Journal of Agricultural and Applied Economics, 33,1(April 2001):117–133

Regulation in Quality Differentiated Markets: Pesticide Cancellations in U.S. Apple Production

Jutta Roosen

ABSTRACT

If agricultural output results from non-separable multiproduct technologies, environmental regulation can change the set of possible output combinations. This will be important when regulation affects the quality composition of a crop. As a result, market and welfare changes have to be assessed in technology-related markets. We present a model that serves to estimate the economic impacts in such instances and use it in the assessment of pesticide regulation in the U.S. apple industry. Impacts for four pesticide cancellation scenarios are assessed. It is shown that changes in the quality of a crop lead to significant market reallocation effects.

Key Words: *apple production, joint production, multiproduct firm, pesticide cancellation, welfare assessment.*

Increased environmental regulation of agricultural production activity has resulted in a need for economic models that aid in estimating the economic impacts of regulatory activity. Agricultural economists have responded by providing partial equilibrium models that serve to estimate the economic impacts using a limited set of information (Lichtenberg, Parker, Zilberman; Sunding). These methods use linear or step function approximations to the supply function in order to calculate the welfare impact of a regulation that shifts the technology (supply) in a partial-equilibrium model. Production to each market is thereby modeled to be independent of all other production activities and markets are exclusively linked by prices. Empirical examples can be found in Buzby and Spreen who assess the impacts of a ban of sodium ortho-phenylphenate on the U.S. grapefruit industry; in Davis *et al.* who consider pesticide cancellations on tomatoes; in Lichtenberg, Parker and Zilberman who estimate the economic costs of canceling ethyl parathion on almonds, plums, and prunes; and in Rice-Mahr and Moffit who analyze the importance of pesticides in cranberry production.

Agricultural production is in many instances characterized by multiproduct technologies which makes it necessary to extend the partial-equilibrium analysis to a host of markets that are linked not only by prices but also by non-separable production technologies. An impor-

---

Jutta Roosen is assistant professor, Catholic University of Louvain, Belgium. Most of this research was done while the author was a graduate assistant at the Department of Economics at Iowa State University, whose support is gratefully acknowledged. She would like to thank David Hennessy, Vickie McCracken, Dave Rosenberger, Bruce Babcock, Alicia Carriquiry, Joe Herriges, Cathy Kling, Jay Brunner, Catherine Daniels, Jeff Derr, Anne Morell, and Kent Smith and two anonymous reviewers for helpful comments on earlier drafts of this paper. The usual disclaimer applies. The research was supported by USDA–NAPIAP funds.

tant class of such non-separable multiproduct technologies is the production of quality differentiated outputs when product is sorted into lots of uniform quality that are sold at different prices as is often observed for fruits and vegetables.

In this paper our concern is to economically measure the production impacts of regulation when production results from non-separable multiproduct technologies. We focus on regulation that affects the quality composition of a crop and that shifts production from high-value to low-value markets. To model such changes we provide an extension of the model by Lichtenberg, Parker, and Zilberman to such a multiproduct analysis. This extension is important for two reasons: (1) A loss in quality leaves open the possibility to sell the crop in a lower quality market. In such instances value loss is not complete and an assessment that does not distinguish between complete and partial value loss would inevitably overestimate impacts. (2) More important is that price changes in the related markets will result in changes of relative prices and these signals will cause growers to reallocate their crop between the different markets. These price incentives will affect all growers, those that are directly affected by the policy and those that are only affected through the resulting price changes.

We apply the model to assess the economic impacts of canceling pesticides in U.S. apple production. The U.S. apple industry is a highly pesticide-intensive industry,[1] and pesticides are in many instances applied to protect the quality of a crop. Price incentives to produce high quality fresh apples are considerable and the premium paid for apples that are sold in the high value fresh market over apples sold to processing can be up to 300 percent. Both complete and partial value losses are therefore important in this analysis.

The use of pesticides in apple production has become of regulatory concern since the Food Quality Protection Act (FQPA) passed into law in 1996. FQPA has replaced the previous approach of risk management by the regulatory agency that considered each pesticide separately and it mandates now a consistent assessment of risks from pesticides with a similar mode of toxic action. Also children's risk exposure has become of greater concern. Apples comprise an important part of children's diet, and it is also for this reason that apples receive more attention in the regulatory process. Economic assessments of single pesticide bans or bans of groups of pesticides are important in order to identify the critical uses of pesticides. Such knowledge facilitates a reduction of the economic cost of the regulation while meeting the risk-reduction objective.

Economic assessments of pesticide regulation scenarios ask not only for an assessment of production impacts but also of benefits that accrue to consumers and to the environment. This study does not attempt to measure these benefits. In the policy-making process benefits are in fact weighed against the risks comprised of human health risks and environmental risks. The way in which the Environmental Protection Agency (EPA) weighs these risks is implicit and risk reductions are not evaluated as monetarized benefits. An analysis of the implicit cost-benefit weighing in EPA pesticide registration decision making can be found in Cropper *et al.* We contribute to the analysis of the regulatory procedure in that we concentrate on the economic evaluation of production impacts. To give an indication of the magnitude of benefits necessary to justify the regulation, we calculate for each pesticide cancellation the minimum increase in willingness to pay (WTP) that is necessary to make the regulation welfare improving. The estimated WTP indicates the minimum shift in the demand function necessary to neutralize the adverse effect on supply. Its size will in general depend on the estimated shift in the supply function.

The paper continues with the description of

---

[1] In 1997, the USDA NASS/ERS Agricultural Chemical Usage: Fruit Summary estimated that 130 different active ingredients of pesticides or growth regulators were applied in apple production. It reports use data on 69 active ingredients. Overall, 96 percent of the bearing apple acreage is treated with insecticides, 90 percent with fungicides, and 60 percent with herbicides. This amounts to 44 lb. of active ingredient (a.i.) applied per acre. The survey covered California, Georgia, Michigan, New Jersey, New York, North Carolina, Oregon, Pennsylvania, South Carolina, and Washington.

an economic model of regulation in quality differentiated markets. We start from a partial-market equilibrium model in which the cost structure acknowledges the non-separability of the production technology. Changes in supply in response to changes in the available technology are derived for the different market segments and issues of welfare analysis in horizontally related markets are addressed. We apply the model to the case of pesticide regulation in the U.S. apple industry. After presenting the data entering the assessment, we report results on estimated welfare changes for four pesticide-cancellation scenarios. The paper concludes with a discussion of the results.

Economic Assessment of Technology Shifts in Quality Differentiated Markets

We develop the model in the context of pesticide regulation in apple production. Here, pesticides are mainly used to preserve quality although protection against yield losses can also be important. Apples are sorted into lots of uniform quality and for simplicity we consider only two categories: (1) high-quality apples sold for fresh consumption and (2) low-quality apples sold for processed utilization. Orchards are modeled as firms producing apples for the fresh and processing market and, in this sense, orchards are modeled as joint-product firms. Generally apple orchards do not exclusively produce for fresh or the processed utilization. In this way they differ from other fruit and vegetable production processes, for example tomato production, where farms grow tomatoes either for fresh consumption or for processed consumption but not for both (Davis *et al.*). The fresh market for apples pays a considerable premium and a deterioration of quality is modeled as a decrease in the share of fruit allocated to the fresh market. The marginal welfare analysis suggested by Lichtenberg, Parker, and Zilberman that considers a host of markets related through prices is extended to an analysis where markets are also linked through technology. Supply function changes are approximated by parallel shifts that are induced by changes in the production technology. Using flexibility estimates, price and quantity changes in the markets in question can be calculated.

The partial equilibrium model is regionalized, and distinguishes $j = 1, \ldots, J$ groups of growers by their marginal-cost structure. The cancellation of a pesticide presents a change in the production technology of each group, and we parameterize the shift in technology by λ. Some groups of growers do not use the pesticide in question, and their technology is independent of λ.

