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**The economics research agenda for agricultural biotechnology  
in developing countries**

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**Abstract**

In the past decade, economists have examined the connections among agricultural biotechnology, developing country adoptions of the new technology and the resultant effects on economic welfare. Initially, much of the research was conceptual, conjectural or theoretical. In recent years, as some developing countries adopted specific GM crops, economic research has become more empirical. This paper surveys recent economic research in such areas as regulation of agricultural biotechnology, concerns about environmental externalities, and issues relating to intellectual property rights systems and policies. With its focus on crop production, the paper does not address issues of consumer acceptance or international trade.

Key words: agricultural biotechnology, environmental externality, welfare, developing countries, intellectual property rights, regulation.

## **The economics research agenda for agricultural biotechnology in developing countries**

### **Introduction**

In the decade since the first genetically modified or “biotech” varieties of agricultural crops have been introduced, economists have spent considerable energy examining the connections among agricultural biotechnology, developing country adoptions of that technology and the resultant effects on economic welfare. Some of these studies have taken a “positive economics” approach to determine specific effects and impacts, whereas other research has been normative in nature, prescribing roles and approaches that can balance the potential costs and benefits that are associated with specific new varieties.

In the earliest stages of new variety introductions, economists sought to address a fairly wide range of research questions, such as:

- How can this advancement in agricultural biotechnology be utilized to serve the food and nutrition needs of the world’s poor?
- Are the crops and varieties being developed those that offer the highest economic potential for developing countries’ production conditions, and are they being developed in a way that includes and enhances developing countries’ scientific research base?
- What opportunities are available to specific countries from the adoption of new commercial biotech varieties, and how will the magnitude and distribution of potential gains be influenced by such factors as monopoly power in the sales of new technologies, aggregate productivity increases for individual crops, and the relative valuation of GM varieties by domestic consumers and global trading partners?
- What could be the associated problems or risks involved with these emerging technologies and how might these risks be managed? What are the relative returns to capacity building in such areas as domestic regulatory policy and the effectiveness of monitoring and enforcement programs?
- What are the respective roles of the private sector and of governments and policy makers in developing countries in the implementation and regulation of agricultural biotechnology?
- What are the specific implications of intellectual property protection (IPR) for agricultural biotechnology, and which reforms to IPR protection might be most beneficial?

To be clear, it will take considerable time and resources to reach even relatively preliminary answers to many of these questions. Those answers, reinforced with field-based evidence, will in turn, invite new questions and alter future research priorities, well before such a research agenda is fulfilled.

Since there were few data available initially and since many countries were slow to adopt any GM varieties, much of this research was conceptual, conjectural or theoretical, seeking to anticipate, to encourage, and in some cases, to prevent specific outcomes or impacts. As greater experience started to be gained with the introduction of specific biotech crop varieties to individual developing countries, a significant part of the economists' contributions to the analysis of these issues has become more narrowed and focused. This is a logical development given the increasing, but still very limited access by researchers to field data and actual country experiences, often analyzed as crop-specific or country-specific case studies. In the context of developing countries and biotechnology, this second stage of economics research is now well underway.

The current paper, written as part of a larger project on developing countries and agricultural biotechnology, provides a constructive survey of where this economics research agenda has come from and of which important issues have yet to be addressed and resolved. The paper seeks to provide a relatively modest overview that focuses on the research by economists into developing country experiences with issues of agricultural crop production. Topics covered include assessment of the introduction and uses of agricultural biotechnology and biotech crop production, concerns about environmental externalities and other production-related risks, and issues relating to intellectual property rights policies, adoption rates and the domestic regulatory environment. Due to limits of space, the paper does not address the extensions of this "production-based" economics literature along the supply chain to issues of consumer acceptance or of trade in biotech crops and products.

The contribution of this paper is to draw together a relatively large number of recent country-focused or crop-focused case studies and reports, most written in the past five years. The set of works cited seeks to be illustrative, but in no way exhaustive. Two key criteria for inclusion are whether there is a clear "developing country" context and whether or not each contribution is

part of a broader “economics” literature that uses economic analysis and methods, or, as in some cases, that draws upon legal or other scholarship to inform about evolving regulatory processes or property rights. By summarizing, classifying and grouping these works, this paper seeks to provide in one place, a clear look at which questions economists have been asking and answering thus far, and which others remain to be addressed.

The remainder of the paper is structured in three sections. The next section provides background and context to the evolving use of GM crops in developing countries and to the issues and popular debates that attend their use. The next section classifies the ongoing economics research agenda into three large and inter-related themes or questions, and cross-references a large number of studies under each theme by crop and country, where possible. A concluding section addresses the topic of existing research needs and future research directions.

