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# Consequences of Biotechnology Policy for Competitiveness and Trade of Southern U.S. Agriculture

**Curtis Jolly, Kenrett Y. Jefferson-Moore, and Greg Traxler**

The effect of policy decisions on the competitiveness of genetically modified (GM) crops was examined. The United States has been an early innovator in the development and use of biotechnology crops and has expanded its export market share of the three major GM crops: soybeans, cotton, and corn. Cotton, soybeans, and corn are all grown in the southern states, but these states have an apparent comparative advantage only in the production of cotton, which may be strengthened with the adoption of genetically modified cotton. The influence of biotechnology on the competitiveness of soybeans and corn for the southern states through the introduction of genetically modified organisms (GMOs) is not clear but is probably negligible.

*Key Words:* biotechnology, competitiveness, southern agriculture

**JEL Classifications:** Q13, Q17, Q16, Q18

The emergence of practical biotechnology protocols for creating genetically modified plant organisms (GMOs) has transformed the system for supplying improved plant varieties to farmers in a few crops in a few countries. Although more than 200 million acres were planted to genetically modified (GM) crops in 17 countries in 2004, the area was highly concentrated among crops and countries. More than 97% of world GM area planted occurs in just five countries (United States, Argentina, Canada, China, and Brazil), and more than 99% of those areas is under crops containing two types of events (herbicide tolerance and

insect resistance) in four crops (cotton, soybeans, corn, and canola) (Tables 1 and 2). Most countries of the world either do not have the capacity to deliver GM technology to their farmers or have some type of restriction on the commercialization of foods containing transgenes. There are large differences among countries in their experiences, public acceptance, and scientific and regulatory capacity to deal with biotechnology products. These differences and the fact that GMOs are concentrated in major traded crops have important implications for international trade. Biotechnology is any technique that uses living organisms or substances derived from these organisms to make or modify a product, improve plants or animals, or develop microorganisms for specific uses (Cohen). Modern biotechnology refers to the applications of new developments in recombinant DNA technology, advanced cell and tissue culture techniques, and modern immunology. Some of the most im-

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**Table 1. Global Area of Biotech Crops and % of Patents Held by Country in 2004 (Million Hectares)**

	Million Hectares	% of Total Patents
United States	47.6	9.68
Argentina	16.2	7.3
Canada	5.4	9.6
Brazil	5	4.1
China	3.7	6.5
Paraguay	1.2	
India	0.5	11.7
South Africa	0.5	2.9
Uruguay	0.3	
Australia	0.2	8.8
Romania	0.1	
Mexico	0.1	0.0
Spain	0.1	9.1
Philippines	0.1	2.9
Colombia	<0.1	
Honduras	<0.1	3.6
Germany	<0.1	
Total	200	

Source: James 2004.

portant applications of modern biotechnology are genomics, bioinformatics, plant transformation, molecular breeding, and diagnostics. The most controversial of these techniques is plant transformation that uses genetic engineering to move genes across species boundaries. Work in all of these areas is progressing in both plants and animals but progress toward commercial products has been greatest in plants.

Biotechnology science is evolving rapidly, spurred by large investments, primarily originating in the private sector (Table 3). An estimated 96% of investment occurs in industrialized countries, and 70% of that investment is undertaken by the private sector. The absence of private investment in developing countries is explained by the small size of their seed markets, the difficulty in protecting intellectual property (IP), the lack of regulatory infrastructure, and the scarcity of good crop varieties in which to incorporate the genetic events. Most of the world's GM area is under feed and oil crops. The delivery of food crops is a new experiment (Table 4). It is not

**Table 2. Dominant Biotech Crops in 2004**

	Million Hectares	% Biotech
Herbicide-tolerant soybean	48.4	60
Bt Maize	11.2	14
Bt Cotton	4.5	6
Herbicide-tolerant maize	4.3	5
Herbicide-tolerant canola	4.3	5
Bt/herbicide-tolerant maize	3.8	4
Bt/herbicide-tolerant cotton	3	4
Herbicide-tolerant cotton	1.5	2
Total	81	100

Source: James 2004.

yet known whether consumer resistance to GM food crops, such as rice, wheat, and food maize will be an obstacle to the spread of those crops.

Cotton is an important crop to southern farmers since most of the U.S. production takes place in the southeast and southwest. Soybean is produced mainly in the Midwest, but a few southern states produce significant amounts of soybeans. Corn production has been affected by biotechnology, but low production and yields received from corn in the southern states are indicators that the southeastern states have a slight comparative disadvantage in the production of corn relative to other states and its competitiveness relative to other crops is weak. On the basis of cost re-

**Table 3. Estimated Global R&D Expenditures on Crop Biotechnology, 2001**

	Total	
	\$ Millions	\$ Millions
Private (70%)	3,100	
Public (30%)	1,120	
Industrial country total (96%)	4,220	
China	115	
India	25	
Brazil	15	
Others	25	
Developing country total (4%)	180	
World total	4,400	

Source: James 2002.

**Table 4.** World Area Planted to GMO Food Crops

Crop	Countries	Area (ha)
Bt food maize	S. Africa, Philippines	100,000
VR peppers	Mexico, China	Uncertain
Bt rice	China	0
VR papaya	United States, Indonesia	1,095
VR squash	United States	1,815

Note: GMO is genetically modified organism.

duction, increase in market shares, and resource allocation, we will investigate whether biotechnology has influenced the competitiveness of southern agriculture.

