INNOVATION AND ENVIRONMENTAL QUALITY

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by

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1. Introduction

The economic literature on pollution control policy instruments is focused almost entirely on incentives or regulations applied to emissions or polluting inputs. Examples include emissions taxes, marketable discharge permits, emissions standards, input taxes, and design standards. Innovations that reduce pollution control costs have generally not been viewed as a means for achieving environmental objectives. Innovation, to the extent that it is considered at all, is viewed as an induced outcome of the policy instruments (e.g., Bohm and Russell, 1985).

Outside of the economic literature, however, innovation is increasingly viewed as a way to reduce pollution rather than as merely a fortuitous byproduct of other pollution control policies. Public interest has been growing since the early 1970s in Europe and the United States in new products and production processes that are both economically attractive and environmentally benign. Correspondingly, governments have been increasing research and development spending on such products and processes (OECD, 1985). While this R&D is still a small proportion of total government-sponsored R&D, there are substantial pressures to further increase spending. This pressure is manifested by an upsurge in public interest in such concepts as "clean," "sustainable," "green," and "low-input" techniques.

R&D has considerable short-run political appeal as a means for reducing pollution. Politicians are always attracted by the idea of a "technical fix" that appears to address the problem while avoiding undue costs for any politically influential group. Unlike many other pollution policies, costs for R&D are quite diffuse rather than concentrated on specific interests (Shortle and Abler, 1991).

However, the long-run political appeal depends on whether or not environmental quality is actually improved. Clearly, this depends on whether R&D yields commercially viable substitutes to offending products or practices, and whether producers and consumers adopt these substitutes. Another, often overlooked, factor is the market-level impact of a new product or practice. Consider an innovation that reduces discharge levels per unit of output while also reducing per unit production costs. The reduction in per unit costs will stimulate output. If the increase in output is large enough, total discharge levels will increase despite the decrease in discharges per unit of output. This possibility suggests that the current enthusiasm for clearer techniques must be qualified, at least insofar as they are viewed as an alternative to more direct emissions control strategies.

To make the caveat more concrete, we examine the market-level impacts of technical innovations designed to reduce the use of chemical inputs on selected agricultural commodities in the European Community and the United States. We examine impacts both with and without taxes on chemical use. We bring taxes into the picture to see if technical change would enhance or reduce the effects of taxes on agricultural chemical use, and if taxes would be more palatable to producers if accompanied by technical change. Agriculture is a focal point of the current interest in low-input/sustainable technologies. There are many reasons for this, but one is the apparent unwillingness of many governments to take strong, direct measures to reduce water pollution by agricultural chemicals (OECD, 1989).

A partial-equilibrium simulation model of agriculture is constructed with three regions: the EC(12), the US, and the rest of the world. There are four commodities in the model: wheat, maize, coarse grains (barley, sorghum, and oats), and soyabeans. There are also four factors of production: capital, labour, land, and agricultural chemicals. Agricultural chemicals is a composite of fertiliser, pesticides, herbicides, and other chemicals, although the dominant component in both the EC and US is fertiliser. The base year is 1982. The focus of the model is on long-run effects, which seems appropriate given the long time typically required to develop and introduce new techniques. We rule out short-run effects of policy changes on rental rates on agricultural capital, wage rates for farm labour, returns to farm management skills, and prices of agricultural chemicals. In addition, the dynamics of resource adjustment are not studied.

A variety of technical innovations designed to substitute for agricultural chemicals on our four commodities are under development (National Research Council, 1989). Techniques intended to substitute for pesticides include releasing sterile insects to mate with fertile ones, spraying insects with synthetic hormones to prevent their development, releasing "beneficial" insects (predators, parasites, or pathogens), "designer" fungi that eat specific insects, and crops genetically engineered to repel insects. Much less progress has been made on fertiliser substitutes. The most promising innovation, though many years away, is nitrogen-fixing cereal varieties. Other, more immediate, possibilities are improvements in fungi important in the uptake of soil nutrients and new legumes that fix more nitrogen than current varieties. The new legumes could be used in rotation with cereal grains. Innovations that could substitute for herbicides include insects that eat weed plants or seeds, and crops that produce substances toxic to weeds.

