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The Political Economy of Agricultural Biotechnology Policies

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This article develops a political-economy framework to analyze the formation of agricultural biotechnology policies. Going beyond accounts that largely attribute differences between US and European regulatory environments to consumer attitudes, we consider the impact of what amounts to a Schmpeterian process of "creative destruction" across the entire range of relevant economic sectors and interests. The analysis suggests that in Europe and in some developing countries a "strange bedfellows" constellation of concentrated economic interests (including incumbent agrochemical manufacturers, certain farm groups, and environmental protest activists) act in rational self-interest to negatively characterize GM technology in the public arena and to seek regulations that block or slow its introduction. In contrast, those interests most likely to experience welfare gains from biotechnology are the more diffused and less informed—including consumers and small farmers. The most profound implications of overregulation of agricultural biotechnology are (1) delays in the global diffusion of proven technologies, resulting in a lower rate of growth in the global food supply and higher food prices, and (2) disincentives for investing in further R&D, resulting in a slowdown in innovation of second generation technologies anticipated to introduce broad consumer and environmental benefits.

Key words: regulation, interest groups, consumer acceptance, precautionary principle, political economy.

Introduction

Why might it be that low income countries would apply regulatory systems for agricultural biotechnology modeled after European standards, even though it means their poor farmers and consumers lose any potential gains in agricultural productivity and social welfare? Ten years of commercial use in the United States, Canada, Argentina, and Brazil have demonstrated that traits such as insect-resistant Bt and herbicide tolerance can increase yields in corn, soybeans, and other crops and can be consumed safely, yet many African regulators continue to ban these traits (Paarlberg, 2008). Analyses of the adoption of Bt within farming systems characterized by limited means of pest control, such as small-scale cotton growers in India, demonstrate significant yield gains (Qaim & Zilberman, 2003). Yet, Indian regulators appeared willing to approve the technology only after an entire state of farmers had effectively bootlegged the technology into their fields (Herring, 2003).

As a general-purpose "enabling" technology, biotechnology can be used to introduce a wide variety of traits appropriate for farming systems around the world. Yet, by lumping all results of this general-purpose technology under a common set of regulatory requirements, policies designed for already commercialized traits (i.e., pest control) are heavily affecting the costs and incentives of developing a wider variety of other "second-generation" traits (Graff, Zilberman, & Bennett, 2005). The resulting orphan traits have included some that are obviously important—such as drought tolerance—and others that are more subtle but potentially potent—such as feed characteristics to increase the efficiency of digestion in animals. Any such improvement in the use efficiency of a crop output—say, by 3%—translates into a comparable reduction in the acreage needed to cultivate that crop, in the water and other inputs used to grow that crop, and in the waste that results from processing or using that crop. In the case of feed efficiency, this would translate into a reduction in the amount of nitrogenous and phosphoric pollution from animal manure. Other orphaned traits, such as increased shelf-life of fresh fruits and vegetables, could benefit producers and consumers—in both developing and developed economies. Such a trait could partially compensate for lack of transportation infrastructure and refrigeration in developing economies, reducing waste and increasing net available food supplies to consumers, while shelf-life traits basically allow for reduced costs and expanded reach of mature supply chains in developed economies.

These two results—the non-adoption by many countries of already developed and commercially proven first-generation traits and the slowdown in the development of a wide range of second-generation traits—both can be attributed to the implementation of precautious policy regimes withholding approvals of biotechnology or the reluctance or inability of governments to implement any functioning policies at all. The range of policies that impact the adoption of agricultural biotechnology include intellectual property, biosafety, trade, food safety and product labeling, and public research investments (Paarlberg, 2001). Why is it that some countries, such as the United States or Argentina, find it reasonable and politically feasible to allow the technology to be rapidly adopted within their agricultural sectors, while other countries, such as Europe and many developing countries, find it either unreasonable or politically unfeasible?

In this article we develop a political economy framework to analyze the formation of agricultural biotechnology regulations. By accounting for the different interests within society and the interactions amongst them, we try to shed light on how the very different regulatory environments for genetically modified organisms (GMOs) have emerged in the United States, Europe, and developing countries. Specifically, we question the notion that regulatory differences between the United States and Europe primarily reflect differences in consumers' underlying attitudes, as many argue. Instead, we highlight the roles of other economic interests in framing the debate and influencing the policy-making process. This is crucial. Our political economic analysis suggests that the broad social welfare gains from introducing the technology are likely to be distributed amongst many consumers and small farmers—particularly those in developing countries—who may not have strong influence over regulators because of their relatively small individual stakes, lack of expertise, and lack of collective cohesion. On the other hand, our analysis suggests a "strange bedfellows" constellation of more concentrated economic interests (including incumbent agrochemical manufacturers, certain farm groups, and environmental protest activists) have incentives to negatively characterize this technology in the public debate arena and support regulations that block or slow its introduction.

Similar to Prakash and Kollman (2003), we argue that domestic politics caused agricultural biotechnology regulation in North America and in Europe to diverge from each other. Different from Prakash and Kollman, however, we argue that groups that stand to gain or lose the most from agricultural biotechnology affect risk perception of the less-informed groups and therefore affect a country's core policy position. Falkner (2006) describes the transformation of the European Union (EU) from a laggard to a leader in the international politics of biotechnology regulation and notes that this transformation stems from a shift in domestic politics. We argue that this shift is, in part, a function of a change in risk perception induced by those economic interest groups in Europe and elsewhere that stand to lose from the introduction of the technology. It is the politics of Schmpeterian "creative destruction."