The adoption of GM crops has brought significant gains to those adopting the crops. Regions and nations have all benefited from the adoption of these crops. Studies by Falck-Zepeda, Traxler, and Nelson calculate the annual distribution of benefits among cotton producers, consumers, and germplasm suppliers for the 1996–1998 period using a standard economic surplus model (Alston, Norton, and Pardey). The estimated amount and distribution of benefits from the introduction of *Bacillus thuringiensis* (*Bt*) cotton fluctuates from year to year, but total annual benefits created averaged approximately \$215 million. The average benefit shares were 45% to U.S. farmers, 36% to germplasm suppliers, and 19% to cotton consumers. Frisvold, Tronstad, and Mortensen use a different modeling approach to calculate aggregate welfare changes from the introduction of *Bt* cotton in the same period. They estimate a smaller amount of average total benefits (\$181 million), a smaller share of benefits to U.S. farmers (20%), and more to U.S. consumers (27%).

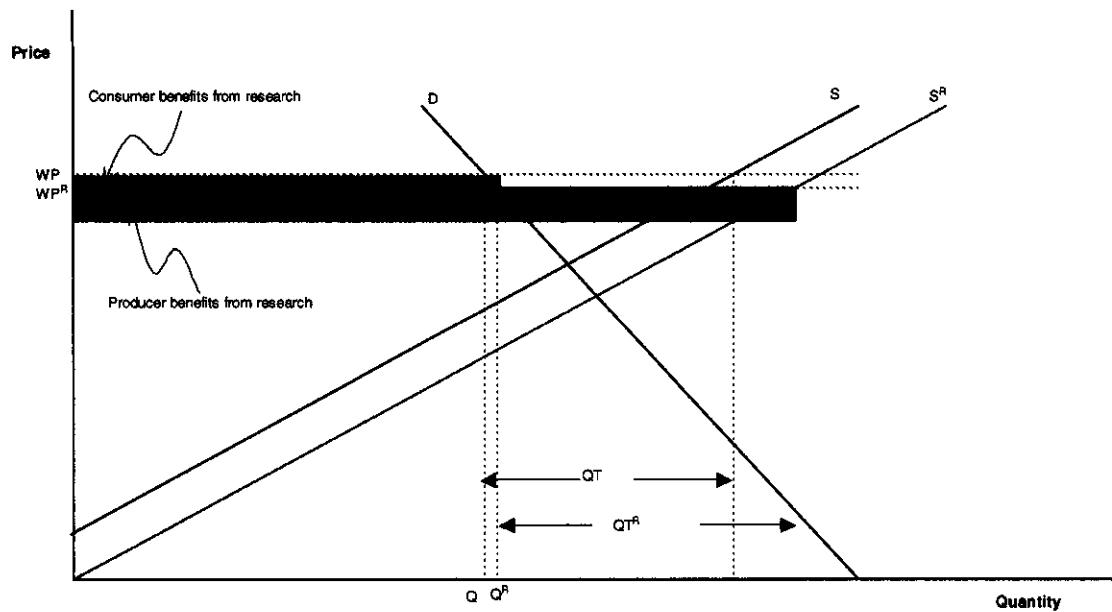
Qaim and Traxler estimated that Roundup Ready (RR) soybeans created more than \$1.2 billion in economic surplus in 2001, about 4% of the value of the world soybean crop. Soybean consumers worldwide gained \$652 million (53% of total benefits) due to lower prices. Seed firms received \$421 million (34%) as technology revenue, nearly all of it from the U.S. market. Soybean producers in Argentina and the United States received net benefits of more than \$300 million and \$145 million, respectively, while producers in countries where

RR technology is not available faced losses of \$291 million in 2001 due to the estimated induced decline of about 2% (\$4.06/mt) in world market prices. Farmers as a group received a net benefit of \$158 million, 13% of total economic gains produced by the technology.

The benefits derived from the adoption of these crops grown in the United States have resulted in rapid farm adoption of GM crops. The main GM crops produced—cotton, soybean, corn, and canola—are all grown in specific regions. The southeastern states produce large quantities of cotton and soybeans but less of corn and canola. In this article, we will examine how the introduction of GM crops affects the competitiveness of the southeastern states relative to other producing regions and international competitors.