These innovations are likely to have effects on production processes that are not easily modeled at the aggregate or even the farm level. The most feasible option is to work with factor-augmenting technical change. Of the four factors within the simulation model, most of the innovations listed above can be characterized as land augmenting, if "land" includes not only the soil but also other elements of the natural environment. Thus we work with land-augmenting innovations.

Of all the agricultural commodities, the four studied here do not represent the greatest environmental risks. In the US, there are greater environmental hazards from the application of pesticides to fruits and vegetables. In the EC, chemical usage on potatoes and glass house products is probably of greater concern. However, when taken together, our four commodities are much more important in both the EC and US in terms of land area, value of production, and government price support expenditures.

2. The Model

a. EC and US Supply

All four goods in the model are produced in the US, while the EC produces the first three but not soyabeans. Production of soyabeans in the EC was nil until only very recently, and even now is still dwarfed by consumption. The production function for each commodity is a two-level CES (Sato, 1967) exhibiting constant returns to scale at each level. At the upper level, the commodity is produced from a composite mechanical input and a composite biological input. The lower levels generate the composite inputs: the mechanical input is produced from capital and labour, while the biological input is produced from land and agricultural chemicals (fertilisers, pesticides, herbicides, etc.). The two-level CES production function is parsimonious in parameters and may represent a reasonable approximation at an aggregate level to agricultural production processes (Kaneda, 1982).

Let Y be production of the commodity, M be the composite mechanical input, and B be the composite biological input. At the upper level,

$$(1)\quad Y = \left[aM^{(\alpha-1)/\alpha} + (1 - a)B^{(\alpha-1)/\alpha}\right]^{\alpha/(\alpha-1)},$$

where $0 < a < 1$ is a distributive parameter and $\alpha \geq 0$ is the elasticity of substitution. Let K be capital, N be labour, L be land, and F be chemicals. Let A_K, A_N, A_L, and A_F be the corresponding levels of factor-augmenting technical progress. At the lower levels,

$$(2)\quad M = \left[m(KA_K)^{(\sigma-1)/\sigma} + (1 - m)(NA_N)^{(\sigma-1)/\sigma}\right]^{\sigma/(\sigma-1)},$$

$$(3)\quad B = \left[b(LA_L)^{(\beta-1)/\beta} + (1 - b)(FA_F)^{(\beta-1)/\beta}\right]^{\beta/(\beta-1)},$$

where $0 < m < 1$ and $0 < b < 1$ are distributive parameters, while $\sigma \geq 0$ and $\beta \geq 0$ are elasticities of substitution. There is no jointness between commodities in production. Attention focuses on changes in A_L.

The cost function dual to this production structure is also a two-level CES. At the upper level, the cost of production for the commodity, C, is a function of the shadow prices of the mechanical and biological inputs, p_M and p_B, and output:

$$(4)\quad C = \left[a^{\alpha}p_M{}^{1-\alpha} + (1 - a)^{\alpha}p_B{}^{1-\alpha}\right]^{1/(1-\alpha)}Y.$$

Let r be the rental rate on capital, w be the wage rate, ρ be the rental rate on land, and v be the price of chemicals. Then the cost functions for the lower levels are

$$(5)\quad C_M = \left[m^{\sigma}(r/A_K)^{1-\sigma} + (1 - m)^{\sigma}(w/A_N)^{1-\sigma}\right]^{1/(1-\sigma)}M,$$

$$(6)\quad C_B = \left[b^{\beta}(\rho/A_L)^{1-\beta} + (1 - b)^{\beta}(v/A_F)^{1-\beta}\right]^{1/(1-\beta)}B.$$

The shadow prices of the mechanical and biological inputs are equal to marginal (and average) production costs: $p_M = \partial C_M/\partial M = C_M/M$ and $p_B = \partial C_B/\partial B = C_B/B$. The price of the commodity itself equals marginal (and average) cost: $p = \partial C/\partial Y = C/Y$. Factor demands are obtained from Shephard's lemma.

Capital, labour, and chemicals are assumed to have perfectly elastic supply curves. These assumptions are in keeping with the small shares of agriculture in national income and the labour force in both the EC and US. In the long run, labour and resources used to produce agricultural capital and chemicals can probably be withdrawn at relatively low cost for other uses.