More specifically, producers are grouped into sets of users and non-users of a pesticide in five distinct production regions. The groups are ordered such that $j = 1, \ldots, k$ identify the producers who are affected by a change in technology λ, and $j = k + 1, \ldots, J$, denote the producers groups that are not affected by the change. Let P denote prices and let Q signify quantities, where subscript j identifies regions and superscript Fr and Pr signifies fresh and processed, respectively. The equilibrium in the markets is described by the following set of equations:

(1.1) Supply User:

$$P^i_j = MC^i_j(Q^{Fr}_j, Q^{Pr}_j; \lambda), \qquad i = Fr, Pr; \qquad j = 1, \ldots, k,$$

(1.2) Supply Non-User:

$$P^i_j = MC^i_j(Q^{Fr}_j, Q^{Pr}_j), \qquad i = Fr, Pr; \qquad j = k + 1, \ldots, J,$$

(1.3) Regional Pricing:

$$P^i_j = h^i_j(P^i), \qquad i = Fr, Pr; \qquad j = 1, \ldots, J,$$

(1.4) Demand:

$$D^i(Q^i_d; \lambda) = P^i, \qquad i = Fr, Pr,$$

(1.5) Net Imports:

$$Q^i_M = M^i\left(P^i, \sum_j Q^i_j\right), \qquad i = Fr, Pr,$$

(1.6) Market Clearing:

$$\sum_{j=1}^{J} Q^i_j + Q^i_M = Q^i_d, \qquad i = Fr, Pr.$$

Equation (1.1) represents the supply function for pesticide users and equation (1.2) is the supply function for non-users. The marginal-cost functions (MC) reflect the multiproduct nature of production and depend on production to the fresh (Q_j^{Fr}) and processing sector (Q_j^{Pr}). According to the equilibrium conditions, users and non-users produce at a level such that their marginal costs equals price both in the fresh and processing market. Equation (1.4) presents the inverse demand function (D) for fresh or processing apples. P^i is the U.S. level price and so demand is modeled at the U.S. level. An econometric study of the apple market resulted in the conclusion that the relationship between the consumption of fresh and processed apples is weak (Roosen). Therefore dependence in the consumption of fresh and processed apples is not considered in the demand function. The demand functions are parameterized by λ and a change in the regulatory environment can be reflected in changes of the demand function. The regional supply functions are linked to the U.S. demand via regional pricing equations presented by $h_j^i(P^i)$ in equation (1.3). Net imports (Q_M^i) are modeled in equation (1.5) and the last equation (1.6) imposes the market clearing conditions.

Totally differentiating this system, we derive the equilibrium impacts of a change in technology (the loss of a pesticide) parameterized as a shift in λ.

$$\text{(2.1a)}\quad f_j^{FrFr}\frac{P_j^{Fr}}{Q_j^{Fr}}dQ_j^{Fr} + f_j^{FrPr}\frac{P_j^{Fr}}{Q_j^{Pr}}dQ_j^{Pr} - dP_j^{Fr} = -\frac{\partial MC_j^{Fr}}{\partial\lambda}d\lambda, \qquad j = 1, \ldots, k,$$

$$\text{(2.1b)}\quad f_j^{PrFr}\frac{P_j^{Pr}}{Q_j^{Fr}}dQ_j^{Fr} + f_j^{PrPr}\frac{P_j^{Pr}}{Q_j^{Pr}}dQ_j^{Pr} - dP_j^{Pr} = -\frac{\partial MC_j^{Pr}}{\partial\lambda}d\lambda, \qquad j = 1, \ldots, k,$$

$$\text{(2.2a)}\quad f_j^{FrFr}\frac{P_j^{Fr}}{Q_j^{Fr}}dQ_j^{Fr} + f_j^{FrPr}\frac{P_j^{Fr}}{Q_j^{Pr}}dQ_j^{Pr} - dP_j^{Fr} = 0, \qquad j = k + 1, \ldots, J,$$

$$\text{(2.2b)}\quad f_j^{PrFr}\frac{P_j^{Pr}}{Q_j^{Fr}}dQ_j^{Fr} + f_j^{PrPr}\frac{P_j^{Pr}}{Q_j^{Pr}}dQ_j^{Pr} - dP_j^{Pr} = 0, \qquad j = k + 1, \ldots, J,$$

$$\text{(2.3)}\quad dP_j^i - \frac{\partial h_j^i}{\partial P^i}dP^i = 0, \qquad i = Fr, Pr; \quad j = 1, \ldots, J,$$

$$\text{(2.4)}\quad f_d^{ii}\frac{P^i}{Q_d^i}dQ_d^i - dP^i = -\frac{dP^i}{d\lambda}d\lambda, \qquad i = Fr, Pr,$$

$$\text{(2.5)}\quad dQ_M^i - e_{MP}^i\frac{Q_M^i}{P^i}dP^i - e_{MQ}^i\frac{Q_M^i}{\left(\sum_j Q_j^i\right)}d\left(\sum_{j=1}^{J} Q_j^i\right) = 0, \qquad i = Fr, Pr,$$

$$\text{(2.6)}\quad dQ_1^i + \cdots + dQ_J^i + dQ_M^i - dQ_d^i = 0, \qquad i = Fr, Pr.$$

In system (2), f_j^{KL} denotes the flexibility of the price of good K with respect to the quantity of good L produced, where j indexes the region. The demand flexibilities are expressed as f_d^{ii}, $i = Fr, Pr$ for fresh and processed apples, respectively. For net imports e_{MP}^i and e_{MQ}^i indicate the elasticities of net imports with respect to U.S. price level and U.S. production for the respective market i. System (2) is equivalent to system (2) in Lichtenberg, Parker, and Zilberman, but for the cross-price flexibilities. These enter the system to account for marginal cost changes of producing fresh (processed) apples caused by changes in the production of processed (fresh) apples. The system is also extended to allow for WTP changes for apples after a ban of a pesticide. A change in the regulatory environment, $d\lambda$, can now shift the demand function as presented in (2.4). We use this shift to estimate the WTP premium necessary to neutralize the adverse surplus effects of a pesticide ban. System (2) is linear and it can easily be solved to yield the endogenous changes in quantities and prices given the exogenous shocks to the marginal-cost functions.

Welfare Analysis

Using the solutions for changes in quantities and prices according to system (2), consumer and producer surpluses can be calculated assuming, as in Lichtenberg, Parker, and Zilberman, that shifts in supply curves can be approximated by linear shifts. This assumption is suitable if shifts are relatively small which is an adequate assumption for the scenarios considered in many regulatory proposals. A review of apple orchard budgets suggests that expenditures for pesticides and plant protection comprise from 5 percent to 30 percent of annual operating costs depending on the orchard system. But investments into planting and into irrigation systems are generally very important and growers' flexibility to substitute inputs once the orchard is planted is rather limited. In many instances the number of substitute pesticides available is small, so that at the regional level it is a suitable approximation to assume that the marginal cost function of all users in one region shift in a parallel manner.

To derive the welfare implications for producers we start from the profit maximization problem of the grower who chooses the optimal quantities Q_j^{Fr} and Q_j^{Pr} according to

$$(3) \quad \max_{Q_j^{Fr}, Q_j^{Pr}} \pi_j = P_j^{Fr} Q_j^{Fr} + P_j^{Pr} Q_j^{Pr} - C(Q_j^{Fr}, Q_j^{Pr}; \lambda).$$

The first-order conditions define the market supply functions and are stated in (1.1) and (1.2) for users and non-users of the pesticide, respectively. The profit-maximizing solutions of Q_j^{Fr} and Q_j^{Pr} are denoted as $\hat{Q}_j^{Fr}$ and $\hat{Q}_j^{Pr}$. Abstracting from fixed costs, producer surplus is defined as $R_j = P_j^{Fr} Q_j^{Fr} + P_j^{Pr} Q_j^{Pr} - C(Q_j^{Fr}, Q_j^{Pr}; \lambda)$. Assuming that output i is a necessary output, the change in producer surplus for the non-users of a pesticide is defined as

$$\Delta R_j = \int_{P_{0j}^i}^{P_{1j}^i} \left\{ \hat{Q}_j^i + [P_j^i - MC_j^i(\cdot)] \frac{\partial Q_j^i}{\partial P_j^i} + [P_j^{-i} - MC_j^{-i}(\cdot)] \frac{\partial Q_j^i}{\partial Q_j^{-i}} \frac{\partial Q_j^{-i}}{\partial P_j^i} \right\} dP_j^i$$

where P_{0j}^i denotes the original price level and P_{1j}^i signifies the price level after the change in λ. Here, the superscript i can denote either Fr or Pr, implying that $-i$ indicates the other. Employing the envelope theorem, the last two terms of the integrand sum to zero and

$$(4) \quad \Delta R_j = \int_{P_{0j}^i}^{P_{1j}^i} \hat{Q}_j^i \, dP_j^i, \qquad j = k + 1, \ldots, J.$$