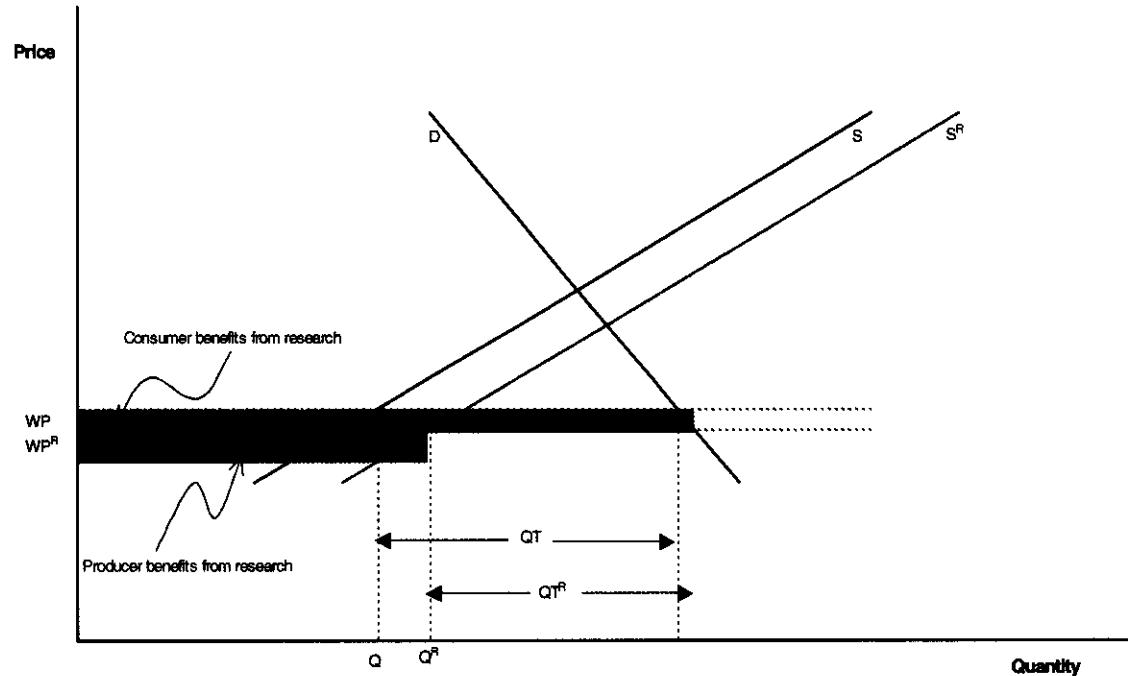
#### Benefits of Adoption of GM Crops

The welfare effects of biotechnology, and the consequences of not pursuing the opportunity offered by biotechnology under open market conditions, are illustrated in Figures 1 and 2. Technological changes in the United States for commodities such as corn, soybeans, and cotton may affect the world price. Figure 1 depicts the incidence and distribution of benefits from research and development (R&D) in a large open-export market. Production increases from biotechnology R&D leads to a shift in the supply curve, inducing a decrease in the world price. This leads to consumer benefits depicted by the lighter-shaded area, and producer benefits depicted in the darker-shaded area in Figure 1. Figure 2 shows the incidence of benefits in a large open-import market. Production increases lead to a decrease in the world price caused by a reduction in excess



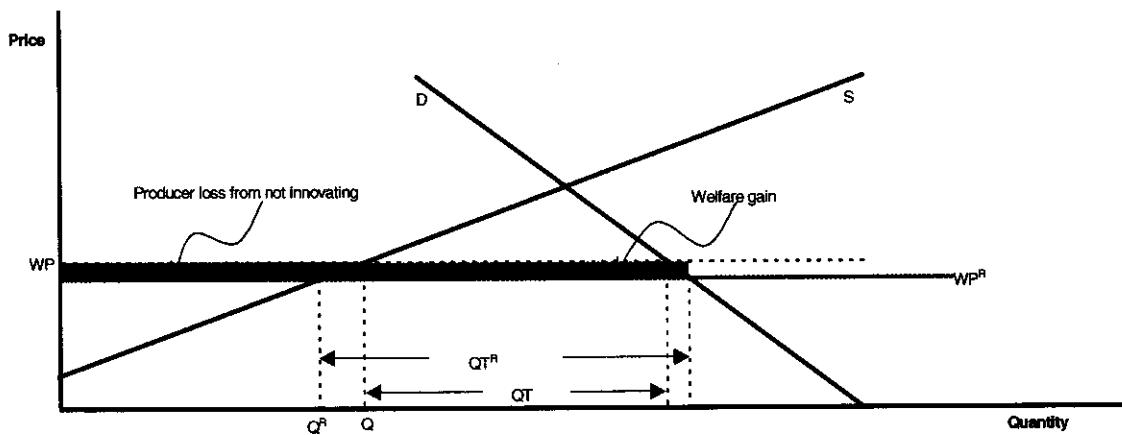
From: Acquaye and Traxler.

**Figure 1.** Incidence of Benefits from Research in an Open Export Market (from Acquaye and Traxler)



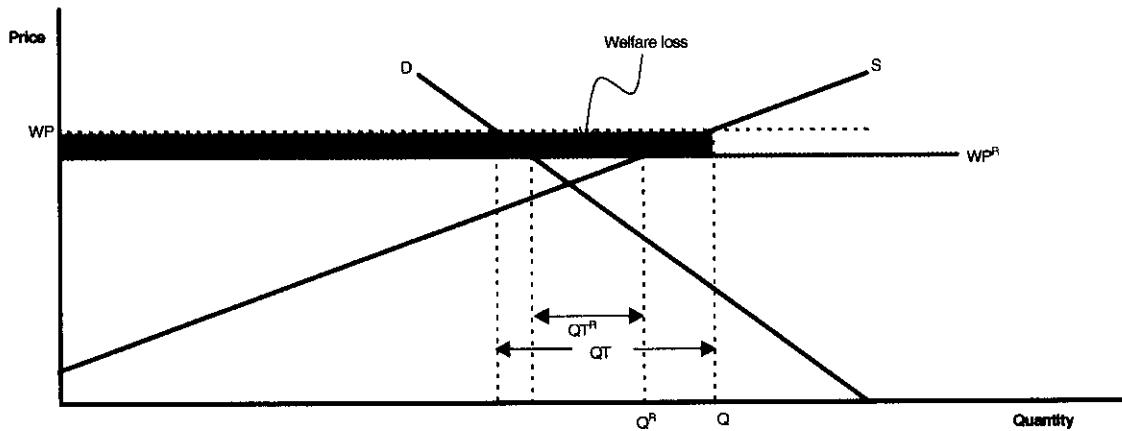
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**Figure 2.** Incidence of Benefits from Research in an Open Import Market (from Acquaye and Traxler)



From: Acquaye and Traxler.