Land supplies, on the other hand, are inelastic. We assume that the stocks of land used for the commodities are imperfect substitutes for each other, so that rental rates on land differ across commodities. The supply of land for the jth crop is a constant-elasticity function of the rental rates for all crops:

$$(7)\quad L_j = \ell_j \Pi_k \rho_k^{\varepsilon_{jk}},$$

where $\varepsilon_{jj} \geq 0$ and $\varepsilon_{jk} \leq 0$ for $j \neq k$. We impose zero-degree homogeneity, so that $\Sigma_k \varepsilon_{jk} = 0$. ℓ_j is a coefficient chosen so that (7) reproduces the base-year data.

b. EC and US Demand

The functional forms for the demand curves are chosen so that it is possible to obtain unique measures of the consumer welfare effects of policy changes. It is well known that, in general, consumer surplus is path-dependent in a multimarket context: consumer surplus depends on the order in which commodity prices are allowed to change. In the case of linear, symmetric demand curves, however, the path dependence problem disappears.

Assume that consumer benefits from consumption of the jth commodity are

$$(8)\quad B_j = (q_j + \Sigma_k \gamma_{jk} Q_k/2) Q_j,$$

where $\gamma_{jj} < 0$, $\gamma_{jk} = \gamma_{kj}$ for all j and k, and q_j is a coefficient chosen so that the resulting demand curves replicate the base-year data. Consumer surplus for the jth commodity is $CS_j = B_j - p_j Q_j$. Aggregate benefits are $B = \Sigma_j B_j$. The demand curves in price-dependent form are $p_j = \partial B/\partial Q_j$, or

$$(9)\quad p_j = q_j + \Sigma_k \gamma_{jk} Q_k.$$

c. EC and US Commodity Policy

EC and US commodity policies have major impacts on market outcomes and need to be incorporated into the model. The EC system of target, intervention, and threshold prices for wheat, maize, and coarse grains is collapsed into a single set of internal producer prices fixed above world prices. EC markets for these three commodities are not completely insulated from world markets, however, because EC planners take world prices into account when choosing internal prices. Assume that the internal price for the jth commodity, p_j^{EC}, is related to the world price, p_j^W, as

$$(10)\quad p_j^{EC} = \phi_j (p_j^{w})^{\eta_j},$$

where $\eta_j \geq 0$ is a world price transmission elasticity and $\phi_j > 0$ is a coefficient chosen so that (10) replicates the base-year data. EC consumer and producer prices are taken to be identical. This causes no problems so long as the consumer-producer price ratio is constant. EC policy during the base period gave soyabeans free entry into the EC, so that the domestic consumer price equals the world price.

The US system of loan rates, target prices, acreage restrictions, and direct payments for wheat, maize, and coarse grains is collapsed into two sets of programs: output subsidies and land supply restrictions. The output subsidy is an amalgamation of payments to producers under the target price, acreage diversion, and disaster programs. Land supply restrictions are modeled as inward shifts in the land supply curves, and are captured by the ℓ_j in equation (7). As an approximation, we assume that market prices exceed loan rates, so that the loan rate programs do not affect market outcomes.

This assumption is in broad agreement with data for the early 1980s. It means that there are no operative programs for soyabeans in the model.

US policies for the four commodities do not directly interfere with consumer prices, so that consumers pay world prices. The world price of each commodity, therefore, is taken to be the US consumer price.

Within the context of the model, EC commodity program expenditures for wheat and coarse grains are measured by exports times the per unit export subsidy (which is the difference between EC and world prices). Since the EC is a net importer of maize, it receives revenues equal to imports times the per unit import levy. The EC is a net exporter of wheat and coarse grains, but not a large net exporter. As we will see below, small policy changes can lead to large percentage changes in measured EC expenditures for these two commodities. US commodity program expenditures are measured by the output subsidies. For a given per unit subsidy, the percentage change in the total subsidy is equal to the percentage change in supply. Of course, actual price support expenditures in both regions encompass many other programs as well.

d. Rest of the World (ROW)

The rest of the world is a net importer of all four commodities, and simple net import demand functions are used in the model. Like the EC and US demand curves, the net import functions are linear and symmetric to yield unique welfare measures. In price-dependent form,

$$(11) \quad p_j^W = \psi_j + \Sigma_k \mu_{jk} Z_k,$$

where Z_k is net imports of the kth commodity, $\mu_{jj} < 0$, $\mu_{jk} = \mu_{kj}$ for all j and k, and ψ_j is a coefficient chosen so that (11) replicates the base-year data.

