hectares by 2004. Although research is ongoing in dozens of countries on dozens of crops, significant commercial production has been limited to four crops (soy, canola, maize and cotton) engineered with two traits (herbicide tolerance and pest – Bt – resistance). These are export crops that have large global seed markets. And though spread over 81.25 million farmers in 17 countries, more than half of the area (59%) was in the USA, followed by Argentina that accounted for a fifth of the global total – countries growing at least one of the four crops where governments have adopted a more ‘permissive regulation’. Social movements opposing GM crops has been present in all these countries but have been less widespread and influential in comparison, for example, to Europe. These countries together accounted for nearly 80% of all areas planted in GM crops (see Tables 1–3).

Table 1 GM crops in 2004 – major countries

Major countries	*2004 total hectares* (*million*)	*Percentage of world total* (%)
USA	47.6	59
Argentina	16.2	20
Canada	5.4	6
Brazil	5.0	6
China	3.7	5
Paraguay	1.2	2
India	0.5	1
South Africa	0.5	1
Uruguay	0.3	<1
Australia	0.2	<1
Romania	0.1	<1
Mexico	0.1	<1
Spain	0.1	<1
Philippines	0.1	<1

Source: James (2004)

Table 2 GM crops in 2004 – major crops

Major crops	*Total area* (*million ha.*)	*Percentage of global area in GM crops production* (%)	*Percentage of total area for crop* (*million ha.*)
Soybean	48.4	60	56% of 86
Maize	19.3	23	14% of 140
Cotton	9.0	11	28% of 32
Canola	4.3	6	19% of 23
Total four crops	81.0	100	29% of 283

Source: James (2005)

Table 3 GM crops in 2004 – major traits

Traits	*Crops*	*Area under cultivation* (*Ha*) (*million*)	*Percentage of total area under cultivation* (%)
Herbicide tolerance	Soybean, maize, canola, cotton	58.6	72
	(Soybean only)	48	60
Insect resistance		15.6	19
Stacked	Cotton, maize	6.8	9
Total		81.0	100

Source: James (2005)

Argentina, USA and Canada control these markets – together they account for 80% of maize, 64% of soy and 42% of canola of global exports. Moreover, these were feed crops for the meat exports that they dominate. These three countries together account for half of all beef exports and 40% of pit and poultry markets. Moreover, these crops were more socially acceptable since they were not food crops such as wheat or rice. This also explains why the fourth significant crop is cotton.

The spread of GM crops is clearly an example of the "globalisation of scientific and technological communities", as the generation and commercial diffusion of this technology is shaped by the global actors, rules and markets. It is also a "technology of globalisation" as it is this technology which is integrating agriculture into a global system, with farmers becoming increasingly engaged with globally generated technology, diffused by global companies, and producing for global markets. All this is of course anathema to the anti-globalisation movements that see this as a process where resource poor family farmers in developing countries lose control of their livelihoods and become dependent on a system that they have little prospects for influencing. That is an important source of the social resistance to this new technology, which in itself, is a force that is shaping the pace and direction of its evolution.

3 Benefits to developing countries: debates about markets, actors and rules

Much of the most publicly visible debate about GM crops has been about whether developing countries *should* adopt GM crops in their agriculture. Understanding the ecological and social consequences, considered in the context of national priorities and values are important in these debates. The literature on these questions is large and growing. This special issue addresses a different debate, less in the public eye, which is about *how* this technology is being diffused in the developing world, and *how* developing countries can benefit to meet their national goals. The papers in this special volume provide insights into some dimensions of this question.

Will the developing countries benefit from GM crops to advance their agricultural sectors? Tables 1–3 show quite unambiguously that the diffusion has been concentrated in the industrialised countries with US, Canada accounting for 65% of total area. But Argentina is the second largest country, and diffusion is rapid in Brazil, China, and India. What is more significant is that for now, the GM crops that have been commercialised are limited to those appropriate to temperate zones therefore excludes usefulness for tropical regions which dominate developing country agriculture. The traits that have been transferred into these crops are pest resistance and herbicide tolerance; thus they are beneficial to farmers using large amounts of inputs. These are commercial farms rather than resource poor family farms in the poorest developing countries.

Why has there been little diffusion to other developing countries and to crops like tubers, wheat and rice? Can this technology be made more pro-developing country and pro-poor, addressing priority constraints of developing country agriculture, especially the small-scale family farming sector? Each of the articles in this volume contributes to these debates with an analysis of the institutional shifts shaping the direction of markets, rules and actors.

3.1 Small markets for the corporate sector

Many argue that biotech firms that dominate research and development would not invest in developing countries, especially for food crops such as cassava, sweet potato, banana, because these markets are too small. Companies themselves argue that they are investing, for philanthropic reasons. Others have argued that institutional innovations are needed, such as public-private partnerships. Yet others point out that public sector in developing countries are investing to meet their own national needs.