Theories of Regulation and Their Implications for Agricultural Biotechnology Policy

A number of theories have been advanced by economists and political scientists to explain the behavior of regulators and the shape and strength of the policies that they make (see Grossman & Helpman, 2001, and references therein). Such theories typically take into account the influence that groups of regulated economic agents, such as producers and consumers, have on regulators.

Capture Theory

One such theory of regulation—called "capture theory"—considers the situation in which a regulator is effectively *captured* by a single interest group, often the very industry that the regulator is charged to regulate, and made to cater to its interests (Posner, 1974; Stigler, 1971). In the context of agricultural biotechnology, capture-theory arguments have been advanced on both sides of the policy debates that have continued over the last two decades. Some have argued that government regulators, particularly in the United States, are too closely aligned with the regulated industry in such a manner that the interests of companies like Monsanto are put before those of the public, for example, with industry representatives populating official posts through a "revolving door" phenomenon (Hayden, 2003; Newell & Glover, 2003; Seelye, 2001). Meanwhile, others contend that regulators, particularly in Europe, have capitulated to the tactics of political activists and thus reflect the agendas of organizations such as Greenpeace or Friends of the Earth more than they do the actual welfare of farmers or working-class consumers (Byrne, 2006; Gilland, 2006; Miller & Conko, 2004).

However, given the complexity of effects when biotechnology is applied in agriculture, it is not obvious what the implications would be for regulators if policy were fully controlled by the agenda of either industry or activists. *A priori*, we might expect industry to want relatively light regulations of transgenic crops, since this would reduce their costs of introducing and maintaining new products. However, we also might reasonably expect the opposite, for industry to desire strict regulatory requirements as a way to shift liability away from themselves and onto governments in the event of actual safety problems or as a way to create barriers to entry by smaller, more innovative biotech startups (or even competitive biotech crop varieties developed and introduced by public-sector researchers and breeders). Similarly, if environmental activist groups fully controlled the biotech regulatory agenda, it would seem reasonable to expect them to promote very strict regulations or outright prohibitions, based upon claims that the technology is too risky for the environment and public health. However, to the extent that environmentalists recognize that the main alternative to biotech traits are the use of agrochemicals (in both the North and South) or the use of no inputs at all (especially in subsistence agriculture in the South, thus increasing pressures to cultivate marginal lands), both of which may be at least as harmful to the environment, then it may be rational for environmental groups to advocate for regulations that allow for limited use of biotech crops; thus, this equally applies a "precautionary principal" towards all feasible short-run alternatives. In sum, observation of the situation in agricultural biotechnology suggests that "capture theory" provides too narrow of an explanation for what is actually going on inside the complex policy formation processes of governments around the world.

Political Economy Models with Multiple Competing Interests

More sophisticated political-economic models have been designed to accommodate more features of political systems (Becker, 1983; Grossman & Helpman, 2001; Peltzman, 1976; Zusman, 1976). Most of these reduce to a politician or regulator that weighs the interests of various groups within the economy, i.e., groups that have managed to solve the collective action problem and are well-enough informed with respect to the likely costs or benefits arising from the regulations in question. The weights attributed by the politician or regulator to those various groups reflect the relative influence each of those groups have over the politician. The groups engage in actions to influence the regulator—for instance, by making political contributions, making endorsements, or simply casting votes—and thereby affect policy outcomes in ways that cause them as a group to gain in terms of economic welfare or economic rents. In fact, Posner's (1974) capture theory can be considered a special case in which one group has full weight and all other groups have zero weight in influencing the regulator. Following the approach of Zusman (1976), we can describe the agricultural biotechnology regulator's problem as the following weighted welfare maximization:

$$\begin{aligned}
\max\ (&\textit{regulator welfare} + A_1\ \textit{consumers' surplus}\\
&+ A_2\ \textit{food retailers' producer surplus}\\
&+ A_3\ \textit{farmers' producer surplus}\\
&+ A_4\ \textit{major biotechnology suppliers' producer surplus}\\
&+ A_5\ \textit{new biotech innovators' producer surplus}\\
&+ A_6\ \textit{competing input suppliers' producer surplus}\\
&+ A_7\ \textit{academic institutions/scientists' benefits}\\
&+ A_8\ \textit{activist organizations' benefits}\\
&+ A_9\ \textit{environmental welfare}). \qquad (1)
\end{aligned}$$

In this equation, the terms for welfare, surplus, or benefits are all common economic measures of welfare or rents. In a case like this—of technology regulation—the welfare terms are a function of the economic effects of the technology's adoption, which in turn is dependent upon which technologies are approved and the costs associated with their approval, adoption, and use. The A_k terms indicate the weight of influence that each group k has over the regulator's decision-making process. Following Zusman (1976), these coefficients are normalized to reflect weights relative to the politician's or regulator's self interest. Indeed, the regulator is not necessarily indifferent to his or her own welfare.