This specification does not assume that domestic ROW prices equal world prices. Differences between domestic and world prices are incorporated into the μ_{jk} in a manner described below.

e. Market-Clearing Identities

The market-clearing equations require that world supply equal world demand for each commodity:

$$(12)\ Y^{EC} + Y^{US} = Q^{EC} + Q^{US} + Z^{ROW}.$$

Changes in government and private stocks are ignored. This is appropriate given the longer run nature of the model.

3. Parameter Values and Data Sources

Base year input and output quantity and price data are drawn from a variety of sources, primarily the U.S. Department of Agriculture (USDA) publications listed in the references. The base year is called 1982, although 1980-84 averages or other multi-year averages centred around 1982 are used in almost all cases.

a. EC and US Supply

The distributive parameters in the production (and cost) functions are derived from base year factor shares. Letting s_i be the share of factor i, and using the fact that the partial output elasticity of each input is equal to its share of total cost in equilibrium, we have $a = s_K + s_N$, $m = s_K/(s_K + s_N)$, and $b = s_L/(s_L + s_F)$. Factor shares are drawn from USDA cost of production data and Stanton (1986).

Substitution elasticities are derived from existing estimates of Allen elasticities of substitution (AES). Let σ_{ij} be the AES between factors i and j. Then

(13) $\alpha = \sigma_{KL} = \sigma_{KF} = \sigma_{NL} = \sigma_{NF}$,

(14) $\sigma = a\sigma_{KN} + (1 - a)\alpha$,

(15) $\beta = a\alpha + (1 - a)\sigma_{LF}$.

Studies estimating AES for US agriculture include Binswanger (1974), Brown and Christensen (1981), Chambers and Vasavada (1983), Hayami and Ruttan (1985), Hertel (1989), Kislev and Peterson (1982), and Ray (1982). Published estimates for the EC relevant to our study are rarer, and so far as we know are limited to Bonnieux (1989) for France and Boyle (1981) for Ireland.

Elasticities of substitution for both the EC and US are set equal to $\alpha = 0.5$ and $\beta = 1.5$. Since the supply prices of capital and labour are fixed, while neither factor experiences technical change, the shadow price of the composite mechanical input is constant. This makes it unnecessary to specify σ. Own-price land supply elasticities are all in the 0.1 - 0.2 range. Cross-price elasticities are set so as to satisfy zero-degree homogeneity requirements on the land supply equations.

b. EC and US Demand

Estimates of price elasticities of demand are available from USDA (1989c), and they indicate own-price elasticities in the 0.2 - 0.5 range. However, in the long run, elasticities are likely to exceed these values as substitutability in livestock feed increases and lags in consumer behavior play themselves out. We use own-price elasticities that are in the 0.4 - 0.9 range. The elasticities are used to obtain initial values (γ_{kj}') for the slope coefficients in equation (9). Symmetry is achieved by taking averages of the initial values: $\gamma_{jk} = \gamma_{kj} = (\gamma_{jk}' + \gamma_{kj}')/2$. However, the initial values themselves are generally quite close to symmetric.

c. EC and US Commodity Policy

Price transmission elasticities from world prices to EC prices are in Tyers and Anderson (1988). Long-run elasticities are 0.15 for wheat and 0.45 for maize and coarse grains. Base-period EC prices exceed US prices by about 40% for wheat, 50% for maize, 70% for coarse grains. Direct payments to US producers were small, about 8% of the farm price for wheat, 3% for maize, and 5% for coarse grains. Acreage restrictions had a similarly modest impact.

d. Rest of the World (ROW)

Equation (11) expresses net imports by ROW as a function of world prices, which in our model are US consumer prices. Long-run price transmission elasticities relating ROW domestic producer and consumer prices to world prices are drawn from Tyers and Anderson (1988). Long-run ROW supply and demand elasticities with respect to domestic prices are based on USDA (1989c). We combined the supply and demand elasticities with the price transmission elasticities and aggregated across countries to obtain net import elasticities with respect to world prices. All own-price elasticities are set equal to 3, with most cross-price elasticities an order of magnitude smaller. These elasticities were used to obtain the slope coefficients (μ_{jk}) in equation (11) following the method used for EC and US demand. In contrast to EC and US demand, however, the initial slope coefficients were quite asymmetric in some cases.