Osgood examines corporate sector's engagement with these small markets, and the 'promise' made that GM crops offer a solution to world hunger and poverty by raising the productivity of small-scale farmers in developing countries. She traces the history of the different reasonings that motivated this engagement, from the search for large markets of low-income farmers or 'selling to the bottom of the pyramid' to philanthropy in an effort to claim a moral high ground as corporations faced hostile fire from anti-GM advocacy groups. The paper surveys the corporate initiatives in place and their achievements, concluding that they fall far short of delivering on the promise made. She concludes that this is not a role that the corporate sector can be expected to deliver on, even in partnership with civil society, and that the public sector must play a proactive role.

Traxler reflects on this issue from a different perspective but comes to the same conclusion that the market environment presents very weak incentives for private sector investment beyond diffusion of crops that are developed for the more profitable large global markets. Except for a few large countries, most of the developing world is constrained by institutional weaknesses in three areas: biosafety regulatory systems, IPR enforcement, and absence of functioning seed markets. He therefore foresees limited prospects for these innovations to spread in the developing world.

These conclusions though provoke further questions. Institutional and infrastructure constraints certainly exist but these are constraints that can potentially be overcome. Moreover, requirements are different with public sector research and development models; China, Brazil and India are investing in GM crops through public sector research. These debates about institutional innovations for the future will no doubt continue to be kept open.

3.2 GM free consumer markets and labelling

Public demands for GM free markets for both seeds and consumer products have been voiced throughout the world but have had more influence on regulatory and trade policies in Europe than elsewhere. In 1998, the European Union placed a *de facto* moratorium on approval of any additional GM crops for commercial planting and importation. In 2004, the moratorium was effectively lifted as new regulatory arrangements were put in place to allow imports, but also requiring labelling and identity preservation measures to segregate GM from non-GM seeds and products. However, the ban remains in place in many countries. This remains an important point of contention between the USA and the EU in the WTO context.

The EU policy has important implications for the rest of the world. Wu analyses the case of Bt maize. She argues that requirements for labelling in Europe and elsewhere are an important factor to take into account for policy makers considering whether to adopt Bt maize. Paarlberg (2001) focuses on Southern and Eastern Africa; he examines the empirical evidence behind the claim that GM free consumer markets in Europe act as a disincentive to African countries from adopting GM technology as they would be eager to present themselves as ‘GM free’ suppliers. The paper examines all the current and potential export products of East and Southern African countries and show that there is little relevance of this argument because current export products of these countries that could be GM are not destined to European markets.

Anderson and Jackson take a broader view. Their paper models the welfare consequences of the EU moratorium. The paper estimates that the moratorium reduced the economic welfare gains from GM corn and soybean varieties for the major exporters (USA, Canada and Argentina) but had a slightly positive impact on other food importing countries because of price effects. It then estimates the global welfare gains if the EU were to lift its moratorium and thereby encourage other countries to adopt these GM crops. That would raise developing country welfare outside the EU by around $1.5 billion per year. Finally, the paper goes on to estimate welfare gains if a export markets were to develop for a second generation of GM crops, namely wheat and rice. In that case, China and India would become the major gainers, and the overall gain to developing countries would be three times greater than from just corn and soybean if the EU were to adopt too.

The paper concludes that welfare gains from these developments would be very large, and offer potential for poverty reduction. Another important policy insight of this paper is that labelling is a more efficient mechanism than trade moratoria for maintaining GM free markets; while producers would incur costs of identity preservation and segregation, welfare gains from expanded supplies of GM crops would be captured.

3.3 Intellectual property protection

Most developing countries have not had a long history of strong protection for intellectual property rights and have weak administrative capacity to implement them. (UNDP, 2001) Some argue that such weak legal regimes and implementation capacity could are a disincentive – and hence an obstacle – to the private sector investing in research and development. Others argue that this varies for different developing countries. Yet others argue that the major challenge with IPR regimes is that unless they are well designed and implemented, they could have no or perverse effects on innovation. They could hinder diffusion of biotechnology to research in developing countries by limiting access to knowledge, and raising the costs of research.

Wright and Pardey look critically at the available empirical evidence on how patents have influenced research processes to date and explore implications for future development. They find a complex picture; on the one hand, researchers have assumed exemption from IP claims not embodied in materials, in research that has yet to have commercial interest. On the other hand, IP claims can lead to discouraging effects on lines of research that require lengthy or costly licensing agreements. They argue that for countries undertaking their own research in the public sector, strong IP protection is not in their interests, unless they develop varieties of new crops that are attractive to other countries. It is clear that it is difficult to predict the impact of patents on future development of GM crop research. It is also important to note that IP has not been an important incentive factor in the diffusion of GM varieties to date, nor the most important constraint to agricultural research in developing countries which for the most part remains finance.