**Figure 3a.** Consequences of an Importing Country Not Innovating (from Acquaye and Traxler)



From: Acquaye and Traxler.

**Figure 3b.** Consequences of an Exporting Country Not Innovating (from Acquaye and Traxler)

demand. Increased domestic consumer benefits are depicted by the lighter-shaded area in Figure 2 and an increase in domestic producer benefits is depicted by the darker-shaded area. Although the price-depressing effect of agricultural R&D is less in an open market, there are benefits that are forfeited by not undertaking the research.

The failure to adopt the innovation may lead to a reduction in global welfare. In Figure 3a,b, we see that producing countries that fail to adopt results in higher domestic prices and a welfare loss. Nonadopting exporting coun-

tries may suffer from welfare losses because of the maintenance of a less-efficient production system. For example, if the European Union (EU) fails to adopt biotechnology and refuses imports from a lower-cost plant biotechnology region, imports will fall. This means that southern GM crop producers export markets may be limited, and potential economies of scale from the use of biotechnology crops may be dissipated.

The large research investments, trusted regulatory system, and favorable public attitude toward GMs in the United States have gener-

ated significant benefits for farmers, industry, and consumers. The southern states of the United States were early leaders in the use of GMOs by virtue of their rapid adoption of *Bt* cotton, the first commercially successful GMO. *Bt* cotton is an example of a technological improvement with very uneven effects geographically. Adoption has varied greatly across growing regions in the United States, depending on the availability of suitable varieties and the particular combination of pest-control problems. Adoption has been slowest in California and Texas, where suitable *Bt* varieties have not been available until recently, and most rapid in states where chemical pesticide resistance has been most pronounced.

### **The Impact of Biotechnology on Competitiveness**

The competitiveness of U.S. agriculture will determine its level of exports. Export revenues, according to the Foreign Agricultural Service, generated 20%–30% of U.S. farm income over the past 30 years. Competitiveness and its measurement are important to U.S. agricultural policy makers. Trade competitiveness is measured in several ways: lowest price, lowest cost, profitability, maintained market share over a sustained amount of time (Kennedy; Kalaitzandonakes), and the theory that focuses on international differences in inherited stocks of resources, such as human capital and knowledge as a basis for comparative advantage in high-technology industries (Grossman and Helpman; Lavoie and Sheldon). When competitiveness is defined as making the goods available to the consumer at a lower price (Kalaitzandonakes), it implies that producers must be able to produce and distribute the goods at the lowest possible cost using the given state of technology. As Kennedy indicated, technology is an important factor in determining costs and the price of goods. The factors influencing competitiveness include technical change, factor endowments, and government resources.

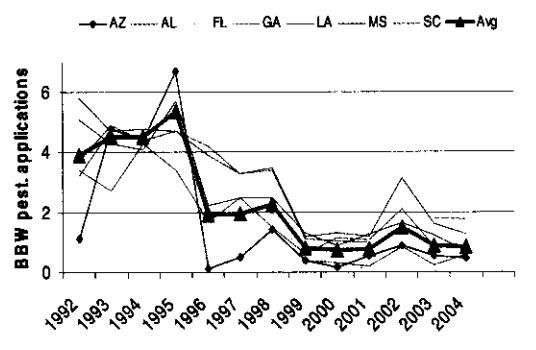
Another measure of competitiveness is based on the intensity of use of abundant factors. The theory states that a country will tend

to export the goods that use its abundant factors intensively. Dohlman, Osborne, and Lohmar stated that the competitiveness of a nation's product is rooted, not in any single outward measure but in the quantity and quality of the country's productive resources. These, they added, are the factors that determine the relative efficiency of making different goods and, consequently, a country's "comparative advantage." They suggested that is not the quality of a nation's resources the sole determining factor of international trade but also institutional, domestic, and international forces. Trade competitiveness is also measured in practical terms as the amount of capital devoted to the production and export of a given commodity. Biotechnology innovations affect competitiveness by differentially reducing production costs across countries and regions, generating benefits to producers and consumers. Adopters have seen their production costs fall, but costs remained unchanged for nonadopters.

### **Biotechnology and Competitiveness of Southern Agriculture**

Biotechnology has resulted in rapid increases in production and exports of three major crops: corn, cotton, and soybeans. These crops have been genetically modified to tolerate herbicides and/or resist pests. Crops carrying herbicide-tolerant genes were developed so that farmers could spray their fields to eliminate weeds without damaging the crop. Pest-resistant crops have been engineered to contain a gene for a protein from the soil bacterium, *Bt*, which is toxic to certain pests, such as the European corn borer or cotton bollworm.

The herbicide- and insect-tolerant crops provided farmers with an alternative strategy for combating weeds and pests in the early years of the adoption cycle. Today, the use of GM crops is widespread in the United States, Brazil, and Argentina. In the United States, the share of transgenic crops in 2003 was 81% for GM soybeans, 71% for GM cotton, and 45% for GM corn (Moschini). In this section, we examine costs, returns, and market shares of cotton, soybeans, and corn to determine



Source: Williams, M. R. Department of Entomology, Mississippi State University, accessed from the internet March 10, 2005 at <http://www.msstate.edu/Entomology/ENTPLP.html> [Accessed March 10, 2005]

**Figure 4.** Chemical Used on Cotton by Farmers from 1992 to 2004 (Williams, M.R. Department of Entomology, Mississippi State University. Internet site: [www.msstate.edu/Entomology/ENTPLP.html](http://www.msstate.edu/Entomology/ENTPLP.html) [Accessed March 10, 2005])

whether biotechnology has influenced their competitiveness in the southern states. We shall also evaluate resource allocation and institutional forces affecting the competitiveness of these crops in the southern states.