4. Effects of Technical Change

This section investigates the effects of land-augmenting technical change, both with and without taxes on agricultural chemicals. We focus attention on innovations that apply to all commodities in the US or EC, rather than innovations specific to one commodity. The techniques mentioned above are either directly applicable to many crops or involve scientific advances at a basic enough level that many crops should benefit from them. Part a looks at land-augmenting technical change without taxes; part b looks at taxes alone; while part c looks at both technical change and taxes together, comparing results to those in parts a and b.

Economists generally think in terms of emissions-based incentives or regulations as solutions to environmental externalities rather than taxes on inputs (Baumol and Oates, 1988). However, the nonpoint character of agricultural pollution makes monitoring emissions by firms impractical, thus ruling out the application of emissions-based instruments. Corrective measures must therefore be applied to polluting inputs and/or land use practices (Shortle and Dunn, 1986). Because of the level of aggregation in this study, we focus on the single chemical input aggregate. Taxes on agricultural chemicals have recently been introduced in several European countries and have been proposed in several others (OECD, 1989). Our tax would represent an addition to existing taxes.

a. Land-Augmenting Technical Change

The impacts of a 10% increase in land productivity in either the EC or the US are shown in table 1. The results indicate that technology is likely to be counterproductive as a pollution control policy for the EC. For all three commodities produced in the EC, land-augmenting innovations actually increase chemical use. To be sure, chemical use per unit of output falls in each case. However, output increases raise the derived demand for chemicals to such an extent that total use increases. Chemical use per unit of land also increases. This occurs despite the high (1.5) substitution elasticity between land and chemicals in the biological production function. Land-augmenting innovations fare somewhat better in the US in terms of chemical use, but they are no panacea. Chemical use for maize and soyabeans falls modestly, but no change occurs for wheat or coarse grains.

What explains differences between commodities and regions in impacts on chemical use? In each case, the percentage increase in land productivity is the same. In addition, substitution effects in production between land and chemicals are the same in each case. The differences are due to the impact of technical change on output prices. By increasing output, technical change reduces output prices by an amount dependent on the elasticity of demand. Other things equal, this reduces the derived demand for chemicals and other inputs. Existing agricultural price support programs largely insulate EC markets from world conditions and, in effect, make the demand curves facing EC producers highly elastic. This can be seen in the results, where technical change in the EC causes negligible changes in EC prices. On the other hand, demand curves facing US producers are much less elastic. Demands are least elastic for maize and soyabeans, commodities for which the US dominates the world market.

By reducing output prices, technical change in one region reduces output and chemical use in the other region. This leads to some interesting results.

For example, if the EC wanted to use R&D as a pollution control policy for agriculture, it would be much better off if it supported R&D in the US than in its member countries. Of course, while this would never occur, it illustrates the limits of innovation as an environmental protection strategy.

Technical change has two competing effects on land rents. On the one hand, market equilibrium requires that price equal average production cost for each commodity. Technical change reduces average cost, which at a given price leaves more left over for landowners. On the other hand, technical change also reduces output prices. To bring average cost back in line with price, land rents must fall. The former effect clearly dominates in the EC, whereas the latter dominates in the US.

Except for soyabean consumers in the case of US technical change, consumer welfare in the EC and US is not significantly improved by increases in land productivity. Changes in total consumer surplus are only 0-1% in each case. Consumers in the rest of the world, however, benefit significantly from lower world prices. Total ROW consumer surplus increases by 5% given technical change in the EC and 9% given technical change in the U.S. Presumably, the ROW figures represent a combination of losses to ROW producers and even larger gains to ROW consumers.