Consumer surplus is measured in the typical manner, and thus accounts for the typical heterogeneity of tastes and preferences amongst consumers. The coefficient A_1 indicates the relative weight given by the politician to consumers, reflecting, among other things, consumers' influence over the politician's ability to get re-elected. Several scholars point out that consumers in the United States and Europe only marginally benefit from GM foods and are therefore not inclined to actively support their introduction, especially given perceptions that there may be risks associated with GM foods (Paarlberg, 2001; Wu, 2004; among others). Indeed, it is not unreasonable for average food consumers to remain "rationally ignorant" (Stigler, 1971) of the welfare impacts of agricultural biotechnology and not be motivated to mount any significant collective action relative to this issue. They instead exercise their influence individually, by making purchase decisions and by voting.

Producers' interests are quite heterogeneous, certainly between different segments of production, but even within a given segment. Our rule must be to accurately disaggregate producers into the different groups that have potentially competing interests; it is important to separate those whose levels of producer surplus are likely to be affected quite differently by the adoption (and thus the regulation) of biotechnology in agriculture. Moreover, these different groups are likely to have different degrees of influence over the politician or regulator. We should thus disaggregate the production side, at a very minimum, into five groups: food retailers, farmers, current suppliers of GM crops (agbiotech incumbents), small agbiotech companies introducing new innovations (agbiotech entrepreneurs or new entrants), and competing input suppliers such as chemical pesticide manufacturers. Depending upon how detailed an analysis one would wish to conduct, it is of course possible to identify other significant groups or to subdivide any one of these groups (such as farmers)[1] based on the heterogeneity of interests within that group.

Academic institutions and scientists in academia will tend to benefit differently under different biotechnology regimes. Public-sector agricultural research and extension services can gain or lose in terms of public funding, royalty income, and/or relevance and prestige within the agricultural sector. They can also have influence over regulators, as their policy advice and their published studies are often consulted in the policymaking process.

Finally, the last two terms in Equation 1 distinguish between direct benefits to activist organizations and benefits to the environment per se. The political economy of activist organizations is discussed in more detail later, but for now we note that the last term is the benefits that serve to perpetuate the activities of environmental activist organizations—such as donations or grants collected, size of budget and staff, rents diverted to supporters of the organization—and build a reputation or brand value. These are certainly different from environmental surplus, the benefit that accrues from a better environment to society as a whole.

Next, consider implications of this framework for the strength of regulations over GMOs. Among those groups listed, the most likely to support a more laissez-faire regulatory environment are new biotech innovators (or the venture capitalists who back them) who depend upon reasonably easy entry into agricultural markets, farmers who seek to profit from growing crops with GM traits, and those consumers who see biotechnology lowering the price of food while not posing a risk to food safety.

From the regulator's maximization problem, however, we see that more groups are likely to support strict regulations, including risk-averse and/or price-insensitive consumers; brand-conscious food retailers; producers of competing inputs like agrochemicals; environmental activist organizations; and the regulators themselves, who desire to enhance their power and budgets by increasing their regulatory mandates. In fact, the established producers of biotech crops are likely to be conflicted; higher costs of entry affect the incumbent's own ability to innovate and introduce new products even as they defend the incumbent's current market position against the profit-eroding effects of new entrants. Farmers are also likely to be conflicted, as differences between regulated and unregulated crops can provide effective non-tariff barriers to trade as well as opportunities for price differentiation in the sale of what would otherwise be a homogeneous commodity.

A Political Economy Model with Interaction Amongst Competing Interest Groups in the Formation of Expectations

While the traditional political-economic framework with multiple interest groups provides some useful insights, it is still too simple to capture some of the key phenomena shaping the political economy of agricultural biotechnology, particularly in terms of actual versus perceived consumer welfare, the affect of risk perceptions in the formation of expectations about future welfare, and interactions among the different groups within society, including the roles of activist organizations and the media. In order to capture some of this, we introduce a more nuanced three-stage theory:

1. *For instance, farmers could be segmented by crop, by method of production (organic or conventional), by market (export cash crops or subsistence), or by ownership and farm structure (Anderson, Damania, & Jackson, 2004; Anderson & Jackson, 2003) and we would find different economic incentives within those subgroups, leading them to influence the regulator towards different policies on the production and consumption of genetically modified foods. Yet, there are net results of policies, such as impact on commodity prices, that affect the entire group and induce it to act in one accord.*

1. The first stage involves an initial consideration of the welfare conditions by each of the various groups in Equation 1. However, actual or objective environmental and health benefits may be considered unknown or uncertain.

2. The second stage is a public debate in which the different groups can affect the perceptions of members of other groups. For example, information from activists, industry, and academic scientists inform consumer perceptions of their own welfare, such as possible health risks or health benefits, even though the actual level continues to be unknown or uncertain. Similarly, resulting *perceived* levels of environmental surplus are based on information provided by different groups about possible environmental risks and benefits, enter the regulator's objective function.

3. In the third stage, the regulator chooses policy to maximize its objective function, accounting for the *perceived* welfare and benefits terms updated in the second stage and the weights of influence of each.