The equilibrium supply $\hat{Q}_j^i$ responds thereby to price changes in both markets, i.e. P_j^{-i} is not held fixed. Welfare impacts in horizontally related markets can thus be assessed using the equilibrium supply curve in any of the affected market (Just, Hueth, and Schmitz, pp. 337–48). For the users of the pesticide, the change in producer surplus can be derived as the analog to (4), but it now acknowledges the shift in the cost function due to the change in λ

$$(5) \quad \Delta R_j = \int_{P_{0j}^i}^{P_{1j}^i} \hat{Q}_j^i \, dP_j^i - \int_0^{P_{1j}^{Fr}} \frac{dMC_j^{Fr}(Q_{1j}^{Fr}, Q_{1j}^{Pr}; \lambda)}{d\lambda} dP_j^{Fr} - \int_0^{P_{1j}^{Pr}} \frac{dMC_j^{Pr}(Q_{1j}^{Fr}, Q_{1j}^{Pr}; \lambda)}{d\lambda} dP_j^{Pr}$$

$$\text{for } j = 1, \ldots, k.$$

Equivalent to (4) and (5), the changes in producer surplus can be calculated in each market separately employing the partial-equilibrium supply curves $Q_j^i(P_j^i; Q_j^{-i})$, $i = Fr, Pr$. Using the latter approach changes in both markets have to be considered because surplus changes in one market are not calculated in the other. Since reallocation of production and surplus between the markets is an important aspect of this study, the latter approach was chosen.[2]

In this analysis, changes in demand result exclusively from changes in prices, and we ignore any possible changes in consumers' preferences for apples that could result from a change in production methods. This assumption is made so that the analysis fits in the regulatory framework of an economic assessment on production changes separately from a

---

[2] As discussed in Just, Hueth, and Schmitz the two approaches are in general not equivalent in empirical applications. The approach chosen has the advantage that the assumption of necessity of the output is not made. In addition, for the empirical application the supply curve is shifted in both markets and in this instance the approach chosen is easier to implement.

risk assessment to assess consumer and environmental benefits.[3] Therefore the demand functions do not shift and the change in consumer surplus can be described by the difference in the consumer surplus before and after a change in pesticide availability. It is calculated as $-dP^i(Q_d^i + dQ_d^i/2)$ in each market.

Pesticide regulation is often motivated by concern about the risks that pesticides pose to consumers and to the environment. Hence, it is likely that consumers express their preference for stricter pesticide regulation in the market. Blend and van Ravenswaay, for example, estimate the demand for ecolabeled apples and, among those, apples produced under reduced pesticide use. Using a telephone survey they found that 72.6 percent of their sample would buy ecolabeled apples at a zero price premium and that, at a \$0.10 price premium, this purchase probability would decrease by only 9 percent. In a study on the Alar crisis, van Ravenswaay and Hoehn estimated an average WTP to avoid Alar in fresh apples at 11 percent early in the crisis in 1984 and at 31 percent in 1989 after the issue had received extensive media coverage. However, in an experimental study on WTP for scenarios of organophosphate cancellations in apple production, Roosen *et al.* found that WTP for single pesticide bans is not significant while WTP for banning all organophosphates is significant and positive. Here we estimate the WTP premia necessary to offset the negative production effects of a pesticide cancellation.[4] It is clear that the negative welfare effects caused by tightening the apple supply could also be offset by other positive, welfare improving effects such as environmental or human health benefits that are not reflected in the market price for apples.

Calculating Marginal-Cost Changes

System (2) can be solved using an estimate of the marginal-cost change for the producer groups $j = 1, 2, \ldots, k$. In system (1) we suppose that a grower chooses the profit-maximizing level of production for the fresh and processed market using the technology described by the cost function $C_j(Q_j^{Fr}, Q_j^{Pr}; \lambda)$. According to the profit-maximization problem (3), the grower will choose the level of production that equates the marginal cost of producing for the fresh and processed market with the respective price, as described in (1.1) and (1.2). The problem can also be presented by choosing the optimal level of overall yield, Y_j, and the optimal share of fruit going to the fresh market, α_j, according to

$$(6) \quad \max_{\alpha_j, Y_j} \pi_j(Y_j, \alpha_j; \lambda) = [\alpha_j P_j^{Fr} + (1 - \alpha_j)P_j^{Pr}]Y_j - \Psi_j(Y_j, \alpha_j; \lambda).$$

Here, $\Psi_j(\cdot)$ is the alternative cost function specification that equivalent to $C_j(Q_j^{Fr}, Q_j^{Pr}; \lambda)$ describes the grower's available technology. We assume it to be convex in Y_j and α_j. The first-order conditions are stated as

$$(7.1) \quad \Psi_{j,Y}(Y_j, \alpha_j; \lambda) = \alpha_j P_j^{Fr} + (1 - \alpha_j)P_j^{Pr},$$

$$(7.2) \quad \Psi_{j,\alpha}(Y_j, \alpha_j; \lambda) = (P_j^{Fr} - P_j^{Pr})Y_j$$

where second subscripts on Ψ_j denote first derivatives. In combination with (1.1) this system of equations can be solved for

$$(8.1) \quad P_j^{Fr} = MC_j^{Fr}(Q_j^{Fr}, Q_j^{Pr}; \lambda) = \Psi_{j,Y} + (1 - \alpha_j)\Psi_{j,\alpha}/Y_j,$$

$$(8.2) \quad P_j^{Pr} = MC_j^{Pr}(Q_j^{Fr}, Q_j^{Pr}; \lambda) = \Psi_{j,Y} - \alpha_j\Psi_{j,\alpha}/Y_j.$$

Following Lichtenberg, Parker, and Zilber-

---

[3] Such an approach can be useful when comparing regulations of the same type where comparisons on similar scales are possible and trade-offs between risk reductions and market surplus reductions can be assessed.

[4] The WTP shift calculated here presents an average WTP change over U.S. produced apples and imported apples. Much more difficult is the question of how the composition of demand for U.S. apples relative to imports will change due to the change in pesticide regulation. Would the consumer shift consumption of imported apples to apples produced under the new and stricter standards applied in the U.S.? Most apples are sold with production location identities at the retail level and it might be possible to perform an analysis on preference changes for apples of different origin. However, such an analysis would require the introduction of a disaggregated demand component into model (1) and was beyond the scope of this study.

man, we approximate locally marginal costs of yield and fresh share by their average costs. Denoting W_j the per-acre cost of production, we set $\Psi_{j,Y} = W_j/Y_j$ and $\Psi_{j,\alpha}/Y_j = P_j^{Fr} - P_j^{Pr}$. The change in technology, λ, impacts all three technology parameters: cost of production, W_j, yield, Y_j, and fresh share, α_j. Totally differentiating the marginal-cost functions with respect to these changes yields the changes in marginal cost for fresh and for processed apples as

$$\begin{aligned}(9)\quad & [dW_j/Y_j - (\alpha_j P_j^{Fr} + (1 - \alpha_j)P_j^{Pr})dY_j/Y_j \\ & - (P_j^{Fr} - P_j^{Pr})d\alpha_j]/(1 + 0.5dY_j/Y_j).\end{aligned}$$

The denominator in (9) corrects for the point of evaluation when approximating marginal by average costs since we are working with finite rather than infinitesimal changes. It is interesting to note that the marginal cost of fresh and processed production change in the same manner. A change in the share allocated to the fresh market will affect the marginal cost of fresh and processed production equally. This is so because the marginal cost of yield, $\Psi_{j,Y}$, refers to the cost of producing apples for fresh and processed consumption. For fresh production, the term $[(1 - \alpha)\Psi_{j,\alpha}/Y_j]$ in (8.1) corrects these costs upward by the part that would otherwise be implied for processed production. If the share of crop allocated the fresh market increases, this upward correction will be reduced. Similarly the downward correction of the marginal cost of yield, $\Psi_{j,Y}$, by $[\alpha\Psi_{j,\alpha}/Y_j]$ in (8.2) will become less important in the marginal cost of processed apples. We have now established all the ingredients to the model and turn next to the data entering the economic impact estimation of pesticide regulation in U.S. apple production.