EC government expenditures are highly sensitive to even modest changes in prices, supplies, and demands. Moderate increases in supplies when there is technical change in the EC cause large percentage increases in expenditures for wheat and coarse grains. Except for soyabeans, changes in US government expenses are identical to changes in US supplies.

b. Taxes on Agricultural Chemicals

The impacts of a modest 10% tax on agricultural chemicals in either the EC or the US are shown in table 2. Large taxes are politically unrealistic given the importance of chemicals to agriculture in both regions and the substantial political clout enjoyed by producers. Nevertheless, a 10% tax is large enough to yield some significant impacts on chemical use. Chemical use in the EC falls on the order of 20% given EC taxes, while US chemical use falls about 10% given US taxes. However, by increasing output prices, taxes in one region encourage more production and chemical use in the other region. This means that the overall environmental gains from taxes are less than they might appear to be at first glance. This effect often goes unrecognized, especially among environmental organizations.

EC taxes reduce rents to EC landowners. Surprisingly, however, US taxes actually increase US land rents. In both regions, land and chemicals are strong substitutes in production. The difference lies in the elasticities of demand facing producers. Since EC demands are highly elastic, EC producers bear virtually the entire burden of a tax in reduced output and lower prices net of the tax. In the US, on the other hand, some of the burden of the tax is passed along to consumers in the form of higher prices. Price increases are large enough, and supply decreases are small enough, that land rents increase.

Consumers in the EC and US lose very little from a tax in either region. Total consumer surplus falls by about 1% in each region with a US tax, while the change in each region given an EC tax is nil. ROW consumers lose significantly more. Total ROW consumer surplus falls by 7% with an EC tax and 10% with a US tax.

EC government expenditures are once again highly sensitive to a modest policy change. Clearly, one must be cautious in interpreting our results in this regard.

c. Technical Change and Taxes

The impacts of a 10% increase in land productivity combined with a 10% tax on chemicals in either the EC or the US are shown in table 3. The results are basically consistent with tables 1-2. In most cases, a cell in table 3 is approximately equal to the sum of the corresponding cells in tables 1 and 2. The 10% technical change and 10% tax have almost exactly offsetting effects on world and EC prices. For chemical use, however, it is a different story. EC chemical use falls significantly when the EC experiences innovation and a tax, but not by as much as the case where there is only a tax. US chemical use also falls significantly when the US has innovation and a tax. Relative to the case where there is only a tax, chemical use is less for maize and soyabeans but slightly greater for wheat and coarse grains. Demand elasticities facing US producers are smaller for the former two commodities than the latter two.

Taken together, the two EC policy changes have almost exactly offsetting effects on rents to EC landowners. Since both US policy changes increase US land rents, however, the two reinforce each other. Consumer surplus effects in the EC and US are negligible given policy changes in either region. ROW consumer welfare effects are nearly as modest: Total ROW consumer surplus falls by 3% given both policy changes in the EC but only 1% given both policy changes in the US.

Since the combined effect of both policy changes in the EC is to reduce EC supply, EC expenditures for wheat and coarse grains fall, while revenues for maize increase. Changes in US government expenses, which are identical to changes in US supplies, are modest.

5. Conclusions

The results of our simulations cast serious doubt on innovation as a pollution control policy for EC and US agriculture. Regardless of whether or not there were taxes on agricultural chemicals, innovation would generally increase the use of agricultural chemicals. The basic problem is that output demands are too elastic, which limits decreases in prices caused by innovation. Larger price declines would be needed to hold the use of chemicals in check or actually reduce their use. The general conclusion is that innovation is unlikely to be an effective environmental protection strategy unless the product in question has a highly inelastic demand. In our case, while domestic agricultural demands are inelastic, export demands and import supplies are highly elastic. The general corollary is that demand is unlikely to be inelastic unless international trade for the product in question is highly limited.

The result that chemical use is greater with technical change and a tax on chemicals than with just a tax also has important implications for taxes as a pollution control strategy. One of the benefits commonly ascribed to taxes and other economic incentives is that they will induce the development and adoption of less polluting techniques (e.g., Bohm and Russell, 1985). However, in our case, the effect of this process is to reduce, not increase, the ecological effectiveness of the tax. In this regard, permits would be preferable to taxes. Permits would induce comparable R&D but would not allow an increase in chemical use. Of course, nonmarketable permits score poorly relative to taxes in terms of cost-effectiveness and allocative efficiency (Shortle and Abler, 1991).