### Evaluating the Effects of GMOs on Southern Farmers' Competitiveness

#### Cost Effects

**Cotton.** The effect of the adoption of *Bt* cotton on yields in the Southeast has been significant. *Bt* cotton adoption has a positive effect on net farm profits while reducing insecticide use (Fernandez-Cornejo et al.). In virtually all instances, insecticide use on *Bt* cotton is significantly lower than on the conventional varieties. Although it is not possible to determine the exact reduction of costs in the production of cotton, the number of applications of pesticides has decreased tremendously from 1996 to 2003 (Figure 4). The reduction of costs on regional competitiveness cannot easily be determined because the reduction of the number of applications varies within a state. However, the rate of adoption of *Bt* cotton in the Southeast suggests that farmers are employing *Bt* cotton on their farms to remain competitive. The cost reduction is not only in the number

of applications but also in labor, management, and tillage costs. The environmental effects of transgenic crops have been strongly positive to date.

**Soybeans.** RR soybeans have been widely adopted by U.S. growers. RR soybeans change the patterns of tillage and chemical herbicide use. Glyphosate substitutes for a number of other products, with the result that per hectare herbicide expenditures decline. Herbicides differ in their mode of action, duration of residual activity, and toxicity, so an increase in total herbicide amounts does not inevitably suggest negative environmental effects. The combination of shifts in herbicide use have resulted in cost reductions as the manufacturers of conventional herbicides dropped prices (sometimes by about 40%) in response to decreasing demand (Carpenter and Gianessi). Glyphosate has little residual activity and is rapidly decomposed to organic components by micro-organisms in the soil. The adoption of RR soybeans led to an almost complete abandonment of highly toxic chemical herbicides.

#### Export Market Shares

As is seen in Tables 1 and 2, the United States commands large shares in GM-produced goods. The U.S. exports about 42% of its soybeans produced, and the EU is responsible for 33% of the exports, or 14% of the total output (Cadot, Suwa-Eisenmann, and Traga). The United States is one of the largest producers of cotton, second only to China, and is responsible for about 22% of the world's exports. The production of cotton has experienced significant increases in acreage planted, and most of the cotton produced today comes from GM cotton. The southern states produce about 75% of the U.S. cotton crop and are responsible for about 65% of exports. The states dominating the production of cotton are Texas, Mississippi, and Georgia. In the past seven years, the growth in U.S. cotton area planted has been dominated by GM cotton. The United States has been losing market share of soybeans to Argentina and Brazil but is still a major exporter of soybeans. The southern states are not major producers of soy-

beans, but they will be affected by changes that affect production and distribution of these crops.

### *Market prices*

Because not all of the world's producers adopt GM cost-saving technology, there is a competitiveness effect. In countries with open markets, extra production is exported (or imports are replaced) at the world price, with a diminished effect on domestic or world prices compared with countries with closed markets. For larger countries whose trade is a significant portion of total world trade, there will be a modest effect on world and domestic prices. The southern states have not experienced major shifts in prices of cotton and soybeans. The pricing system for those two crops varies by season and regions within states. The fall in output prices of cotton and soybeans has been offset by the fall in production costs.

### *Resource Allocation*

Even though some countries have restricted the importation of biotechnology products, we are unable to infer a lack of interest in biotechnology crops. Hence, countries are allocating resources to capture rents from this new innovation. The estimated global expenditure on crop biotechnology in 2001 was \$4,400 million, and the United States is the leading contributor. If we use patents as a proxy measure of investment, the United States has 46% of all biotechnology investments, the EU 33%, Japan 11%, and the rest of the world 10%. Economic principles state that as a country opens up for free trade the demand for the goods in which it has a comparative advantage rises (Thompson). The investment in biotechnology and the market share of exports of GM crops indicate that the United States has a comparative advantage in the production of certain GM crops. If the comparative advantage in the production of GM crops relative to non-GM crops exists, and based on Rybczynski's theorem, as we increase our endowment of capital in GM crops with prices constant, output of the good from the factors we use

intensively must increase. Output of the other goods from factors we use less intensively must fall. With prices of goods constant in the factor proportions model, the output of corn, cotton, and soybeans in the United States is positively related with endowment of biotechnology. Output of non-GM corn, soybean, and cotton is negatively related to the other factor endowment (Thompson). Hence, with time, the United States is expected to increase its output of GM cotton, soybean, and corn if the markets for its exports increase. Argentina and Brazil are rapidly expanding their production of GM soybean and corn. China is rapidly expanding its production of GM cotton.

In 2004, 76% of all U.S. cotton produced was GM, with Arkansas, Georgia, Mississippi, and Louisiana producing 97%, 94%, 94%, and 93% of their cotton crop in GM cotton, respectively. The rates of adoption of GM cotton in the southern states have been rapid over the past seven years, with Alabama having an adoption rate of up to 70%.

In 2003, the world production of soybeans was about 6,982 million bushels. The United States produces about 34% of the world production and is responsible for 36% of exports. Most of the U.S. soybean production takes place in the midwestern states. The southern states produce only a small quantity of soybeans. The only southern states that produce a significant amount of soybeans are Arkansas and Mississippi. Arkansas produces 2.5 million acres and Mississippi produces 1.5 million acres. However, most of the soybeans produced in both states are GM soybeans. About 93% and 92% of the soybeans produced in Mississippi and Arkansas are GM. Hence, GM crops are important to the United States and the southern states.