Data

The U.S. apple industry has a $1.7 bill. annual value of production at the farm level (1996). Production is concentrated on the two seaboards of the United States and production conditions differ considerably due to climatic differences. This is particularly true with respect to disease pressure where western production regions benefit from their arid climate. A regional analysis of the impacts seems therefore of particular importance. We distinguish five major apple-producing regions: West, Midwest, Northeast, Mid-Atlantic, and Southeast. The states comprising each region are listed in Table 1 together with production and revenue data. The West is the most important production region and receives annual revenue of $1.1 bill. from apple production. Midwest, Northeast, and Mid-Atlantic are relatively similar in their importance, each with annual revenue of about $150 mill., and the Southeast is the smallest production region with $39 mill. revenue coming from apple production.[5]

Change in Cost of Production, Yield, and Quality

Derr and also Rosenberger report data on current pesticide use patterns and on pesticide replacement scenarios in the case of pesticide cancellations. Current use data is largely based on existing USDA: NASS/ERS: Agricultural Chemical Usage: Fruit Survey, while replacement scenarios have been estimated using expert surveys. These data permit the calculation of changes in the cost of production using a partial-budgeting approach. Pesticide prices are taken from USDA/NASS agricultural prices statistics (1996 for herbicides, 1997 for fungicides).[6] The application costs are estimated using updated estimates from enterprise budgets (Clark and Burkhart; Funt *et al.*; Hinman *et al.*; Kelsey and Schwallier; Parker *et al.*; Pennsylvania Agricultural Extension Service; Vossen *et al.*) and the cost of applying herbi-

---

[5] The states included in the following analysis account for 97.6 percent of U.S. total production. Impacts in remaining states are negligible in the overall impacts and can safely be ignored in this analysis.

[6] If a price for a particular pesticide is not published, chemical suppliers in different geographical regions were contacted by phone and asked for the price at which the product would typically be sold to apple orchards. Averages were formed for our analysis. We cross-checked prices published by USDA/NASS with prices elicited from chemical suppliers and found only minor differences.

Table 1. Production and Revenue by State and Region, 1994–96

	Revenue $ Mill.	Acreage 000 Acres	Yield 000 Lb./ Acre	Total Prod. Mill. Lb.	Fresh Prod. Mill. Lb.	Proc. Prod. Mill. Lb.	Fresh Share	Fresh Price $/Lb.	Proc. Price $/Lb.
WA	938.2	152.7	35.4	5400.0	3900.0	1500.0	0.72	0.212	0.074
CA	149.1	35.2	26.5	933.3	326.7	606.7	0.35	0.325	0.071
OR	18.5	8.6	18.6	159.7	118.3	41.3	0.74	0.131	0.074
West	**1105.9**	**196.5**	**33.0**	**6493.0**	**4345.0**	**2148.0**	**0.67**	**0.218**	**0.073**
MI	100.2	54.3	18.2	988.3	315.0	673.3	0.32	0.148	0.080
OH	21.4	7.7	13.0	100.0	78.3	21.7	0.78	0.255	0.068
Midwest	**121.7**	**62.0**	**17.6**	**1088.3**	**393.3**	**695.0**	**0.36**	**0.170**	**0.079**
NY	134.7	57.3	18.8	1080.0	490.0	590.0	0.45	0.181	0.078
New England	46.4	20.5	11.4	233.2	163.5	69.7	0.70	0.253	0.073
North-East	**181.1**	**77.8**	**16.9**	**1313.2**	**653.5**	**659.7**	**0.50**	**0.199**	**0.077**
PA	46.8	22.0	19.6	430.3	131.7	298.7	0.31	0.179	0.078
VA	32.4	18.8	16.9	317.0	98.3	218.7	0.31	0.152	0.080
WV	14.6	9.7	13.7	133.3	31.7	101.7	0.24	0.212	0.077
Mid-Atlantic	**140.8**	**79.0**	**16.8**	**1331.0**	**391.7**	**939.3**	**0.29**	**0.171**	**0.079**
NC	23.3	9.3	25.8	240.0	72.0	168.0	0.30	0.158	0.071
SC	6.6	3.6	14.4	51.7	21.3	30.4	0.41	0.209	0.070
KY	3.1	2.4	5.4	13.0	8.6	4.4	0.66	0.294	0.139
GA[a]	2.9	2.4	10.8	26.0	9.3	16.7	0.36	[b]	[b]
TN[a]	2.6	1.6	7.7	12.3	9.6	2.7	0.78	0.248	[b]
South-East	**38.5**	**19.3**	**17.8**	**343.0**	**120.8**	**222.2**	**0.35**	**0.186**	**0.072**

[a] Regional averages are employed if a price is not available.

[b] Prices received for fresh or processed apples are not recorded in these states.

cides/fungicides is appraised at $6.40/$10.84 per acre. Mowing is a frequently suggested replacement strategy for the application of herbicides and its cost is estimated at $11.83/acre. Using the estimates for cost of production, yield, and quality changes, marginal-cost changes are estimated via equation (9).

The quality of the estimated surplus changes will depend on the reliability of the expert opinion data. To address this concern, some studies, such as Sunding, have used the variability of experts expected changes to indicate the range of possible outcomes. However, there is no reason to believe that the variability of the expected value estimates will coincide with the variability of the true underlying random variable.[7] To improve the reliability of the experts' estimates, the surveys by Derr and by Rosenberger used a Delphi-type survey method (Webb, p. 280–82), where experts were confronted with other experts' estimates and given the opportunity to change their estimate if they felt that this was appropriate.

In some instances the marginal costs are lower under the replacement scenarios than under current use patterns and this poses a problem for our analysis. Such results can occur when growers choose a pesticide for indirect benefits that are not acknowledged in (9). In these cases, the change in marginal cost is set to zero. We justify this by the assumption that the nonquantifiable benefits, on e.g. worker safety, integrated pest management (IPM) programs, or resistance management, are at least as large as the extra cost of using the currently used pesticide. Hubbel and Carlson have shown that this can be the case with regard to insecticide choices where apple producers incorporate variables such as worker

---

[7] If one asks three experts about the expectation of a random variable that they all believe to be distributed normal with a zero mean and a variance of one, then they will all respond zero. This does not mean that the outcome will surely be zero.