The policy maker's objective is, in this case, to maximize a weighted sum of the *perceived* well-being of the various groups. For simplification, since producers, activists, and regulators can be assumed to be better informed and more risk-neutral, their perceived well-being (perceived producer surplus, etc.) will usually be close to its actual or objective value. Consumers, however, are assumed to have limited initial knowledge about biotechnology and to be risk-averse. Thus *consumers' perceived welfare* (CPW) is defined as the sum of consumer surplus from purchase and consumption at market prices minus the corresponding value of their *perceived* risks of doing so. Furthermore, it is this perceived risk component of CPW that depends at least partially upon information provided by other groups, which is weighted by each group's credibility or influence with consumers. When the individual's objective gain in consumer surplus is quite small—as is clearly the case with biotech foods—it is relatively easy for the risk perception generated in the public debate to overwhelm the "objective" gain in consumer surplus. Genetically engineered drugs provide a clear counter example: the objective gain in consumer welfare from a new biologic pharmaceutical certainly seems to overwhelm any perception the consumer may have of risk, even though it is also the product of a GMO.

What arises is a situation in which each of the various groups seeks to shift the others' perceptions in a direction that generally serves its own interest (Babinard & Josling, 2001; Herring, 2008). Groups that stand to lose welfare from the introduction of biotech will, for instance, seek to provide consumers with bad news. Those who stand to gain will provide good news. Consumers weigh the evidence—filtered through the degree of trust and confidence they have in the group providing the evidence—to form their risk perceptions. Empirical assessments of the development of consumer attitudes, particularly in Europe, bear out that there has been a process of informing and shifting public opinion (e.g., Brossard, Shanahan, & Nesbitt, 2006; Gaskell et al., 2006). The prominence of this stage-two interaction distinguishes agricultural biotechnology from other uses of biotechnology, such as genetically engineered drugs. Since the introduction of a new biologic pharmaceutical is not as likely to challenge existing economic interests, it does not provoke the same tenor of public relations effort to sway public opinion and thereby influence the regulator.

The interactions can flow in multiple directions. As CPW is established, for example, it in turn affects the perceptions of the other groups about likely impacts on their own welfare. In particular, consumers' emergent attitudes about biotechnology affect retailer expectations. A retailer's producer surplus is highly dependent upon the reputation of its brand, which itself is a function of consumer's perceptions. Accounts from the retail sector in Europe clearly indicate the strong effect that consumers' attitudes toward biotech foods have had on retailers' policy positions (Kane, 2001).

And, to introduce a final elaboration, interactions between the identified groups can flow across national borders. For example, consumers in a commodity-importing country can affect farmer attitudes in exporting countries. In fact the full model, employing an implicit convention of the trade literature, would include separate terms in the regulator's objective function for domestic and foreign counterparts of each of these identified group. Domestic consumers would be considered separately from foreign consumers. And crucially, domestic consumers (as voting and taxpaying constituents) have much greater weight in the objective function of that country's regulator than do their foreign counterparts. Similarly, the welfare of domestic farmers and domestic companies is of greater concern to a regulator, as they and their lobbyists have considerable political influence over that regulator relative to foreign farmers and foreign companies.

"Activist" (or "non-governmental" or "non-profit") organizations play an integral role in the information flow amongst the other interest groups, in addition to weighing into the regulator's objective function themselves (Collingwood, 2006; Meyer, 1997). Even when committed with full integrity to idealistic goals, such organizations succeed and fail in very real ways, often as a function of the policy position they advocate and their ability to influence policy outcomes in that direction. Revenues for such groups are sustained by being viewed by potential donors and grant makers as effective in at least two functions: (1) collecting and sharing information that may be more complete or more objective than official government or industry accounts (a "watchdog" or "informant" function) and (2) representing the donors' interests in the policy process and ultimately changing policy to serve those donors' interests (an "advocate" or "representative" function).

Unfortunately, these dual roles create a situation in which conflicts of interests can become endemic. In policy areas (like agricultural biotechnology) where uncertainty and unfamiliarity causes anxiety levels to be high, incentives exist for activist organizations to provide information (sometimes even misinformation) that accentuates the anxiety and undermines trust in government regulators. As anxieties about the possible risks rise and as donors are convinced that their interests are better represented by the activist organizations than by the regulator, the flow of revenues to such organizations will tend to increase. In extreme situations, activist organizations can even be catapulted into a quasi-regulator role.

Furthermore, complete resolution of a policy issue tends to have an unfavorable effect on donations to activist organizations, as well as their political relevance. Thus, those organizations that tend to persist are those that periodically achieve high-profile but partial "wins" in the policy arena, enough so that the organizations can claim credit and legitimacy for making progress but not so much as to assuage donors that their underlying problems have been truly solved. Then, together with occasional high profile "revelations" of ongoing governance failures, the organizations publicize new problems or risks that threaten the interests of the donor-base. Furthermore, survival depends upon these organizations' information revelations and policy actions being reliably communicated to an often highly dispersed donor-base. This implies a reliance of successful activist organizations on media outlets.