### **Background and context to the economics research agenda in agricultural biotechnology**

The use of genetically modified (GM) crop varieties in commercial agriculture is a comparatively new and fast growing phenomenon, dating from the mid-1990s. The number of GM crops grown is relatively small and their commercial production is concentrated in a relatively small number of countries. For the purposes of this paper and its examination of the experience of developing countries, Argentina, Brazil, China, Paraguay, India and South Africa (and others) are classified as “developing countries.” These are the top six countries (in decreasing order) in terms of area planted to biotech crops in 2004.

In this paper, European and former Soviet Union countries, along with Australia, New Zealand and other member countries of the G8 group of countries are classified as “developed countries.” In GM crop production, the major “developed countries” (also in decreasing order of area planted in 2004) are the USA, Canada, Australia, Romania, Spain and Germany. Table 1 shows that, in 2004, all developing countries collectively were responsible for about one third of the 81 million hectares planted to GM varieties globally (James 2005).

Table 1 also shows the importance of relatively few GM crop types in developing countries, focusing on cotton, maize and soybean, and to a lesser extent papaya, potato, squash and rice. Historically, herbicide tolerance and insect resistance (individually or together) have been the

**Table 1: Area of biotech crops in developing countries in 2004, classified by crop and country (millions of hectares)**

	COTTON	MAIZE / CORN	SOYBEANS	CANOLA	OTHER <sup>a</sup>	TOTAL
ARGENTINA	++ <sup>c</sup>	++	++			16.2
BRAZIL			5.0			5.0
CHINA	3.7					3.7
INDIA	0.5					0.5
MEXICO	++		++			0.1
PARAGUAY		1.2				1.2
PHILIPPINES		0.1				0.1
SOUTH AFRICA	++	++	++			0.5
URUGUAY		++	++			0.3
OTHER <sup>b</sup> DEVELOPING	++	++				<0.1
DEVELOPING COUNTRY TOTAL	++	++	++			27.6
GLOBAL TOTAL	9.0	19.3	48.4	4.3	<0.1	81.0

Notes:

<sup>a</sup> includes papaya, potato, rice, squash, sugar beet, tomato

<sup>b</sup> includes Colombia (cotton), Honduras (maize)

<sup>c</sup> ++ signifies principal biotech crops grown without specific area estimate

Source: from James (2004)

most important modified traits exhibited by these commercial crops. Cohen (2005) surveyed GM crop research at 61 public research institutes in 15 developing countries targeted at 45 different crops. Some of this research, although somewhat removed from commercial readiness, goes well beyond herbicide tolerance to address target specific types of disease resistance (bacteria, fungi, viruses), abiotic stress (drought, salinity) and product quality enhancements (nutritional, shelf-life). James (2005) speculates on the potentially immense role that the expected introduction of *Bt* (insect resistant) rice in China will have, not only on global biotech production areas and shares, but also on the overall acceptance and attitude toward GM varieties as food and as livestock feedstuffs.

The existing and historical patterns of GM crop production areas reflect the convergence of a number of economic forces, including which countries have been the dominant producers and exporters of those crops for which GM varieties have been developed. Private and public developers of new varieties will have been sensitive to which countries were thought to offer the greatest potential markets for GM traits—both in terms of relative demand due to prevalence and severity of insect and weed pests, for example, and in terms of ability to pay—and which countries would also offer an accommodating regulatory regime with timely approvals and low transactions costs to bring a new GM variety to market. Some attention has focused on a range of related issues, including examination of private versus public sector research roles and the focus of each research model on cash crops for exports versus crops that might be important dietary staple (Dutfield 2000; Paarlberg 2001; Persley and Serageldin 2003).

### **The evolving economics research agenda in agricultural biotechnology and crop production**

At the risk of generalizing too much, or of missing important connections or over-arching themes, it will prove useful in what follows to reduce the multifaceted research agenda described on the first page of this paper, to three sets of research issues or questions. A very large portion of the economic analysis on crop biotechnology that has most recently been reported can then be related to (in most cases, just) one of these three issues. Moreover, there is considerable informational content in noting the country-specific and crop-specific cases or contexts in which these research questions are addressed or answered. By constraining the scope of this three-part

classification to issues of production agriculture and its surrounding environment, one avoids numerous other important economics research questions further down the supply chain, such as those related to consumer rights, consumer perceptions and commodity valuations. These would be beyond the scope of the current paper and could not fit well the three proposed categories.