Biotechnology in plants has experienced the fastest adoption rates of any agricultural technology. This rate of adoption will slow down as countries develop policies that restrict its spread. Policies employed by countries can facilitate or retard the growth of biotechnology. Some countries invest heavily in biotechnology development. Table 3 shows the distribution of public and private funds that support biotechnology. Other than the north-

ern countries (the United States and Canada) that are more open to the use of biotechnology products, most countries may be more cautious about the advantages and disadvantages of biotechnology and may attempt to regulate the use of biotechnology crops and products until more is known about the associated risks.

#### *Comparative Advantage and Crop Production by Region*

We will use cost and return analysis to examine whether the southern states have a comparative advantage in the production of the principal GM crops. It is difficult to use cost and return figures for any one year for such analysis since the returns obtained from growing any of these crops are affected by a number of environmental and market factors. We will use data for 2002 and 2003 for this exercise because environmental conditions for growing these crops varied during these years. We must also note that the use of delimitation of production zones changed with crop and by years. Hence, when we talk about the southern states, we are talking about the general area (Southern Seaboard, most of the Fruit Rim, part of the Eastern Uplands, and the Mississippi Portal) that may almost represent some of the southern states.

Cost and returns data for 2002 and 2003 for cotton production showed that the southern states had a comparative advantage over the other states in cotton production. A look at Table 5 shows that for the United States it costs \$0.58 and \$0.90 to produce \$1.00 from cotton in 2002 and 2003, respectively. During the same years, \$1.00 of operating expense generated \$1.11 and \$1.68, respectively. For the states occupying most of the southern region (those in the Southern Seaboard, Fruit Rim, and the Mississippi), the returns from operating and total costs were higher. This means that the states in the southern region are more efficient and are able to compete with the other states in cotton production. One may also infer that the southern states will benefit more than the other states from cost-reducing technologies because of their already existing

comparative advantage in cotton production due to physical resource endowments.

If we look at Table 5, we see that the United States received \$0.90 for every \$1.00 spent on soybean production in 2002 and \$0.98 in 2003. The returns to \$1.00 spent on operating cost were \$2.86 and \$3.01 in 2002 and 2003, respectively. When we compare these with the data from the states considered as southern, we see that for the Southern Seaboard in 2002 farmers on the average received \$0.67 for every \$1.00 spent on growing soybeans and \$1.56 for every \$1.00 of operating cost. The figures for 2003 are \$1.21 for every \$1.00 spent on growing soybeans for the Southern Seaboard and \$2.88 for every \$1.00 spent on operating cost. For the Mississippi Portal in 2002 farmers on the average received \$0.81 for every \$1.00 spent on producing soybeans, and \$3.34 for every \$1.00 spent on operating cost. A cursory look at the data in Table 5 shows that the southern states are competitive in soybean production in good years, as in 2003 but fare worse than other states in bad years. Therefore, the adoption of a cost-reducing technology may well depend on farmers' expectations of growing conditions.

In terms of corn production, the southern states (the Southern Seaboard) seem to have a slight comparative disadvantage in the production of corn. The southeastern states received \$0.72 and \$1.57 in 2002 for every \$1.00 spent on producing a unit of corn in 2002, compared with \$0.95 and \$2.22 for the United States in 2002. In 2003, the southeastern states received \$0.90 and \$1.92 per \$1.00 spent on total and operating costs compared with \$0.91 and 2.04 for the United States and \$0.90 and \$2.20 for the heartland. The southeastern states are adopting GM corn more slowly than other states.

#### *International Competitiveness*

Economic theory dictates that trade restrictions tend to influence competitiveness by shifting the terms of trade. Regulations related to mandatory labeling and traceability put in place by Europe also increase transaction costs of doing business and reduce efficiency and

**Table 5.** Cost for \$1.00 Spent Comparison for the United States and Major Producing Cotton, Soybeans, and Corn by Production Regions 2002 and 2003

Region/Return/\$	2002			2003		
	Cotton	Soybeans	Corn	Cotton	Soybeans	Corn
<b>United States:</b>						
Total Cost	0.58	0.90	0.95	0.90	0.98	0.91
Oper. Cost	1.11	2.86	2.22	1.68	3.01	2.04
<b>Heartland:</b>						
Total Cost	0.74	0.95	1.00	1.08	0.96	0.96
Oper. Cost	1.40	3.26	2.42	2.20	3.14	2.20
<b>Northern Crescent:</b>						
Total Cost		0.86	0.89		0.77	0.85
Oper. Cost		2.54	2.02		2.19	1.85
<b>Northern Great Plains:</b>						
Total Cost		0.99	0.82		0.98	0.79
Oper. Cost		2.71	1.86		2.58	1.68
<b>Prairie Gateway:</b>						
Total Cost	0.48	0.72	0.83	0.61	0.93	0.83
Oper. Cost	1.04	1.97	1.78	1.33	2.53	1.72
<b>Eastern Uplands:</b>						
Total Cost		0.82	0.67		1.21	0.82
Oper. Cost		2.19	1.58		3.17	1.81
<b>Southern Seaboard:</b>						
Total Cost	0.50	0.67	0.72	0.92	1.21	0.90
Oper. Cost	0.90	1.56	1.57	1.57	2.88	1.92
<b>Fruit Rim:</b>						
Total Cost	0.65			1.27		
Oper. Cost	1.20			2.25		
<b>Mississippi Portal:</b>						
Total Cost	0.71	0.81		1.03	1.21	
Oper. Cost	1.28	2.34		1.82	3.34	