In fact, there appears to be a natural symbiosis between those activist organizations that persist in the public arena and the media (Brossard et al., 2006). Analyses indicate that economic interests of the media mirror those of a successful activist organization's strategy, as revenues to media are enhanced by repeating familiar stories, perpetuating stereotypes, playing on readers/viewers anxieties, and emphasizing bad news over good news (Curtis, McCluskey, & Swinnen, 2008; Gaskell, Bauer, Durant, & Allum, 1999; McCluskey & Swinnen, 2004). However, we have not directly entered the media as a group into the regulator's objective function (Equation 1). We do not see that any particular policy outcome on biotech regulations would have a welfare- or rent-producing effect on media companies. The media do not have to stake reputation—and thus, revenues—on achieving any particular policy outcome in the same way that activist organizations do. The media do play an essential role, however, in the public debate phase—our Stage Two—of the policy-making process. Perhaps a bit like divorce lawyers, the media benefit from the fact that there is a conflict, and they gain regardless of how it is settled in the end.

A Political-Economic Interpretation of the European Ban on Agbiotech

Let us use this framework now to analyze the regulation of GMOs as it unfolded in Europe in the 1990s. Specifically, let us consider whether differences between US regulations and EU regulations primarily reflect differences in consumer attitudes, as many contemporary accounts argue or imply (see, for example, Bernauer, 2003; Hoban, 1998; Runge, Bagnara, & Jackson, 2001; Sheldon, 2004). Let us look in detail first at the interests of agricultural inputs producers, then at the interests of farmers and of consumers. We will then consider the respective political weights and the interactions among these various groups as they influenced European regulators.

As a starting point, consider differences in the innovative capacities of the United States and Europe. Patent data on the agricultural biotechnology and agricultural chemical industries indicate broad national differences in innovative capacity. In agricultural biotechnology, American inventors have been far more prolific in both the quantity and quality of patents granted to them than have European inventors. One metric that has been used to rank the quality or value of a patent is the number of citations it receives from other patents. Analysis shows that the population of agbiotech patents granted to US inventors since 1980 have historically garnered roughly 10 times more patent citations than has the population of agbiotech patents granted to European inventors since 1980; the imbalance was particularly striking in the 1980s and early 1990s during the foundational development of the technology and before there was much public awareness of it (Graff & Zilberman, 2007). For comparison, agrochemical patents granted to US inventors have historically garnered roughly a similar number of citations as the agrochemical patents granted to European inventors. In other words, Americans enjoy an innovative comparative advantage in making biotechnology invention, while Europeans enjoy a comparative advantage in chemistry. This should come as no surprise, as the European—and particularly the German—chemical industry has been the dominant innovator and supplier of agricultural chemicals for the better part of a century.

However, consider how global crop protection markets have changed during the 1990s. Corporate sales figures reveal that, over that decade, most of the growth in the industry occurred in the category of *genetic* crop-protection products, while growth in categories of *chemical* crop protection was very weak. Changes in market share in 2001, once adoption of biotech varieties was well under way, were symptomatic. Virtually all of the growth was seen in genetic pest-control products. Sales in 2001 of new genetic technologies created by US companies were up 13% over 2000; sales of new genetic technologies by European companies were up by 2%. In contrast, sales of agrochemical pest control products were in decline. In 2001, sales of chemical pest-control products by both US and European companies were down 1%, and sales by Japanese chemical companies were down 10%.

Taken together, the picture that emerges is one of the US pest-control industry having a comparative innovative advantage in a new technology that is gaining market share and the incumbent European industry having a comparative innovative advantage in an older technology whose market share is being displaced. To the extent that this is an accurate description, we would expect the ascendant bio-based US industry to advocate for regulations that would help it to maintain its newfound comparative advantage, in particular against its larger but slower rivals in the European chemicals sector. Similarly we would expect the major European chemical firms to favor a regulatory regime that would, at the very least, slow the rate at which they lose market share to biotechnology, if not halt the losses altogether.[2]

Next let us consider European farmers and biotech crops. It would be expected that, all else being equal, some European farmers would prefer to plant GM varieties because of their cost-saving characteristics. However, supporting a ban on biotech crops helps a large proportion of European farmers in other ways, primarily as a non-tariff barrier to trade, protecting prices for domestic producers. European farmers may also support more stringent regulations on biotech crops, as they create an opportunity for systematic price differentiation of their commodity outputs, allowing them to collect a price premium while maintaining existing production practices of growing conventional crops. Furthermore, since a large proportion of European farmers are at least partially supported under the Common Agricultural Policy (CAP), any policy that tends to support farm incomes will likely be favored for reducing budget pressures on the CAP.

The relationship between European consumers and GM foods may simply be interpreted as one of straightforward rejection, a case in which the benefits of biotech for consumers simply do not outweigh the costs and risks (see, for instance, Bonny, 2004; Kane, 2001). It is estimated that European consumers pay 3-5 billion Euros more per year in food costs as a result of the ban on biotech agricultural products (Anderson & Jackson, 2004). This indicates the extent to which European CPW diverges from a simple computation of consumer welfare. This divergence can result from two things. First, food consumers are arguably less organized as an interest group than are the European agrochemical industry or European farmers, and following Stigler (1971), some of the excess cost may be a result of more concentrated interests prevailing against less concentrated interests in the policy process. While consumers as individuals may each be paying a few Euros more per year on food, efforts to organize an opposition to the prevailing policy might cost individuals more than it would save, and thus inaction on this issue may be the