Table 2. Elasticities (calculated at means)[a]

		Short Run (Year 1)		Long Run (Year 5)	
Northwest					
Fresh Production	$\epsilon_{QPFNW,PF}$	0.306	(0.229)	0.623	(0.310)
	$\epsilon_{QPFNW,PP}$	−0.059	(0.110)	−0.006	(0.126)
Processed Production	$\epsilon_{QPPNW,PF}$	−0.220	(0.660)	0.237	(0.587)
	$\epsilon_{QPPNW,PP}$	0.229	(0.325)	0.272	(0.263)
Southwest					
Fresh Production	$\epsilon_{QPFSW,PF}$	0.346	(0.149)	0.540	(0.229)
	$\epsilon_{QPFSW,PP}$	−0.225	(0.110)	−0.065	(0.169)
Processed Production	$\epsilon_{QPPSW,PF}$	−0.055	(0.160)	0.215	(0.155)
	$\epsilon_{QPPSW,PP}$	0.279	(0.131)	0.452	(0.097)
Central					
Fresh Production	$\epsilon_{QPFC,PF}$	0.868	(0.319)	0.981	(0.425)
	$\epsilon_{QPFC,PP}$	−0.288	(0.112)	−0.269	(0.116)
Processed Production	$\epsilon_{QPPC,PF}$	−0.831	(0.298)	−0.668	(0.370)
	$\epsilon_{QPPC,PP}$	0.291	(0.105)	0.295	(0.105)
East					
Fresh Production	$\epsilon_{QPFE,PF}$	0.638	(0.204)	0.708	(0.213)
	$\epsilon_{QPFE,PP}$	−0.162	(0.047)	−0.157	(0.048)
Processed Production	$\epsilon_{QPPE,PF}$	−0.467	(0.153)	−0.288	(0.248)
	$\epsilon_{QPPE,PP}$	0.133	(0.035)	0.180	(0.047)
Consumption					
	$\epsilon_{QPF,PF}$	−0.374	(24.370)	−0.374	(24.370)
	$\epsilon_{QPP,PP}$	−0.701	(3.053)	−0.701	(3.053)
Import					
	$\epsilon_{NIF,PF}$	−0.609	(1.702)	−0.609	(1.702)
	$\epsilon_{NIP,PP}$	−0.791	(2.134)	−0.791	(2.134)
	$\epsilon_{NIF,QPF}$	−3.276	(2.482)	−3.276	(2.482)
	$\epsilon_{NIP,QPP}$	−3.193	(45.557)	−3.193	(45.557)

[a] Numbers in parentheses report standard errors.

safety or environmental soundness into their insecticide choice.[8]

Elasticity Estimates and Market Data

Regional supply elasticities are estimated together with demand elasticities and import responses in an econometric model (Roosen). The model arranges U.S. apple production into four apple-producing regions—Northwest, Southwest, Midwest, and East—for each of which a production and allocation component is estimated. The supply component follows closely the modeling approach of Willet and estimates a yield and an acreage equation. The demand component of the model describes demand for fresh and processed apples at the U.S. level, and regional price levels are allowed to differ by linking the demand and the supply components via regional pricing equations. Short-run (Year 1) and long-run (Year 5) elasticities are numerically estimated by shocking the model at the means of the data.

We report the resulting estimates in Table 2. A nonparametric bootstrap method of 1000 iterations was used to determine the statistical significance of the elasticity estimates and standard errors are reported in parentheses.

---

[8] The problem with this approach is that such benefits might in fact be larger or that they might also accrue to pesticides for that marginal costs increase. It seems, however, to be the best feasible solution to the problem of nonquantifiable benefits. As a result, we might not completely capture the welfare costs of a pesticide cancellation, and so it is acknowledged that our estimates would underestimate the true cost.

Given the structure of the model, the elasticities for the first year after an exogenous change in output price include only yield and allocation changes, while at a five-year lag acreage might adjust as well. For the demand and net import equations the model is static; hence elasticities are the same for all years. Supply responses are inelastic to price changes in the short run. The technology of apple production allows only for slow adjustments because newly planted orchards take several years to come into full bearing and yields can only be adjusted to a very limited extent. While technology constrains growers to a relatively inelastic response in total production, they can also adjust by reallocating production between the fresh and processing sector if relative prices change.

Cross elasticities of supply are negative in all regions in the short run. The increase in average price due to the increase in the price for fresh or processed apples will induce an increase in yield but the change in relative prices will in addition cause the reallocation of crop to the utilization for which prices increase. This reallocation outweighs the increase in total production in the short run. For the long run, however, the cross-price elasticity of processed production with respect to fresh price turns positive in the Northwest and Southwest, as now, given the increase in fresh price, total production including the acreage adjustment will increase so much that both fresh and processed production increases.

Because experts report opinions only on production technology changes for the year after a hypothetical pesticide ban, short-run elasticities are inverted to yield flexibility estimates that are used in the estimation of market impacts.[9] Data on current prices and quantities were obtained from USDA publications, and market quantities and prices for fresh and processed apples were calculated using an average of 1994–96 data. They are listed in Table 1. A three-year average was used because prices and quantities in the apples market can be quite volatile depending on weather, pest, and (foreign) market conditions. By averaging prices and quantities we obtain impact estimates for an "average year."

Pesticide Cancellation Scenarios

We present the results for four pesticide cancellation scenarios where we consider two different cancellations of fungicide uses and then we turn to a study for two scenarios of herbicide bans. Information about the treated acreage for all considered pesticide cancellation scenarios is given in Table 3 together with expert estimates of cost, yield, and quality changes. For the first scenario considered, the cancellation of carbamates, we will not only estimate the first-year impacts but also fifth-year impacts to give an indication of how our results would change in the longer run. We also perform a Monte Carlo simulation based on the distributions of the elasticity estimates to indicate the range of possible outcomes.

We turn first to the analysis of fungicide regulation where we consider a ban on the carbamates captan, metiram, and mancozeb. Then we discuss a ban on the ergosterol biosynthesis inhibitores (EBI). Fungicides are used to manage a very complex system of diseases and the implications of fungicide regulation are complicated by two factors. On the one hand, a fungicide can be used to combat several diseases at the same time. On the other hand, fungicides are often applied in combination to increase their efficacy in combating one disease or several diseases.

The carbamates captan, metiram, and mancozeb are contact fungicides that are widely used to control many diseases especially in the central and eastern United States. They are multi-site inhibitors of most fungi, and therefore none of the apple diseases has developed resistance to these fungicides. Often suggested alternatives in the instance of their cancellation are thiram, ziram, and EBI fungicides. Human health concerns exist in particular for metiram and mancozeb, which belong to the group of ethylene-bis dithiocarbamate (EBDC). Those can break down to thiourea, a suspected carcinogen. Thiourea breaks down

---

[9] Flexibilities could not be estimated directly because of the dynamic structure of the model on the supply side.

Table 3. Cost, Yield and Quality Changes after Pesticide Losses

	Acreage Treated Percent	Change in Cost ($/Acre)	Change in Yield Percent	Change in Fresh Share Percent
Captan + Mancozeb + Metiram				
West	31.2	6.4	0.0	−0.4
Midwest	100.0	26.8	0.0	−4.4
Northeast	100.0	57.9	0.0	−5.0
M-Atlantic	100.0	14.0	0.0	−5.6
Southeast	100.0	49.2	−2.5	−2.5
EBI-Fungicides				
West	23.2	59.0	−3.2	−4.4
Midwest	50.5	30.1	0.0	0.0
Northeast	46.8	4.0	0.0	−0.3
M-Atlantic	30.9	11.4	−1.8	−2.6
Southeast	57.8	−12.7	−1.4	−1.3
Glyphosate				
West	64.8	6.8	−0.3	−8.9
Midwest	34.5	1.3	0.0	0.0
Northeast	40.0	0.0	0.0	0.0
M-Atlantic	17.1	4.9	−0.6	0.0
Southeast	85.0	9.5	−3.0	0.0
Simazine				
West	41.9	7.5	0.0	−9.3
Midwest	32.9	7.4	0.0	0.0
Northeast	40.0	7.3	0.0	0.0
M-Atlantic	35.3	4.5	0.0	0.0
Southeast	40.0	0.4	0.0	0.0

further quickly and an extended preharvest interval was introduced for EBDCs in the early 90s as a risk-reduction tool. However, health concerns still exist.

The EBI fungicides are a group comprised of fenamirol, myclobutanil, and triflumazole. They are important management tools against scab, rust, and mildew. With scab being the economically most important disease in the East and mildew being the economically most important disease in the West, EBI are critical for disease control in all regions. All fungicides within this group have a very similar mode of action and are usually applied in tank mixes with a contact fungicide such as captan or mancozeb to control resistance development and to increase the effectiveness of the treatment. Often suggested alternatives for the scenario of a ban on EBI are increased use rates and increased numbers of application for these contact fungicides.

