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The impacts and acceptance of agricultural biotechnology: an introduction to the special issue

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ABSTRACT. Attitudes towards and acceptance of agricultural biotechnology, which involves inserting genes that carry new traits into existing varieties, has been subject to much debate. This special issue aims to address several gaps in the literature on genetically modified (GM) technology in agriculture. Some of the papers in the issue address the economic and health aspects of genetic modification in agriculture while others examine consumers' attitudes towards GM products, and the marketing and labeling of GM products.

1. Introduction

The discovery of the structure of DNA and the development of recombinant DNA technology paved the way for modern biotechnology. While medical biotechnology has already been widely adopted across the world, attitudes towards and acceptance of agricultural biotechnology, which involves inserting genes that carry new traits into existing varieties, has been subject to much debate. It is useful to distinguish between three generations of genetically modified (GM) varieties: first generation varieties which consist of production traits; second generation which enhance nutritional content and tolerance to abiotic stresses; and third generation which include the production of industrial fine chemicals and pharmaceuticals from plants. A large area of land of three major crops (corn, soybean and cotton) has been planted with first generation traits (mostly herbicide tolerant and insect resistant) in a few large countries, including the United States, Brazil and Argentina, as well as India and China which have only adopted cotton. However, GM varieties have not been introduced in major food crops like wheat and rice and have been sparsely adopted in Africa

and practically banned from Europe. Bennett *et al.* (2013) report that 25 per cent of traits in the premarket stage and 75 per cent of traits in field trial or experimental stages are second or third generation varieties, and regulatory constraints prevent the development and adoption of many more varieties that have significant potential for improving human wellbeing. There is an ongoing societal debate about the future role of genetically modified organisms (GMOs) in agriculture and their capacity to address challenges of food security, climate change and sustainable development.

This special issue aims to address several gaps in the literature on GM technology in agriculture. It includes papers that address the impact of genetic modification on productivity and health, and papers that address attitudes towards and the marketing and labeling of GM products.

2. Economic and health impacts of genetic modification

There is a large and growing literature on the various economic aspects of genetic modification in agriculture (see surveys by Qaim, 2009; Bennett *et al.*, 2013; Barrows *et al.*, 2014a). Much of the literature consists of farm-level studies which suggest that genetic modification contributes to increased yields, reduction of insecticide use and increased worker safety. However, there are fewer studies on the aggregate effect of genetic modification in terms of prices, food supply and the environment, which is addressed in this special issue by Barrows *et al.* (2014b). The authors estimate the aggregate impact of GM varieties on the supply and prices of major crops. They distinguish between increased supply at the *intensive margin*, as adoption of GM varieties reduces pest damage and tends to increase the use of complementary inputs like fertilizers, and the *extensive margin*, which reflects the growing range of lands that have become and may become profitable with GM technology. The intensive margin effect was a dominant contributor in the increased supply of corn and cotton, but the extensive margin was crucial in the expansion of the production of soybean. Much of the expansion of land in GM soybean was the result of double cropping, which did not increase the footprint of agriculture, but instead used arable land more effectively. The paper presents alternative econometric estimates of the yield effect of GM technologies using data on total production and land allocation among three of the major GM crops and between GM and non-GM varieties of each of these crops for more than 100 countries between 1996 and 2010. They estimate that in 2010, the introduction of GM varieties increased the supply of corn between 5 and 12 per cent, the supply of cotton between 15 and 20 per cent, and the supply of soybean between 2 and 40 per cent. Without the introduction of GM varieties, it is estimated that in 2010, prices of corn would have been between 5 and 19 per cent higher, cotton between 19 and 33 per cent higher, and soybeans between 4 and 66 per cent higher.

The paper also estimates that the yield effect of GM varieties and the increase in double cropping as a result of their use has reduced the land required to produce current levels of output, saving at least 13 million ha of land from conversion to agriculture in 2010. The averted emissions from

this reduction are equivalent to roughly one-eighth of the annual emissions from automobiles in the United States. The paper suggests that if adoption of genetic modification were expanded to countries in the EU, Asia and Africa that have not yet adopted it, the price reduction effects would likely offset the price increases caused by the introduction of biofuels, and the agricultural footprint would likely be reduced as well. Thus, poor consumers of food and fuel, as well as the environment, are the major losers of not expanding the adoption of GM varieties.