2. *Some may object on the grounds that a strict interpretation of the precautionary principle has led to stricter regulation of chemical products as well. Yet, upon closer analysis, even this may be in the European industry's interests. An incumbent industry can be ambivalent about stricter regulations: On the one hand, they raise costs to the industry, yet on the other hand, they erect a barrier against new entry. When it comes to regulations in the chemicals market, strict precautionary standards may be helpful. European companies with advanced R&D capacity are able to introduce advanced (patented) compounds with better, more compliant environmental characteristics, while the highly precautionary regulations help to clear older, more dangerous (and off-patent) compounds from the European market, thereby reducing competitive pressure for the pricing of the new products.*

rational response. Second, there is also likely some extent to which there is a premium that European consumers are willing to pay to reduce the risk to which they perceive themselves to be exposed. These perceptions and the relative risk aversion of European consumers have reasonable groundings, yet we must be clear that they largely derive from the public debate that has been informed by other groups who have their own interests in the matter, including activists, industry, and farmers, as well as being shaped by the public's recent experience with regulators' inefficacy at mitigating food-related risks like BSE and foot-and-mouth. It is widely acknowledged that European consumers are less confident in their food-safety regulators and of agricultural scientists in general, and conversely, that environmental activists and Green political parties enjoy greater credibility in Europe than they do in the United States.

However, the dynamics of how the perceptions of European consumers developed over time are far more complex and nuanced than conventional accounts often suggest. European activist organizations have utilized the issue of food biotechnology to engage in a contest with European regulators for legitimacy according to the logic of how such organizations survive and advance. Changes in media coverage in Europe were in no small part driven by the campaigns of activist organizations pursuing such a strategy. Analysis of early media coverage of biotech foods in the United States and Europe (Gaskell et al., 1999) indicates that the volume and content of press accounts were roughly comparable through about 1990. Thereafter, the quantity of coverage increased in the European press relative to the United States. New narratives emerged in the European public debate. At least two major themes emerged. One maintained that biotech crops do not serve consumer interests, ignoring the effect that a cost-reducing agricultural technology tends to have in reducing consumer food prices; the welfare impact on developed economies, especially in Europe, is very small in contrast to developing economies where consumers might spend more than 50% of their income on food consumption (Paarlberg, 2008). The other theme has been to hold up the GMO as a symbol of the negative effects of globalization, characterizing it as an "American" technology that is anti-Green and pitted, in some sense, against a European way of life.

Finally, let us consider that in some cases unilateral decisions by private-sector actors can introduce *de facto* regulations in the form of industry standards. These can be especially influential in commodity markets with large economies of scale and undifferentiated marketing channels. Price-sensitive producers may seek to stop adoption of a technology if they are worried about preempting negative price effects that may result if major domestic retailers or foreign export markets that are major purchasers of their commodity decide not to purchase products that use that technology. By this logic it was, in fact, the major European retail chains that in effect decided and implemented European policy toward biotech crops. But, such effects have not been limited to Europe. For example, potato growers effectively ended the development of biotechnology for potatoes in the United States and globally in response to the decision in 1999 by McDonalds Corporation to not purchase GM potatoes (Kaniewski & Thomas, 2004). Likewise, decisions by the Canadian Wheat Board and North Dakota wheat growers in response to expected price affects led to the demise of Bt wheat.

In conclusion, the ban of biotech food in Europe does not appear to be simply a crisis of consumer acceptance but rather a convergence of the influence of several distinct economic interest groups within Europe, each with self interests in slowing or stopping the introduction of biotechnologies into European and global markets. To summarize, we argue that US academics and companies, since the 1970s, have held a relative advantage in biotech innovation, which began to threaten the market dominance of European corporations in agricultural pest-control markets by the mid 1990s. The interests of the European chemical industry concurred with the interests of other groups that stood to gain from restricting biotechnology. European chemical corporations did not need to be proactive in their opposition. First, since any new technology of this sort requires a new regulatory regime to be implemented, all the incumbent industry needed to do was to abstain from advocating for the implementation of a new policy. Without an effective champion, policy formation stalled. Second, given that activist groups were already highly motivated for their own reasons, all the incumbent industry needed to do to achieve a desired result was to abstain from intervening in the public debate and to leave the activists unchallenged in informing the public's opinions and risk perceptions of biotechnology. The convergence of these multiple interests then had a significant influence on the decisions of European regulators, effectively allowing the approval of new biotech crops to come a halt in 1998, withholding certain forms of patent protection from biotech crops, underfunding public research in plant biotechnology, and introducing labeling requirements that impose supply chain costs and further stigmatize the technology in the eyes of consumers.

A Political-Economic Interpretation of Developing Country Policies

Next, let us use this framework to analyze the regulation—or the difficulties thereof—in developing countries. Some accounts frame the policy positions of developing countries as a power struggle between farmers of the South and multinational corporations of the North (Scoones, 2008). Other accounts describe how developing country policies reflect the concern of developing country farmers about losing export markets in Europe (Chaturvedi & Rao, 2004). While these are certainly salient issues, the political economy within most developing countries is no less complex than to what we observe in Europe (see, for instance, Lieberman & Gray, 2008; Stone, 2002).