In contrast to fungicides that are often used to combat diseases affecting the fruit, herbicides are often applied to control weed competition in young orchards and to improve the general performance of the orchard. Another important role is the control of weed blooms during apple pollination, so that fruit trees do not compete for bees with other flowering plants. We consider a cancellation of the herbicide glyphosate and also a cancellation of simazine. Glyphosate is a herbicide used for the control of annuals and perennials, and in the West and Southeast it is applied to a large share of the acreage. Most alternatives are less effective, and the often-suggested alternative paraquat is problematic from a worker-safety perspective because of its higher acute toxicity. Simazine is the pre-emergence herbicide that is often rotated with diuron, and banning simazine will lead to increased use of diuron. As a result, diuron re-

Table 4. First-Year Economic Surplus Changes after a Ban on Captan, Metiram, and Mancozeb, in $ 000

		Fresh Apples				Processed Apples			
	Total 000 $	Total 000 $	User 000 $	Non-User 000 $	Quantity Mill. Lb.	Total 000 $	User 000 $	Non-User 000 $	Quantity Mill. Lb.
West	840.0	870.7	325.2	545.5	1.7	−30.8	−129.7	98.9	−1.3
Midwest	−35.9	11.7	11.7	0.0	−0.9	−47.6	−47.6	0.0	−0.8
Northeast	−974.3	−888.1	−888.1	0.0	−5.5	−86.2	−86.2	0.0	−1.3
M-Atlantic	−413.0	−350.8	−350.8	0.0	−2.4	−62.2	−62.2	0.0	−0.9
Southeast	−210.3	−180.4	−180.4	0.0	−1.1	−29.9	−29.9	0.0	−0.5
Prod.	−793.6	−536.9	−1,082.4	545.5	−8.2	−256.7	−355.6	98.9	−4.8
Cons.	−1,631.4	−1,516.5			−2.2	−114.9			−1.9
Total	−2,425.0	−2,053.3				−371.6			

sistance could become a concern once simazine is banned.

Results

Table 3 shows the direct production impacts for all four scenarios. The second column gives the percentage of apple acreage treated in each region. Estimates of changes in cost of production, of changes in yield, and of changes in share allocated to the fresh market are given in the following columns. For the carbamates captan, metiram and mancozeb, Table 3 shows that large impacts are expected east of the Mississippi and those result in particular through quality changes. In the West, marginal costs of production change only little and overall these fungicides are not widely used. Resulting economic surplus changes are presented in Table 4 and all users except users in the West incur losses. There even users benefit from the shortened supply for fresh apples so that price increases outweigh the upward shift in costs and producer surplus increases.

Given the premium paid for apples in the fresh market, losses there are in general more important than in the processing market. Furthermore, we observe that in the fresh market a larger share of total losses is borne by consumers while in the market for processed apples producers carry the larger share of the cost. This results from the relatively inelastic demand for fresh apples (0.37) and the more elastic demand for processed apples (0.70), so that in the fresh market growers can realize price increases that compensate them to a large extent for the marginal cost increases. The effect that producers might in fact benefit from a supply contraction if demand is sufficiently inelastic is a well-known result and has been analyzed for instance by Lave or Babcock.

In our case not only the elasticities of demand are important in determining this effect; the responsiveness of net imports to price and home production changes is also consequential. The change in net imports depends on changes of U.S. production and U.S. price levels and can be read off as the difference between quantity consumed and quantity produced. In Table 4, net imports increase by 6.0 mill. lb. in the fresh market and by 2.9 mill. lb. in the processed market. The change in net imports is greater in the fresh market in absolute but also in relative terms. The reduction of U.S. production is to 73 percent compensated by additional net imports in the fresh market and by 60 percent in the market for processed apples. Regarding the reallocation impacts between fresh and processed production one observes that due to changes in relative prices, growers reallocate production from processed to fresh utilization. Effects like this would not be recognized in models that treat the markets separately. Overall welfare losses are $2.1 mill. in the fresh market and $0.4 mill. in the processing market.

This analysis measures only production effects of pesticide cancellations and ignores possible changes in consumers' preferences that are reflected in demand changes. Because of the lack of sufficiently reliable data on WTP for pesticide bans, we estimate the minimum change in WTP necessary to offset the tightening of product supply. For a ban on the carbamates Captan, Metiram, and Mancozeb, a WTP premium of 0.5 percent of market price would offset the adverse welfare effects of a pesticide ban.

The results depend on the elasticity estimates entering the simulation. To evaluate the impact of the uncertainty underlying the elasticity estimates, we perform a Monte-Carlo study in the spirit of Griffiths and Zhao on this pesticide cancellation scenario and place confidence bounds on the estimated surplus changes. Elasticities are sampled from their empirical distribution function imposing nonnegativity on the own-price supply elasticities and nonpositivity on the demand flexibility and import price elasticities by truncating the distribution at zero. Furthermore, the second-order conditions on profit maximization require that $\partial MC^{Fr}/\partial Q^{Fr} \cdot \partial MC^{Pr}/\partial Q^{Pr} - \partial MC^{Fr}/\partial Q^{Pr} \cdot \partial MC^{Pr}/\partial Q^{Fr} \geq 0$ which is equivalent to $\epsilon_{FrFr}\epsilon_{PrPr} - \epsilon_{FrPr}\epsilon_{FrPr} \geq 0$ given the assumption that $\partial MC^{i}/\partial Q^{l}$, $i, l = Fr, Pr$, can be approximated by $\partial P^{i}/\partial Q^{l}$.[10] We impose this restriction by implementing an acceptance-rejection sampling algorithm when drawing the realizations of elasticity estimates.

The results of this Monte-Carlo study are given in Table 5 where upper and lower bounds of the 90-percent confidence interval are reported. Bounds have been obtained separately for groups and aggregates, so that the bounds on aggregates do not result as the sum of the bounds on the respective groups. The lower bound of the 90 percent for total welfare changes is found at $6.6 mill. and so is more than twice as large as the mean estimate. Considerable interactions between the different elasticities in the system make it difficult to ensure that all elasticity estimates adhere to the theoretic restrictions that have to be present in the model. Some draws of positive welfare changes occurred which can a-priori be rejected given that we assume that the demand functions do not shift, and so we set the upper bound of the confidence interval for total welfare changes at zero. In general it can be concluded that the uncertainty surrounding the elasticity estimates is reflected by the relatively wide confidence bounds on the economic surplus change estimates. However, in terms of total value of U.S. apple production we are reassured about the relative order of magnitude.

Table 5. 90-Percent Confidence Bounds on First-Year Economic Surplus Changes after a Ban on Captan, Metiram, and Mancozeb, in $ 000

	Total Surplus Changes in 000 $: Fresh and Processed Markets		
	Mean	Lower 5 Percent[a]	Upper 5 Percent[a]
West	840.0	−319.0	4,392.0
Midwest	−35.9	−1,416.0	1,187.3
Northeast	−974.3	−1,560.9	375.1
M-Atlantic	−413.0	−593.8	402.6
Southeast	−210.3	−328.8	128.7
Prod.	−793.6	−2,566.4	5,219.4
Cons.	−1,631.4	−11,592.7	494.3
Total	−2,425.0	−6,622.1	0.0

[a] Since confidence intervals are formed separately for groups and totals, the confidence bounds for the groups do not sum up to the bounds of the totals.