competitiveness. Hence, as countries in Europe adopt trade-restricting policies, it is expected that the United States, Brazil, and Argentina, which are highly competitive in soybean production, will suffer losses if these exports are restricted from entering certain markets. Oehmke, using a Hecksher-Ohlin framework, and dividing the world into three trading blocks, concluded that restrictive European biotechnology policies diminish the effective growth rate of their capital stock; these restrictive policies lead to a decline in European agricultural growth and trade. The lack

of European agricultural biotechnology production provides developing economies with an enhanced opportunity to engage in biotechnology production and trade. The developing countries have an expanded opportunity for effective capital accumulation and increased economic growth. It is expected that the United States will lose a large portion of its \$6 billion in agricultural and food exports to the EU (Moschini). The regulations enforced for the use of biotechnology also limit domestic production of the biotechnology crops. However, if the European Union, because of food-

safety concerns fails to extract the benefits from trade-distorting measures, the developing countries and the southern states that produce cotton and soybeans will benefit.

### *Institutional Forces*

Institutional regulations may influence competitive advantage of any country. Regulating countries may implement trade regulations to enhance their comparative advantage. Large country adopting rules may also affect trade in another country. For instance, the EU ban on GMs may affect the competitiveness of trade in the southern states. Hence, it is important to examine the rules affecting GMs, adopted by other countries and the World Trade Organization (WTO).

Countries usually employ one of two principles to the regulation of GMOs: the *equivalence principle*, which is considered reactive rather than proactive, and the *precautionary principle* approach, which is proactive. On the basis of the levels of production and use of biotechnology crops and products and the characterization made by Oehmke, we divide the world into three groups for the sake of analysis: The United States and Canada, which we will consider the north (N); the European Union (EU); and other countries we will call the south (S). According to Sheldon and Josling, countries that use a reactive approach tend to base rules on consensus scientific information, regulate the product rather than the process, and use the biotechnology product as a point of comparison. Countries that favor the precautionary approach tend to pay more attention to unconventional scientific ideas, often regulate the process rather than the product, and prefer to make absolute judgments about health and environmental safety rather than compare with the non-GM product. The equivalence approach, based on an implied confidence in the scientific information available, tends to favor either no labeling or voluntary labeling of whatever characteristics the private sector wishes. The N finds itself in this grouping. Mandatory labeling is only seen as necessary where actual health risks are envisaged. The EU and most S countries find them-

selves in this grouping. Of countries' characterized by their regulations on GMOs in the study by Sheldon and Josling most (76%, 19) adopted mandatory labeling, (24%, 6) having voluntary labeling, and (8%, 2) having preference for no labeling or having no scheme proposed. These regulations vary by country, product, and organization. Irrespective of the policy type, each one affects the flow of trade. As Pinstrip and Andersen stated, biotech policies can operate through three mechanisms to influence trade flows. We shall briefly examine the countries' regulatory policies.

The United States was the first country to implement a comprehensive set of policies to regulate biotechnology crops and livestock. The regulatory framework in the United States is based on the Coordinated Framework for Regulation of Biotechnology Products, published in the *Federal Register*, June 26, 1986. This framework established that biotechnology should be regulated through existing agencies rather than a new, dedicated agency (Belson). The three agencies concerned are USDA's Animal and Plant Health Inspection Service (APHIS), the Environmental Protection Agency (EPA), and the Food and Drug Administration (FDA). The FDA deals with the premarket approval of GMOs and foods containing GM ingredients. APHIS relied on the federal Plant Pest Act to deal with GM plants, and now operates under the federal Plant Act of 2000, which replaced the earlier act. The EPA is responsible for regulating plants that are genetically engineered to express pesticides, such as *Bt* corn. It operates under federal statutes: the federal Insecticide, Fungicide, and Rodenticide Act. The U.S. policy is based on the doctrine of substantial equivalence as a basis for regulation of GMOs.

GMO regulation in Canada is similar to that of the United States in terms of the involvement of multiple agencies, the premarket approval of products, and the principles on which they base their approach to regulation of labeling. Voluntary positive labeling and voluntary negative labeling are allowed.

Before 1990, the EU had no coordinated biotechnology policy (Josling and Patterson).

In June 1999, the Council of the European Union formalized a moratorium on GMO approval by recommending to the European Commission an amendment to directive 90/220/EEC. The final stages of the EU legislation are still being implemented. The EU is mainly concerned about mandatory labeling and traceability. In fact, the European Union's regulations are so stringent that they must be considered prohibitive. Merchant and Song discussed the effects of the EU's biotechnology policy on U.S. corn exports. They showed that after the EU's GM-imposed five-year de facto moratorium on approving new transgenic varieties, U.S. corn exports to the EU dropped from 3.9 million metric tons in 1995 to 0.09 million metric tons in 2003.

Australia, Brazil, Chile, Japan, and other countries are putting into place mandatory labeling requirements. Whatever the form of regulation and policies adhered to, the institutional regulations affect trade flows. Merchant and Song discussed China's regulatory policy on GMOs.