Many countries, as they begin to industrialize from an agrarian economy, develop some form of capacity in agricultural inputs. This has resulted, to some extent, in a set of domestic producers of agricultural inputs—including seeds, basic generic fertilizers, and pesticides—which can become an influential sector of such an economy, given the importance of agriculture and the relative dearth of other industrial sectors. Domestic agribusinesses can also become closely aligned with a country's public-sector agricultural research, often itself representing a leading force within a developing country's overall R&D capacity. Domestically manufactured agricultural inputs are most typically utilized by the more advanced segments of a country's domestic agriculture, which is often that which has developed as an export-oriented business. These farmers are the ones that may need to conform to Europe's policy. To the extent that domestic supplies of agricultural inputs—including some seeds, but particularly more advanced and specialized pesticides—are not met by a domestic supply, imports are sourced from abroad, and, as we noted above, global markets have historically been dominated by the European chemical majors. In fact, developing country markets have constituted about one third of the total sales for these multinational European producers. In addition, as the domestic agrochemical sectors have matured in some countries—such as India, and Brazil, and former Soviet states—they have themselves begun aggressively expanding their exports of generic agrochemicals, with a primary focus on neighboring developing countries. Finally, exceedingly few of the agricultural input manufacturers in developing economies have developed any innovative capacity in biotechnology, as well as very few public sector agricultural R&D institutions.

The other major set of producers in most developing countries—the large population of subsistence farmers—is subject to many of the same dynamics that consumers are, in terms of initially lacking information about this new technology and using information provided by other interest groups who are seeking to influence their *perceived surplus*, which is what ultimately enters the regulator's consideration in making policy. Indeed, an analysis of how subsistence farmers perceive the welfare impact of adopting biotechnology needs to account for that fact that they are in fact both producer and consumer. To the extent that they have low incomes, their resulting welfare is highly price sensitive, on both the production side and the consumption side. As producers, they minimize cost of inputs by replanting saved seed and purchasing much less in the way of manufactured agricultural inputs such as chemicals, thus the cost of a biotech alternative is very important. As food consumers, a significant portion of what they consume is, of course, that which they produce themselves. To the extent that biotechnology increases yields, the effective reduction in their cost of food would mean an increase in their consumer surplus. Or to the extent that a biotech trait enhances a consumer quality—be it nutrition, storage, or ease of processing—their consumer's surplus also would increase. However, to the extent that the welfare impact of biotechnologies is felt both as producers and consumer, they are also sensitive to perceived risks on both sides. Finally, the influence of subsistence farmers over national regulators can be large if they represent a large population within a voting democracy, as in India. They are also, however, a much more diffused group and therefore face large collective action inertia.

Indeed, those interest groups within developing countries most likely to experience welfare gains from biotechnology are the most diffused and the least informed—including consumers and small-scale farmers. Yet, the large number of poorly informed consumers and small-scale farmers means that the public-debate stage of the policy formation process is likely to be very highly contested, with the other more concentrated interest groups such as activists, agricultural inputs producers, and exporting farmers vying to inform the *perceptions* that consumers and subsistence farmers have of their own welfare. Since most of these concentrated groups have little to gain or much to lose from biotechnology, the public debate often invokes possible price pressures on the poor, health risks, and yield risks.

In the developing country environment, many activist organizations succumb to their endemic conflict of interest problem, simultaneously convincing consumers or small farmers of the risks they face from biotechnology and promising to advocate for their interests in the policy process. Contests of legitimacy between non-government organizations and official regulators can be accentuated in those countries with weak or corrupt systems of government.

There should be little surprise then that developing country regulators have not readily developed policies to facilitate the adoption of agricultural biotechnologies. Considering the developing country agricultural biotechnology regulator's problem as a weighted welfare maximization, it is the influential groups whose producers' surplus is threatened by biotechnology—including domestic producers of competing agricultural inputs and the influential segment of exporting farmers—that tend to prevail. Moreover, domestic public-sector research institutions and academic scientists are often likely to have their interests aligned with these groups, as they represent both the primary source of funding and the main client base for their R&D and extension efforts. The massive potential welfare gains that could be had by consumers and small-scale growers do not factor into the policy process because they do not perceive themselves to gain, they perceive their risk to outweigh their gain, or they simply have such small weight in the regulator's decision.

Implications for Global Agriculture

If, indeed, it was the self-serving interests of major political-economic forces behind regulatory regimes that slowed the introduction of biotechnologies into agriculture, then the observed rate of development and adoption of biotechnology in global agricultural has arguably been slower than that which would have been called for by a putatively more disinterested consideration of the trade-offs between objective benefits and risks. This collective action problem holds several major welfare implications for global agriculture.

Dampened Growth in Global Agricultural Productivity and Higher Food Prices

The first implication is a lower rate of growth in the global food supply along with higher prices, relative to what would be achieved if agriculture operated closer to its production possibility frontier. The comparison in Sexton, Hochman, Rajagopal, and Zilberman (2009) of annual supply figures among major commodity crops, including some for which biotech traits have been developed versus some for which biotech traits have *not* been developed, supports this first implication. It appears that growth in supply has been constrained due to the lack of adoption of available biotechnologies. Compare consumption of corn between 2004 in 2008 with consumption of wheat for the same years: Corn consumption grew over these seasons, reflecting growing supply, while wheat consumption was largely stagnant, arguably because of supply constraints. There are clearly numerous factors involved in the differences in consumption trends between these two commodities. One factor is the wide availability of biotech corn varieties and the lack of biotech wheat varieties.