In a last simulation concerning the carbamates, we assess the possible long-run impacts. This assessment acknowledges, however, the long-run changes only partially because Rosenberger and also Derr report only short-run production impacts. While the long-run assessment acknowledges more elastic responses on the supply of production, it does not take into account possible technological

---

[10] The result can be obtained by noting that the system of flexibilities equals the inverse of the system of elasticities, i.e.,

$$\begin{bmatrix} \partial \ln P^{Fr}/\partial \ln Q^{Fr} & \partial \ln P^{Fr}/\partial \ln Q^{Pr} \\ \partial \ln P^{Pr}/\partial \ln Q^{Fr} & \partial \ln P^{Pr}/\partial \ln Q^{Pr} \end{bmatrix}$$

$$= \begin{bmatrix} \partial \ln Q^{Fr}/\partial \ln P^{Fr} & \partial \ln Q^{Fr}/\partial \ln P^{Pr} \\ \partial \ln Q^{Pr}/\partial \ln P^{Fr} & \partial \ln Q^{Pr}/\partial \ln P^{Pr} \end{bmatrix}^{-1}$$

Table 6. Fifth-Year Economic Surplus Changes after a Ban on Captan, Metiram, and Mancozeb, in $ 000

		Fresh Apples				Processed Apples			
	Total 000 $	Total 000 $	User 000 $	Non-User 000 $	Quantity Mill. Lb.	Total 000 $	User 000 $	Non-User 000 $	Quantity Mill. Lb.
West	1,433.3	1,186.2	127.3	1,058.9	3.1	247.1	−220.6	467.7	−1.0
Midwest	−583.0	−211.7	−211.7	0.0	−3.2	−371.3	−371.3	0.0	−5.8
Northeast	−2,013.3	−1,235.3	−1,235.3	0.0	−7.8	−778.0	−778.0	0.0	−10.9
M-Atlantic	−997.7	−432.6	−432.6	0.0	−3.0	−565.1	−565.1	0.0	−8.0
Southeast	−507.7	−237.9	−237.9	0.0	−1.6	−269.7	−269.7	0.0	−4.0
Prod.	−2,668.4	−931.4	−1,990.3	1,059.0	−12.6	−1,737.0	−2,204.8	467.8	−29.7
Cons.	−3,043.4	−2,332.2			−3.4	−711.2			−11.8
Total	−5,711.8	−3,263.5				−2,448.2			

changes beyond the first year. How such changes might affect the production system is not clear. On the one hand, the use of fewer pesticides might result in increased resistance development and impacts might become larger, and on the other hand, growers might find better substitute technologies and impacts might becomes smaller.

The results using the long-run elasticities are reported in Table 6. Impacts are much larger mostly because acreage adjustments are now taken into account and total economic surplus changes are estimated at $5.7 mill. In comparison to first-year impacts, the redistribution of production from eastern and midwestern states to western states becomes more substantial.

For the EBI fungicides, results are presented in Table 7 and the large impacts experienced in the West dominate the final outcome of the regulation. In the West growers lose $2.2 mill., 57 percent of which occurs in the processed markets. Overall impacts result in an economic surplus loss of $4.4 mill., half of which is borne by consumers. A WTP increase of 0.9 percent of market value in response to the cancellation of EBIs would be sufficient to offset the negative surplus impact of the tightened supply.

Turning now to the results for the cancellation of herbicides, Table 3 shows that a loss of glyphosate would cause significant quality impacts in the West and would lower yield in the Southeast. Hence the western states suffer substantial losses of $5.5 mill., most of which occur in the market for processed apples (Table 8). Impacts in other regions are compensated for by changes in the market environ-

Table 7. First-Year Economic Surplus Changes after a Ban on EBI Fungicides, in $ 000

		Fresh Apples				Processed Apples			
	Total 000 $	Total 000 $	User 000 $	Non-User 000 $	Quantity Mill. Lb.	Total 000 $	User 000 $	Non-User 000 $	Quantity Mill. Lb.
West	−2,163.7	−941.7	−1,477.7	536.0	−7.6	−1,222.0	−1,525.0	302.9	−20.4
Midwest	52.9	−0.6	−10.3	9.7	−0.1	53.4	20.8	32.6	−0.1
N-East	−64.5	−99.6	−137.5	38.0	−0.7	35.1	6.3	28.8	−0.2
M-Atlantic	−46.1	−75.2	−95.2	20.1	−0.5	29.1	−4.6	33.7	−0.2
S-East	−5.3	−17.6	−23.0	5.5	−0.1	12.3	4.9	7.4	−0.1
Prod.	−2,226.8	−1,134.6	−1,743.8	609.2	−8.9	−1,092.2	−1,497.6	405.5	−21.0
Cons.	−2,160.7	−1,657.4			−2.4	−503.4			−8.4
Total	−4,387.5	−2,792.0				−1,595.5			

Table 8. First-Year Economic Surplus Changes after a Ban on Glyphosate, in $ 000

		Fresh Apples				Processed Apples			
	Total 000 $	Total 000 $	User 000 $	Non-User 000 $	Quantity Mill. Lb.	Total 000 $	User 000 $	Non-User 000 $	Quantity Mill. Lb.
West	−5,469.9	−2,056.3	−2,427.6	371.3	−15.8	−3,413.6	−3,753.1	339.5	−56.4
Midwest	195.7	23.0	7.3	15.7	0.5	172.8	59.9	112.8	0.1
Northeast	228.5	90.0	36.0	54.0	0.5	138.5	55.4	83.1	0.1
M-Atlantic	165.4	35.8	2.0	33.8	0.2	129.6	20.3	109.4	0.0
Southeast	−26.8	−59.9	−62.4	2.5	−0.4	33.2	26.2	7.0	−0.2
Prod.	−4,907.1	−1,967.5	−2,444.8	477.3	−14.9	−2,939.5	−3,591.3	651.8	−56.3
Cons.	−4,104.6	−2,758.9			−4.0	−1,345.7			−22.4
Total	−9,011.6	−4,726.4				−4,285.2			

ment, i.e., by price increases. Consumers would suffer large losses especially in the fresh market. Total losses amount to $9.0 mill. Here a WTP shift of 1.9 percent would be necessary to offset the negative welfare impacts.

After a loss of simazine, major quality losses are expected in the West (Table 3) where growers suffer significant losses of $4.6 mill. (Table 9). Consumers would also be severely affected by the reduction of apples available for fresh consumption and total first-year welfare impacts amount to $7.5 mill. An increase in WTP of 1.6 percent of market value would be enough to render a ban on simazine welfare neutral.

For the different pesticide cancellation scenarios, total economic surplus losses vary $2.4 mill. and $9.0 mill. In terms of value of production, losses in the order of 0.2 percent to 0.6 percent would be experienced. While these seem rather small, they are well within the range of impacts found by other empirical studies of single pesticide cancellations such as Buzby and Spreen on grapefruit (0.3 percent – 1.8 percent); Davis et al. on tomatoes (most under 1 percent); or Lichtenberg, Parker, and Zilberman on plums, almonds, and prunes (0.3 percent – 0.6 percent). Also the flexibility of our model limits the size of the impacts by allowing for the reallocation of fruit between the fresh and processed utilization.

Estimated WTP changes rendering the pesticide cancellation scenarios welfare neutral vary between 0.5 percent and 1.9 percent of market value. Whether such WTP changes are realistic will very much depend on the real and perceived changes in risks to consumer health and the environment. Van Ravenswaay and Hoehn have estimated the WTP to avoid Alar in apples at up to 31 percent. Also Roos-

Table 9. First-Year Economic Surplus Changes after a Ban on Simazine, in $ 000

		Fresh Apples				Processed Apples			
	Total 000 $	Total 000 $	User 000 $	Non-User 000 $	Quantity Mill. Lb.	Total 000 $	User 000 $	Non-User 000 $	Quantity Mill. Lb.
West	−4,607.4	−2,454.5	−3,013.4	558.9	−14.9	−2,152.9	−2,527.6	374.7	−35.3
Midwest	133.5	25.8	6.6	19.2	0.5	107.7	35.8	71.8	0.0
Northeast	166.4	81.1	19.7	61.4	0.5	85.2	32.9	52.4	0.0
M-Atlantic	119.5	38.2	9.8	28.4	0.3	81.3	27.6	53.6	0.0
Southeast	48.1	18.7	7.3	11.4	0.1	29.4	11.7	17.6	0.0
Prod.	−4,140.0	−2,290.6	−2,969.9	679.3	−13.6	−1,849.4	−2,419.6	570.2	−35.1
Cons.	−3,357.0	−2,516.8			−3.7	−840.2			−14.0
Total	−7,497.0	−4,807.3				−2,689.7			

en et al. have found consumers' WTP premium for apples not treated by organophosphates to be 18 percent of market value. However, the latter study also showed non-significant WTP for apples not treated by a single pesticide that could easily be replaced by pesticides with similar risk characteristics.