3.4 Enforcement of biosafety regulation

There is strong consensus on setting up an effective system of biosafety regulation as a pre-requisite for commercial production of GM crops. It is also recognised that weak administrative capacity is a significant obstacle in developing countries. Moreover, enforcement is particularly difficult in the smallholder agriculture sector where farmer to farmer exchange of seeds has been a common practice, and where smaller seed companies have been active in commercialising seeds without going through the biosafety process. In India, China, Argentina, Brazil and elsewhere, GM seeds have spread rapidly through sales that have not been approved, as farmers are eager to try varieties that have high returns. A related problem is enforcement of IPR as some of the ‘illegal’ seeds are of varieties approved but sold without license from the patent owner. Ineffective systems can hamper innovation, or have other adverse effects.

Pray et al. compare the experience to date in China and India. The paper documents the learning process ongoing in those countries with implementation, both with the process of biosafety trials as well as with IPR enforcement. Both cases show the great practical difficulty in controlling the emergence of informal sector entrepreneurs that commercialise seeds without license, nor without obtaining the necessary biosafety approvals. The paper shows that the costs are higher in India and that enforcement is more effective in China; the difference can be explained by the strength of national interest groups in China. Coordination among agencies involved in the approval process is an important element in the predictability of the approval process. Approaches to enforcement can have either positive or negative influence on the diffusion of innovation.

In China, the seed supplier was encouraged to replace the unapproved variety with the approved variety, while in India, the supplier was put out of business, and farmers were told to destroy their crops. This method of enforcement is not a politically feasible one, and so could not be implemented. Institutional learning and innovation in this area is clearly an important challenge, but one that is taking place.

3.5 Monopoly prices and distribution of benefits

With patent protection, seed companies and multinational corporations might be expected to extract monopoly rent from farmers, and the corporate sector may be expected to capture the most of the technology gains with little shared by the farmers. In the pharmaceutical sector, private research and tight IPRs resulting in high prices and restricting access to people who need drugs has generated heated controversies. It has led to questions about private corporate sector being the appropriate source of financing R & D for important public goods such as medicines. Do the same problems apply for GM crops?

Traxler’s detailed review of evidence from North and South America for cotton (USA, Mexico, Argentina), soy (USA, Argentina, Paraguay), maize (USA) and canola (Canada) shows that even though these GM crop varieties were developed and commercialised through private companies, the benefits have been “widely distributed among industry, farmers and final consumers”, suggesting that “the monopoly position engendered by intellectual property protection does not automatically lead to excessive industry profits” (Traxler, 2006). This is perhaps because markets for crop varieties are location specific while markets for pharmaceuticals are global.

3.6 The non-adopters as losers

An important distributional consequence of technical change in any production technology is that adopters get the competitive benefit of the new technology and squeeze non-adopters out. At the global level, Anderson and Jackson’s paper gives clear evidence of implications of the EU moratorium.

3.7 Policy alternatives

For policy makers faced with choices about the adoption of GM crops, it is important to weigh the benefits and risks, both of which would vary crop by crop and country by country. Wu carefully examines the risks and benefits for Bt maize, but points out that developing country policy makers should also ask what the alternatives are. Critical constraints to policy goals such as food security and increasing production may lie elsewhere and adoption of Bt maize may not be the most effective approach considering its financial and administrative costs.

4 Prospects

Five years ago, the seminal report on prospects for GM crops in developing countries by the UK Nuffield Council on Bioethics (2003) warned

> "As GM crop research is organised at present, the following worst-case scenario is all too likely; slow progress in those GM crops that enable poor countries to be self sufficient in food; advances directed at crop quality or management rather than drought tolerance or yield enhancement; emphasis on innovations that save labour costs (for example herbicide tolerance), rather than those that create employment; major yield-enhancing progress in developed countries to produce, or substitute for GM crops now imported in conventional (non-GM) form from poor countries."

The papers in this volume tend to give evidence of these trends, but these papers have focussed on global trends rather than on national level developments. Just as Monsanto, the global actor is driving research at the global level, national – and public sector – research institutes in China, India and Brazil are investing heavily on crops and traits that are their local priorities. The second wave of GM crops may well come from these actors aimed at local markets rather than global export markets. When this second wave appears, we must look closely at the distributional consequences – the winners and losers. Anderson, Traxler and Wu document significant financial benefits but their papers do not – nor are intended to – address the indirect social consequences fully. That would require exploring for example impacts on employment and land distribution, identifying the adopters and non-adopters, winners and losers. It is too early to conduct such a study for now.

For the second wave to happen cannot depend entirely on national public sector efforts alone. The issues raised in this volume – about public-private partnership, building regulatory and IPR enforcement mechanisms, and having the right kind of IPR regimes globally are all critical.

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Notes

[1]This history is particularly significant since it is thanks to Pioneer that germ plasma that is now used to carry the transgenes is in the private sector (Osgood, 2005).

[2]Paarlberg classifies a country's policy stance, including not only biosafety frameworks but also trade, IPR and investments between permissive to precautionary (see Paarlberg, 2001).