Commodity production trends point to similar differences. The areas planted and yields of rice, wheat, and sorghum—all crops for which biotech traits have not been made available—have experienced declining growth rates in the last decade, and ending stocks are significantly down. In contrast, soybean yields have continued to grow in line with historic trends, while the global area planted to soy and ending stocks have increased significantly in the last five years. Cotton has seen a sharp increase in productivity recently, and ending stocks are today at historic highs. Similarly corn yields have surged in the last five years. Again, while this qualitative analysis cannot control for a host of other factors, crops with approved and widely adopted biotech traits have experienced productivity growth at several percentage points above crops without approved biotech varieties.

A Slowdown in the Development of Second-Generation Traits

The second implication is that strict regulation of first-generation pest-control biotechnologies has slowed the rate of R&D of second-generation biotechnologies, such as product quality traits, improved processing efficiencies, and environmental traits. This may be even more significant in the long run. This line of reasoning is based on the fact that the tools for inserting novel traits into existing crop germplasm, in fact, constitutes a very general-purpose technology that can, at least in theory, be used for a broad range of potential crop traits and economic applications. However the evolution of agricultural biotechnology has resulted in a much more limited range of traits actually entering commercial production than virtually any expert would have predicted 15 years ago. The first generation of pest-control traits, as just observed, has helped to increase yields, even in developing countries. However, the wider adoption of even these first-generation technologies by inserting traits into local germplasm varieties—and a wider range of crops—could significantly increase global crop yields, while at the same time preserving crop biodiversity. The question for maintaining both productivity and biodiversity is not whether to undertake such dissemination of currently available traits into a much wider base of germplasm, but *how*. Such dissemination, however, has been greatly curtailed by the high levels of regulatory stringency, and, even in some jurisdictions, by the complete lack of a regulatory pathway to approval and development of these technologies that have already been proven in a wide range of agro-environmental and human food-safety contexts. Of course, further development requires commitment and investment in agricultural R&D, both in the areas of technology development and in the areas of environmental risk and biosafety analysis. The political-economy however, largely responding to the surplus impacts of these market-disrupting pest-control biotechnologies, appears to be aligned against regulatory approvals for wider development, let alone public spending on agricultural R&D necessary to introduce second-generation traits.

Second-generation traits include those with the potential to increase nutritional quality or processing efficiencies of agricultural products, thereby increasing the value of agricultural production or reducing its environmental impact. A recent survey (Graff et al., 2005) reviewed R&D activities across ten different product quality technology categories including improved protein, fat, and carbohydrate contents, vitamins and minerals, functional foods, reduction of allergens and toxins, improved ripening characteristics, product esthetics and convenience, and high-digestibility fiber quality. The survey identified the early commercialization of such second-generation traits as the long shelf-life tomato and low-linolenic canola oil followed, by a rapid intensification of R&D in such traits during the mid-1990s. All growth in second-generation R&D stopped in 1999, just as European regulators stopped approving new transgenic products and companies like McDonalds declined to purchase transgenic crops.

Conclusions

This analysis, based on a refinement of traditional political-economy models, has argued that the degree of regulation of new agricultural biotechnology has been affected by the alignment of self-interested welfare maximization and rent seeking by the various interest groups engaged in the policy-making process. The resulting regulatory environment has delayed and eliminated the introduction of many new technologies and products. The foregone benefits from these otherwise feasible production technologies are irreversible, both in the sense that past harvests have been lower than they would have been if the technology had been introduced and in the sense that yield growth is a cumulative process of which the onset has been delayed. The dynamics of this impact are likely to be accentuated by the fact that R&D has been dis-incentivized and investments that would have helped to disseminate and further advance the technology have not been as broad as they likely would have been in a technologically more tolerant and rational world. Resulting high costs of entry have led individuals and companies to exit the industry, reducing the development of human capital and innovative capacity to address impending crises of productivity as demand from the biofuel sector increases.

Low-cost and environmentally sustainable supplies of food and biofuels will require significant R&D investment in agriculture, yet agricultural research has been deemphasized in recent years as a spending priority of governments. At the same time, as we are postulating, governments have overregulated biotechnology, which has led to it being underused relative to a putative optimal rate of use and moreover underdeveloped relative to a rate of R&D investment that an objective analysis of risk versus returns might have recommended.

Consider, for example, the welfare implications if wheat and rice had experienced yield increases over the last decade comparable to those observed in cotton. When aggregated to the global scale and considered over the long run, such differences in growth rates can have massive impacts on food supply and use of arable lands, which in turn have massive implications for social and environmental welfare. Furthermore, the bulk of the impact is felt at the margin, including the marginal consumer—those poor consumers whose operate at the most inelastic portion of their demand curves and whose household budgets are the most sensitive to food prices—and marginal lands—those lands which yield the lowest gains in agricultural productivity and incur the highest costs from environmental disruption. Unfortunately, these are the interests least likely to be directly represented in any political-economic calculation of policy by any government.

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