Most of the micro-level studies on the impact of genetic modification in major crops like cotton were done in early adopting countries, including the United States, China and India in the late 1990s and early 2000s, and there is a growing need to see if these patterns are found elsewhere. Kouser and Qaim (2014) address the impact of the adoption of GM technology in Pakistan, where it was first allowed in 2010 and consisted of mostly Chinese varieties rather than Monsanto-developed varieties. The paper demonstrates that conventional cotton growers in Pakistan suffered significantly from pest damage that was not effectively controlled by chemical pesticides, which were over-applied prior to the adoption of Bt cotton. Adoption of Bt cotton in Pakistan significantly reduced pesticide use, increased yields by 25 per cent, improved the quality and yield of the fiber, increased the productivity of irrigation, improved health and water quality from reductions in pesticide use and increased the incomes of subsistence farmers. So the results in this paper support early findings on the benefits of Bt cotton and suggest that this technology adds to the sustainability of cotton production.

There is significant evidence of the regulatory and intellectual property challenges facing the development of new GM varieties, especially in developing countries (Just *et al*., 2006), but there is sparse evidence on the cost of some of these regulatory constraints. The restriction on the introduction of GM varieties is justified by precaution and uncertain environmental and health costs. However, some GM varieties aim to improve human health, and their delayed introduction has health costs. The paper by Wesseler and Zilberman (2014) assesses the health benefits foregone by the delay in introducing 'Golden Rice' in India. Golden Rice has a GM trait that fortifies rice with vitamin A, and its consumption by subsistence farmers can prevent blindness and even death. Between 250,000 and 500,000 people (mostly children) are estimated to go blind every year due to vitamin A deficiency. Since 2002, scientists in India have requested permission to conduct field tests for cultivation that would lead to the development of a commercial variety, but these requests have been continuously denied in India and other countries. The paper models the regulatory choice of the Indian government that has to decide whether to approve or delay the cultivation of Golden Rice. The model uses a real option approach that considers the uncertainty about the benefits and costs as perceived by the regulator, explicitly accounting for the irreversibility of health benefits and costs and uncertainty about the effectiveness and impact of the technology. The model also considers the random arrival of new information. The authors conclude that the Indian government must assume that adoption of Golden Rice will result in substantial social costs, considering the

benefits of the technology are at least US$1.7 billion or about US$200 million per year, in order to justify the delay of introducing Golden Rice. The authors interpret this amount as the economic power of the resistance to Golden Rice. According to the authors' calculation, the delay over one decade may have resulted in at least 1.4 million cases of blindness. The paper demonstrates the large social cost that is associated with the delay in the introduction of GM varieties like Golden Rice, and develops a framework that can be generalized for other cases.

3. Analyzing attitudes, marketing and labeling of GM products

There is a large literature on the attitudes towards and acceptance of genetic modification by consumers, mostly in the developing world (Curtis *et al*., 2004), and realization of the important role of retailers in the spread of the technology. However, there is very little evidence about retailers' attitudes towards genetic modification and consumers' preferences regarding it in developing countries. The development of the technology may have been slowed by the introduction of private standards by retailers that restrict the sale of GM products. The paper by Vigani and Olper (2014) investigates the factors that lead to the selection of GM-free standards among the largest retailers. They find that the probability of adopting a GM-free labeling strategy tends to *decline* as the number of markets in which retailers operate increases, if the markets are larger and if the share of reliable media sources is higher. On the other hand, the probability of adopting a GM-free labeling policy increases when biotechnology regulations differ between the nations in which the retailer operates, when the markets in different countries are similar, and when the retailers have relatively higher market power. The paper also finds that pressure from environmental groups has an insignificant effect on adoption of a GM-free labeling policy, perhaps because the measure of environmental group pressure was a discrete variable and did not adequately capture the influence environmental groups had. Nevertheless, the results suggest that retailers happily adopt GM-free standards, not only because it increases their profits, but also because the lobbying by environmental pressure groups serves as an excuse to avoid GM products.