Innovation does have the advantage of making taxes on agricultural chemicals look more attractive to producers. Land rents are higher than they would be with taxes alone and, within the context of our simulations, are higher than in the status quo (no additional innovations or taxes). Rents to landowners are the relevant measure of producer welfare because, in the long run, supplies of other farmer-owned resources are highly elastic. Moreover, within the context of our simulations, innovation and taxes together do reduce the use of agricultural chemicals. The general conclusion is that while innovation cannot be counted on as a pollution control strategy by itself, it can be effective in mitigating producer opposition to other pollution control policies.

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Table 1.

Impacts of 10% Land-Augmenting Technical Change.[a]

	Region Undergoing Change/Commodity							
	EC				US			
Variable	Wheat	Maize	Coarse Grains	Soya-beans	Wheat	Maize	Coarse Grains	Soya-beans
Supply								
EC	9	9	5	--	- 1	- 5	- 4	--
US	- 4	- 1	- 6	0	6	2	6	3
Prices								
World	- 2	0	- 2	0	- 2	- 2	- 2	- 3
EC	0	0	- 1	0	0	- 1	- 1	- 3
Rents								
EC	9	9	5	--	- 2	- 5	- 4	--
US	- 5	- 2	- 7	- 1	0	- 3	0	- 5
Consumer Surplus								
EC	0	0	1	0	0	1	1	4
US	1	0	2	0	1	1	1	3
ROW	9	1	3	1	10	11	- 1	18
Government Expenses	50	-16[b]	91	--	- 2	10[b]	-78	--
EC	- 4	- 1	- 6	--	6	2	6	--
US								
Chemical Use	8	9	2	--	- 2	- 7	- 6	--
EC	- 8	- 2	-11	0	0	- 3	0	- 5
US								

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[a] Percentage Changes, rounded to the nearest integer.
[b] Refers to revenues, not expenses.

Table 2.

Impacts of 10% Chemical Tax.[a]

	Region Imposing Tax/Commodity							
	EC				US			
Variable	Wheat	Maize	Coarse Grains	Soya-beans	Wheat	Maize	Coarse Grains	Soya-beans
Supply								
EC	-12	-15	- 9	--	1	9	3	--
US	- 6	2	11	0	- 4	- 4	- 4	- 2
Prices								
World	2	1	3	0	2	4	1	3
EC	0	0	1	0	0	2	1	3
Rents								
EC	- 7	- 9	- 4	--	1	8	3	--
US	7	2	13	1	1	2	0	3
Consumer Surplus								
EC	0	0	- 1	0	0	- 1	0	- 3
US	- 1	0	- 3	0	0	- 1	0	- 2
ROW	-11	-1	- 7	- 2	- 8	- 19	2	-14
Government Expenses	-61	25[b]	-167	--	0	-19[b]	66	--
EC	6	2	11	--	- 4	- 4	- 4	--
US								
Chemical Use	-23	-25	- 18	--	2	14	5	--
EC	12	3	22	1	-13	-10	-13	-10
US								

[a] Percentage Changes, rounded to the nearest integer.
[b] Refers to revenues, not expenses.

Table 3.

Impacts of 10% Technical Change and 10% Tax.[a]

	Region with Change and Tax/Commodity							
	EC				US			
Variable	Wheat	Maize	Coarse Grains	Soya-beans	Wheat	Maize	Coarse Grains	Soya-beans
Supply								
EC	- 4	- 7	- 4	--	0	3	- 1	--
US	2	1	5	0	2	- 2	2	1
Prices								
World	1	0	1	0	0	1	0	- 1
EC	0	0	1	0	0	1	0	- 1
Rents								
EC	1	- 1	1	--	0	3	0	--
US	2	1	5	0	4	4	4	3
Consumer Surplus								
EC	0	0	- 1	0	0	- 1	0	1
US	0	0	- 1	0	1	- 1	1	1
ROW	- 3	- 1	- 4	- 1	2	- 9	1	4
Govern-ment Expenses	-19	11[b]	-75	--	- 1	- 8[b]	-13	--
EC	2	1	5	--	2	- 2	2	--
US								
Chemical Use	-16	-19	-15	--	0	5	- 1	--
EC	4	1	9	0	-12	-12	-12	-14
US								

[a] Percentage Changes, rounded to the nearest integer.
[b] Refers to revenues, not expenses.