The three sets of research issues that will serve to sort or classify recent research are:

1. What are the potential gains to developing country economic welfare from adopting or promoting the use of new GM crops or varieties, and on which specific factors do these depend?
2. What are the associated risks or costs of GM crop production, including any environmental externalities, and what are the associated needs in terms of regulatory capacity, monitoring and enforcement?
3. Which policies, including domestic regulatory policies and those governing intellectual property rights, will provide the greatest possible gains in economic welfare from the new varieties, and how are these related to associated economic incentives and transactions costs?

Each will be examined in turn.

#### Potential Gains and Impacts:

As noted by Scatasta and Wessler (2005), the recent contributions to this line of research build upon a broader literature that examines the returns to R&D in agriculture. Recent works have contributed by focusing on such aspects as the role played by proprietary and monopoly rights (intellectual property rights) exercised by the vendors of GM seeds or varieties, and by differences in the relative market valuations of the GM versus traditional crop or commodity. Illustrative examples of papers in this line include Moschini and Lapan (1997, 2005), Falck-Zepeda *et al.* (2000), Moschini *et al.* (2000), Pray *et al.* (2001, 2002), Frisvold *et al.* (2003), Scatasta and Wessler (2005) and Sobolevsky *et al.* (2005). Only some of these papers apply the analysis to developing countries but each makes some contribution to the methodology that has been used since.

Table 2 provides a listing and classification of the most recent of these references and numerous others. The Table follows the same general list of developing countries and GM crops as was used to report global production areas in Table 1, except that countries are not included in Table 2 if there are no illustrative entries.

As shown, most of the countries that have significant acreages of GM varieties have been the subject of specific studies to address potential welfare gains. Paraguay and Uruguay are the exceptions, and some of these countries' experiences may have been studied but too recently to have yet been published. Even in countries where GM crops have been introduced, some of the studies are highly conjectural, and seek to ascertain how production and prices might adjust if productivity gains follow specific predictions or if they follow that crop's experience elsewhere. That is, few studies seek to generalize future gains from one or two years' experience in the early stages of adoption.

As Spillane and Pinto (2002) suggest, potential gains from the adoption of GM crops may be categorized into three main groups. First, GM crops generate new options for pest and disease resistance. A significant proportion of plant biotechnology is aimed at developing new strategies for pest and disease control for which there are currently few options. Second, weed management is a major labour and resource-consuming issue, particularly to the poor farmers of the developing world. Herbicide-resistant GM crops could offer significant advantages to many farmers. Third, malnutrition is a widespread problem among world's poor. A range of transgenic approaches, such as "golden rice," are now being developed to improve the nutritional quality of food.

As shown in Table 1, canola was not an important GM crop in developing countries in 2004, and Table 2 does not report any studies that seek to estimate how canola would contribute to developing countries' agriculture or economic welfare. A number of the studies cited in Table 2 address a range of crops, including those not currently grown in developing countries, and some studies examine the potential role of agricultural biotechnology in lowering costs or increasing productivity in a manner that is not crop specific.

**Table 2: Citations of recent research into the potential gains from GM crops, classified by crop and country<sup>a</sup>**

	COTTON	MAIZE / CORN	SOYBEANS	CANOLA	OTHER <sup>b</sup> OR NOT CROP-SPECIFIC
ARGENTINA	Qaim & de Janvry (2003)		Qaim & Traxler; Sobolevsky <i>et al.</i>		
BRAZIL			Constanza <i>et al.</i> ; Sobolevsky <i>et al.</i>		
CHINA	Pray <i>et al.</i> (2001, 2002)				
INDIA	Qaim (2003); Qaim & Zilberman (2003)				
MEXICO	Traxler <i>et al.</i> (2003)				
PHILIPPINES					Zimmermann & Qaim (2002)
SOUTH AFRICA	Thirtle <i>et al.</i> (2003)				
OTHER AFRICA	Cabanilla <i>et al.</i> (2003), Vitale <i>et al.</i>	DeGroote & Mugo; Vitale <i>et al.</i>			Anderson & Jackson (2004); Langyintuo; Zambrano <i>et al.</i>
OTHER AMERICAS					Falck-Zepeda <i>et al.</i>
NOT COUNTRY-SPECIFIC	Carpenter <i>et al.</i> (2002)	Carpenter <i>et al.</i> (2002)	Carpenter <i>et al.</i> (2002); Moschini <i>et al.</i> (2000); Weaver & Curtiss		Evenson (2004); Fukuda-Parr; Pinstруп-Andersen & Schiøler (2001), Scatasta & Wesseler; Zilberman <i>et al.</i> (2004)

Notes:

<sup>a</sup> all author citations are in References as (2005) unless otherwise stated