Conclusion

In this paper we have developed a methodology for assessing the impacts of environmental regulation in quality differentiated markets. Our framework provides a means of assessment when complex relationships between different marketing channels are important. It allows for two related but distinct effects: (1) Stricter environmental regulation may lead to a quality deterioration of the crop that might not be directly measurable by a reduction yields or by an increase in production costs. (2) Growers can respond to changing market conditions by reallocating output between the affected markets. We implement the model to estimate welfare changes due to fungicide and herbicide cancellations in U.S. apple production. The results show that the increased flexibility of our multi-market model has important implications for the reallocation of output between markets.

Our simulations show that consumers bear a large share of the overall welfare losses in the fresh market because of the relatively inelastic demand, whereas producers bear the larger share of losses in the processing market. Furthermore, changes in net imports are significant and it is important to acknowledge these in the assessment. In several scenarios, growers in some regions would gain from a pesticide ban because losses by users of pesticides in those regions are out-weighed by gains accruing to non-users. In particular, a reduction in the supply from western states can have large impacts on prices and hence benefits growers in other regions. This is not surprising since the West supplies 61 percent of all apples produced in the United States. This assessment does not include estimates of the benefits of stricter pesticide regulations. We estimated the minimum WTP premia necessary to make each cancellation scenario welfare improving. These values vary between 0.5 percent and 1.9 percent of market value.

Questions of product quality have become pivotal in the marketing of agricultural products and quality deterioration due to environmental regulation needs to be considered in welfare and policy assessments. This is particularly true if the improved environmental quality of a product can not be distinguished in the market through effective labeling policies. If exports or imports are important, as is the case for apples, the regulation will impact the international competitiveness of the industry. In fact, reduced U.S. production is to a large extent replaced by increased net imports and consumption is reduced by only a fraction of production losses. Our analysis indicates that in the long term regional and international distribution effects could become more important to the disadvantage of regions that so far rely heavily on pesticides in order to protect the quality of their crop. Future research could investigate if and how U.S. growers could successfully communicate to consumers that their production methods according to the stricter standards warrant a preferential treatment of U.S.-grown fruit.

References

Babcock, B.A. "The Value of Weather Information in Market Equilibrium." *Amer. J. Agric. Econ.* 72(February 1990): 63–72.

Blend, J.R. and E.O. van Ravenswaay. "Measuring Consumer Demand for Ecolabeled Apples." *Amer. J. Agr. Econ.* 81(December 1999): 1072–77.

Buzby, J.C. and T.H. Spreen. "The Impacts on the U.S. Grapefruit Industry of Banning the Pesticide Sodium Ortho-Phenylphenate." *Amer. J. Agr. Econ.* 76(December 1994): 1262.

Clark, S. and D. Burkhart. *Enterprise Budget: Apples Delicious: North Central Region.* Oregon. State University, EM 8491, Jan. 1992.

Cropper, M.L., W.N. Evans, S.J. Berard, M.M. Ducla-Soares, and P.R. Portney. "The Determinants of Pesticide Regulation: A Statistical Analysis of EPA Decision Making." *J. Polit. Econ.* 100(February 1992): 175–97.

Davis, R.M., G. Hamilton, C. Osteen, W.T. Lanini, and T.H. Spreen. *The Importance of Pesticides* *and Other Pest Management Practices In U.S. Tomato Production.* A Special Funded Project of the United States Department of Agriculture, National Agricultural Pesticide Impact Assessment Program, Document Number 1-CA-98, 1998.

Derr, J. "Biological Assessment of Herbicide Use in Apple Production." Unpublished Manuscript, Virginia Tech. and State University, 1999.

Funt, R.C., T.A. Baugher, H.W. Hogmire, and W.C. Kleiner. *Profitability of Different Apple Orchard Systems in the Eastern United States.* Ohio Agric. Research & Dev. Center. Horticulture Department Series 624, March 1992, Wooster, Ohio.

Griffiths, W. and X. Zhao. "A Unified Approach to Sensitivity Analysis in Equilibrium Displacement Models: Comment." *Amer. J. Agric. Econ.* 82(February 2000): 236–40.

Hinman, H.R., P. Tvergyak, B. Peterson, and M. Clements. *1992 Estimated Cost of Producing Red Delicious Apples in Central Washington.* Farm Business Management Reports. EB 1720. Coop. Ext. Service. Washington State University. Pullman, WA, 1992.

Hubbel, B.J. and G.A. Carlson. "Effects of Insecticide Attributes on Within-Season Insecticide Product and Rate Choices: The Case of U.S. Apple Growers." *Amer. J. Agric. Econ.* 80(May 1998): 382–96.

Just, R.E., D.L. Hueth, and A. Schmitz. *Applied Welfare Economics and Public Policy.* Prentice Hall, Inc. Englewood Cliffs, NJ, 1982.

Kelsey, M.P. and P. Schwallier. *Cost of Producing Fresh Apples in Western Michigan.* Coop. Ext. Service. Michigan State University, Ext. Bulletin E-110, Oct. 1989.

Lave, L.B. "The Value of Better Weather Information to the Raisin Industry." *Econometrica* 31(1963): 151–64.

Lichtenberg, E., D.D. Parker, and D. Zilberman. "Marginal Analysis of Welfare Costs of Environmental Policies: The Case of Pesticide Regulation." *Amer. J. Agric. Econ.* 70(November 1988): 868–74.

Parker, M.L., C.R. Unrath, C. Safley, and D. Lockwood. *High Density Apple Orchard Management.* North Carolina Cooperative Extension Service, AG-581, June 1998.

Pennsylvania Agricultural Extension Service. *Estimated Cost and Returns for Apples.* Pennsylvania State University, 1996.

Rice-Mahr, S.E. and L.J. Moffit. "Biologic and Economic Assessment of Pesticide Usage on Cranberries." NAPIAP Rep. No. 2-CA294; USDA, Washington DC, 1994.

Roosen, J. "A Regional Econometric Model of U.S. Apple Supply and Demand." Staff Paper #317, Department of Economics, Iowa State University, 1999.

Roosen, J., J.A. Fox, D.A. Hennessy, and A. Schreiber. "Consumers' Valuation of Insecticide Use Restrictions: An Application to Apples." *J. Agric. Res. Econ.* 23(1998): 367–84.

Rosenberger, D.A. "Biological Assessment of Fungicide Use in Apple Production." Unpublished Manuscript, Cornell University, 1999.

Sunding, D.L. "Measuring the Marginal Cost of Nonuniform Environmental Regulations." *Amer. J. Agric. Econ.* 78(November 1996): 1098–107.

U.S. Department of Agriculture. *Agricultural Statistics.* Washington, DC. Various Years.

U.S. Department of Agriculture. ERS/CED. *Fruit and Tree Nuts Situation and Outlook Report: Yearbook.* Washington, DC, various years.

U.S. Department of Agriculture. ERS/CED. *Noncitrus Fruit and Nuts Annual Summary.* Washington, DC, various years.

U.S. Department of Agriculture. NASS. *Agricultural Prices: Annual Summaries.* Washington, DC, various years.

U.S. Department of Agriculture. NASS/ERS. *Agricultural Chemical Usage: Fruits Summary.* Washington, DC, various years.

Van Ravenswaay, E.O. and J.P. Hoehn. "The Impact of Health Risk Information on Food Demand: A Case Study of Alar and Apples." In J.A. Caswell (ed.). *Economics of Food Safety.* New York: Elsevier, 1991, p. 155–74.

Vossen, P., K. Klonsky, L. Tourte, and P. Levingston. *Sample Costs to Establish an Apple Orchard and Produce Apples.* U.C. Coop. Ext. 1994.

Webb, Samuel C. *Managerial Economics.* Houghton Mifflin Company, Boston: 1976.

Willet, L.S. "The U.S. Apple Industry: Econometric Model and Projection." *Agric. Res. Econ. Rev.* 22(October 1993): 138–49.