The WTO legal framework regarding trade in GMO products include the Sanitary and Phytosanitary (SPS) Agreement and Agreement on Technical Barriers to Trade (TBT) and a multilateral environmental agreement. The WTO Agreement on Sanitary and Phytosanitary Measures (SPS Agreement) requires that measures regulating imports be based on "sufficient scientific evidence" and the countries operate regulatory approval procedures "without delay" (Larson). The southern states' cotton and soybean producers may be affected by the regulations of enforcing countries. The labeling of products is mainly for corn and soybean products, and not much of the crops produced are from the southern states. Since cotton production, for which the southern states seem to have a comparative advantage, is not affected by consumers' demand for labeling, the effects on the southern states' competitiveness may not be seriously affected.

#### **Policy Implications of Biotechnology (Enhanced Crops) to Developing Economies**

Developing countries are identified as emerging markets for U.S. products of soybeans and

corn. They are also competitors for products heavily grown in the southern states. Most developing countries have been slow to import GM foods despite problems of food scarcity because of health and other concerns. According to Diaz-Bonilla and Robinson, a world with an adequate food supply is clearly more desirable than a Malthusian world in which food is scarce. They also emphasized that it is neither efficient nor environmentally sound for developing countries to seek food security by becoming self-sufficient in the production of food crops, particularly when such production involves inefficient, unstable methods on fragile lands. Hence, developing countries are likely to resist the production and use of biotechnology crops because of their own concerns, but they may be forced to accept these crops because biotechnology crops and products provide a faster way of reducing hunger. Policy makers in developing economies might consider addressing the challenges of biotechnology as an alternative means of preventing food shortages. There are new products in the pipeline with genetically modified genes that may help food producers to combat natural disasters. For instance, new rice developed by Cornell University researchers contains a hardening strain that enables rice to endure various weather environments, such as droughts and cooler weather (Council of Biotechnology Information 2005a). Policy makers might further research such developments in other crops to prevent crop shortages. With well-established market development of like varieties, producers may become less risk adverse because of adoption premiums distributed by the public sector and have more incentives to increase production. However, there might be some consumer skepticism and rejection of such technologies. Therefore, policy makers should consider informing consumers about the benefits of consumption of GMs, which may help to overcome resistance to the technologies.

Consumers in a number of developing countries eat rice three times a day, and they could benefit from changes in rice production levels. Rice is produced largely in the southern states, in Texas, and in California. The United

States produces only 3% of the world's total rice output but is responsible for 11% of rice trade. Hence, adoption and distribution of GM rice in the future may affect southern competitiveness. Furthermore, if demand shifts because of changes in consumer taste and attitude, producers may seek the capital to develop new GM products to satisfy this existing demand. Increased demand for food products may influence southern producers' competitiveness in rice and soybeans production.

Another alternative that policy makers should consider in increasing the growth of value-enhanced crops (VEC) in developing economies is the use of enhanced biotechnology crops in combating vitamin deficiencies. In several developing countries, children suffer from vitamin A deficiency, which can lead to blindness and death. According to the Council of Biotechnology Information (2005b), golden rice created by German and Swiss scientists contains a gene that produces beta carotene, which is a precursor to vitamin A. Policy makers should consider further production of such technologies. Future developments in these areas could markedly alter the competitive position of southern U.S. farmers as they compete for shares in the global market of these crops.

### **Summary and Conclusion**

Southern states have been early adopters for *Bt* cotton and adopters of soybeans. The rate of adoption of corn in the southern states is still slow. Competitiveness in these crops is based on market share and the levels and rates of public and private investments. Competitiveness has been stimulated by cost reduction of cotton, maize, and soybean, primarily due to a reduction in use of pesticides. The reduced use of pesticides can be considered an environmentally friendly way of growing crops. The increased contribution of biotechnology crops to total exports has resulted in depressed prices as the EU, a major importer of those crops, has put in place a moratorium on the import of GM crop varieties, even though the benefits derived from the use of

these present low health risks and yield high environmental benefits.

Market changes in the movement of these crops are exogenous, and obstacles in the shift of the demand curve of GM crops to the right will depend mainly on institutional and economic factors. Hence, major emphasis to shift the market demand curve to the right should be placed on changes in public perception of biotechnology crops. Also investors should be provided with the incentive to supply more GM crops and products as consumers' acceptance of the GM crops is altered through the provision of more information.

The southern states have increased their competitiveness in the production of GM cotton and this is demonstrated by the rapid adoption of GM cotton. The adoption of GM soybeans has also been rapid and has permitted the states to maintain their competitiveness relative to the other regions of the United States. The adoption of corn in the southern states is less spectacular but similar to that of the other major producing states.

The initial momentum of the agricultural biotechnology industry was that of first-generation GMs. These input trait plant varieties that modified or substituted for chemical input use in soybean, corn, and cotton were initially introduced to enhance productivity benefiting private industry, producers, and consumers. The acute market growth rate demonstrated from first-generation GMs within the United States and developing economies has not been the case for second-generation GMs, or VEC. Although several new GMO products are in the pipeline, the public sector may be needed for regulations. Policy makers should consider the type of regulations to implement in addressing the major challenges such as adoption incentives, market development, and the willingness to pay for nutrition that face the biotechnology industry in developing economies. Currently, each country is struggling to put in place policies to regulate biotechnology. Sheldon describes the process of regulation as a patchwork. The WTO should put in place a commission to examine the development and use of biotechnology crops and products. This would unify the global regulatory policies of

GMOs. The risks associated with the production and consumption of GMOs would be better understood. A dynamic market may have a pull effect on the production and supply of GM products. The United States is already a leader in the production and supply of GM crops; therefore, an open market may mean an increase in demand for GM products, which the southern states are able to produce. Changes in consumption of GMO crops could influence the competitiveness of the southern states and demand for their products.

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