<sup>b</sup> includes cowpea, and others

Source: authors

### Risks and Externalities:

In spite of the numerous potentially positive impacts of GM varieties, developed and developing countries have expended considerable effort to identify and understand any risks, costs or negative externalities associated with the proposed adoption of these varieties. Is it clear, especially with such a new technology, that the absence of any short-term effects in initial field trials or testing is a sufficient indicator that such effects will not arise later? Which investments in the developing country's ability to monitor, to enforce and otherwise regulate each new technology are the most important? What about the country's capacity to enforce against the illegal or unlicensed entry of GM varieties, absent any form of testing, perhaps in advance of domestic capacity to detect in a reliable manner when such varieties are in use? These are all issues that are starting to receive attention within the economics research literature.

Many risks or potential risks have been raised in public debate and these include such issues as effects on the natural environment, food safety effects, socio-economic concerns, human health risks and ethical considerations, as examples. In the case of food crops, including livestock feedstuffs, a country's decision to introduce production of new GM crop varieties brings with it the extended set of concerns and responsibilities about other risks in the food chain for consumers. People's attitudes and perceptions of risk or harm may bring great social costs, even when the actual harm is not present. For example, the introduction of a new gene into a food crop or a change in the expression of an existing gene may cause that foodstuff to become allergenic. Consumers' actions to avoid these foods and perceived risks may cause them to incur real costs even if no allergic reaction is ever experienced.

Potential environmental impacts most commonly considered are concerns about loss of biodiversity, transgenic contamination across species, (including weeds that might be made more noxious) and any potentially harmful effects on non-target species of plants, insects or birds, for example (Persley and Serageldin, 2003; Swaminathan and Swaminathan, 2004; Das, 2005). Often a motivation for a country's adoption of a GM variety is an expected reduction in the use of chemical pesticides, possibly including an accompanying reduction in energy use, and beneficial effects on soil tilth or fertility. Moreover, the increase in productivity, output and

income, as improvements at the intensive margin of crop production may forestall other adjustments at the extensive margin. That is, marginal or forested lands may not be well suited to more intensive crop production systems used for a successful GM variety, and as a result, these marginal lands are not brought into agricultural production. The environmental “benefits” notwithstanding, countries considering the adoption of biotech crops need to understand, assess and manage the accompanying risks.

Table 3 provides a classification by developing country and by crop of a number of recent economic studies that have explored these issues of risks and environmental effects, either by looking at a specific GM crop or by considering the adoption of GM crops in general. Two types of studies stand out. As practical works with an important field-based focus, Varma (2004) and Peñalba *et al.* (2005) look closely at the capacity of a number of developing countries in Asia to put in place the types of regulatory regimes and scientific expertise that these countries feel are necessary prerequisites to GM crop production. At the conceptual level, Hahn and Sunstein (2005) and Turvey *et al.* (2005) use economic analysis to examine the precautionary principle and the rationale for public decision making about risky activity when much remains unknown.

#### Policies, IPRs and Incentives:

The third major area for economic research into agricultural biotechnology follows logically in diverse countries’ examination of the pros and cons of adopting or promoting specific varieties. Once having ascertained that there may be significant potential gains and manageable levels of risk, a country would then want to address appropriate systems of incentives, rewards, controls and regulations to allow and encourage that crop variety to be introduced. Why is it that rates of adoption by farmers in developing countries may vary considerably by country and by crop? Which new policies, and which reforms of existing regulatory apparatus, might be required to achieve these objectives with transactions costs for participants that are sufficiently low?

An important part of this regulatory framework is the role played by intellectual property rights, such as patents or plant breeders’ rights. The system of rights that is adopted can provide incentives to both private and publicly funded innovators to develop varieties suited to a developing country’s production conditions and to supply these varieties to domestic producers. This rights system can also incorporate protections, safeguards and enforcement mechanisms that

**Table 3: Citations of recent research into the potential production-related risks and externalities from GM crops including examination of countries' regulatory capacity, classified by crop and country**