The literature on willingness to pay (WTP) for GM varieties has found that consumer attitudes about genetic modification vary significantly. While there is a substantial part of the population in developed countries that is willing to pay significantly more (10 per cent or higher) for GM-free food, a large share of sampled populations are not willing to pay anything (Zilberman *et al*., 2014). Attitudes towards GM products also vary based on information provided about the products as well as the product traits. The paper by Heiman (2014) integrates new findings in behavioral economics and marketing to conduct a survey in Israel analyzing the role of information in consumers' attitudes towards GM products. His analysis confirms that consumers' attitudes towards GM products are burdened by information complexity and perceived risks. The debate over genetic modification revolves around aspects like health and environmental effects, costs and tastes. He finds that the complex technical debate contributes to

consumer doubt about whether GM products are likely to taste better than non-GM 'natural' products, and that consumers need concrete information to believe health claims. Consumers are likely to improve their attitudes towards genetic modification when it addresses a single, uncontroversial attribute (e.g., GM cotton reduces water use). Attitudes towards genetic modification are not likely to improve when consumers are provided with information addressing multiple attributes of it, even positive ones. Heiman suggests that efforts to introduce GM products should emphasize one simple and essential trait rather than giving a complex narrative.

Attitudes towards GM products are affected by negative as well as positive labeling strategies that are overseen by regulatory agencies. An important question is whether consumers trust the regulatory agencies and if they would trust labels of transgenic products. The paper by Kikulwe *et al*. (2014b) analyzes trust in food labels and consumers' WTP for GM bananas in Uganda. GM bananas are expected to provide substantial economic benefits if introduced (Kikulwe *et al*., 2014a). About 55 per cent of the sampled population holds positive attitudes about them, but a large share of consumers express a negative WTP for GM bananas and also do not trust food labels, especially those provided by governments. Interestingly, these are consumers who buy bananas, generally have higher incomes, are better educated and live in urban areas, and hence make up the group of consumers that would benefit less from the GM technology compared to the group of consumers that not only eat but also cultivate bananas, including the majority of small-scale farmers in Uganda (Kikulwe *et al*., 2011). This poses a problem for governments that want to introduce GM bananas as well as a labeling policy to address the concerns of consumers who are opposed to the technology. The first group of consumers would not trust such labels if they were provided by the government; rather, they express a higher trust in food labels of the private sector. Hence, the authors conclude that a voluntary label introduced by the private sector may be the best response.

4. Conclusion and future research

The regulation and future of agricultural biotechnology has been a subject of ongoing debate. GM technology has been practically banned from Europe and Africa, and its use has been restricted to only a few crops in the rest of the world. There have been concerns about its potential contribution in addressing issues like poverty, climate change and overall environmental quality. The papers in this special issue present evidence suggesting that, even under the current restrictive regulatory environment, the diffusion of GM varieties has been very fast and they have been adopted in developed and developing countries. GM varieties have already made a difference to the lives of the poor. By increasing the supply of corn, soybean and other crops, they contribute to significant reduction in these commodities' prices, and increase the supply of meats available to consumers throughout the world. Our analysis suggests that by increasing productivity per unit of land, GM contributes to the reduction of the land footprint of agriculture, greenhouse gas emissions and deforestation.

The special issue also suggests that excessive regulation can be very costly. The case of Golden Rice is an example where numerous lives could have been saved and cases of blindness prevented if the commercialization and development of Golden Rice had been allowed. The benefits attained from the use of genetic modification and the lost benefits from excessive regulation suggest that policy makers should reconsider the additional burden imposed on the developers and adopters of this technology, and introduce regulatory mechanisms that allow the technology to flourish while preserving health and the environment.

This special issue also suggests that the introduction of the technology has been hampered by consumer attitudes and acceptance of genetic modification, manipulation of markets by suppliers, and restrictions imposed by food retailers on GM products. The results suggest that the introduction of new GM varieties should be accompanied by information that effectively communicates their essential benefits, and that there is a role for trusted voluntary labeling in ushering in the adoption of the technology. The research on genetic modification and its implications should be ongoing in order to assess the value of new traits and develop mechanisms to introduce them.

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