	COTTON	MAIZE / CORN	SOYBEANS	CANOLA	OTHER <sup>a</sup> OR NOT CROP- SPECIFIC
ARGENTINA			Economist (2004)		
BRAZIL					Di Ciero & Amaral (2005)
INDIA	Pray <i>et al.</i> (2004)				Das (2005)
PHILIPPINES		Peñalba <i>et al.</i> (2005)			
SOUTH AFRICA		Morris <i>et al.</i> (2005)			
OTHER AFRICA					Njamnshi (2005)
OTHER ASIA					Dubock (2005), Varma (2004)
NOT COUNTRY- SPECIFIC	Carpenter <i>et al.</i> (2002)	Carpenter <i>et al.</i> (2002)	Carpenter <i>et al.</i> (2002)		
NOT COUNTRY- OR CROP- SPECIFIC	Amerasinghe (2002), Hahn & Sunstein (2005), Khoury & Smyth (2005), Lipper <i>et al.</i> (2005), Maredia <i>et al.</i> (2005b), Masood (2005), Sullivan (2005), Paarlberg (2001), Persley & Serageldin (2003), Smyth <i>et al.</i> (2004), Pinstруп-Andersen & Schiøler (2001), Spillane & Pinto (2002), Swaminathan and Swaminathan (2005), Turvey <i>et al.</i> (2005)				

Notes:

<sup>a</sup> includes rice and others

Source: authors

will provide some measure of protection to the innovator against piracy or duplication of proprietary materials. This could be especially important to the innovator where there is a risk that these infringing materials might be re-exported to compete against the innovator's own GM varieties in other countries. A related strand of this part of the literature addresses questions of who should define which crop biotechnology research is needed (e.g., cash crops destined for export or dietary staples important in the local diet) in specific developing countries, and which agencies or firms should carry it out (e.g., various forms of private, public or joint-venture enterprises).

Table 4 provides a categorization of how economists have been addressing a number of these issues in the last few years. This has been a very active area of research, and in contrast to the work on assessing potential gains, much of this work has not been crop-specific. Much of it, however, is country-specific, examining and comparing regulatory approaches and effectiveness across jurisdictions.

### **Future economics research directions**

This paper provides an illustration of the economics research agenda that has developed in the last ten years alongside these new technologies and varieties. So far, agricultural biotechnology has been commercialized on a large scale for relatively few crops in relatively few countries. Field-based economics research has followed these cases while at the same time scouting and previewing the prospects for others. It is to be expected that as the first decade of experience (and supporting data) with agricultural biotechnology is completed, there will be an opportunity to consolidate and to reflect to an even greater degree on the patterns, similarities and differences in this experience. There appears to be growing interest in comparative work that addresses both the magnitude and the distribution of associated gains and losses, and some of this work may lend itself to natural policy experiments.

In recent years, many researchers have proposed that agricultural biotechnology should be thought of as a potential answer to problems such as poverty and malnutrition faced by the developing countries of the world. Initially physical scientists played a leading role in developing and adapting this agricultural biotechnology. More recently, social scientists have

**Table 4: Citations of recent research into adoption rates for GM crops, including domestic regulatory policies, transactions costs and the role of intellectual property rights, classified by crop and country <sup>a</sup>**

	COTTON	MAIZE / CORN	SOYBEANS	CANOLA	OTHER <sup>b</sup> OR NOT CROP-SPECIFIC
ARGENTINA	Qaim & de Janvry (2003)		Qaim & Traxler; Sobolevsky <i>et al.</i>		
BRAZIL			Sobolevsky <i>et al.</i>		
CHINA					Eaton <i>et al.</i> ; Wailes & Durand-Morat
INDIA	Qaim (2003)				Chaklatti <i>et al.</i> ; Eaton <i>et al.</i> ; Ting Chi & Adcock
MEXICO		Léger			
SOUTH AFRICA					Maredia <i>et al.</i>
OTHER AFRICA		De Groote <i>et al.</i>			Aerni; Anderson & Jackson (2004); Annou & Henson; Eaton <i>et al.</i> ; Taylor & Cayford (2003); Wafula
OTHER ASIA		Pray			Ting Chi & Adcock; Wailes & Durand-Morat
OTHER AMERICAS					Eaton <i>et al.</i>
NOT COUNTRY-OR CROP-SPECIFIC	Alston <i>et al.</i> ; Blakeney; Chattopadhyay & Horbulyk (2004); Cohen; Giannakas (2002); Gibson; Hansen & Van Fleet (2003); Kalaitzandonakes (2004, 2005); Kalaitzandonakes & Alston; Kumar & Smyth; Moschini <i>et al.</i> (2000); Moschini & Lapan; Paarlberg (2001); Pray & Naseem; Pachico; Runge & Ryan; Knudsen & Scandizzo; Schimmelpfennig (2004)				

Notes:

<sup>a</sup> all citations are in References as (2005) unless otherwise stated

<sup>b</sup> includes cassava, potato, rice and others

Source: authors

started to play an important role in recommending how and where to deploy this technology. Clearly, the challenges confronting developing countries include understanding, addressing and balancing a diverse set of potential gains and losses in a way that can contribute meaningfully to domestic economic wellbeing. ■

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