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 profitable 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 accounted for 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 analyzed. It is shown that changes in the quality of a crop lead to significant market reallocation effects.

Key Words: apple production, joint production, multiproduct farms, pesticide cancellation, welfare analysis.

Increased environmental regulation of agricultural production activity has resulted in a need for economic models that are used to estimate 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, Baron, Zilberman: Modeling). 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 in 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 Stubble and Spencer who assess the impacts of a ban of certain ortho-phenylphenolate on the U.S. grapefruit industry; Davis et al., who consider pesticide cancellations on tomatoes; in Lichtenberg, Baron, and Zilberman who estimate the economic costs of canceling ethyl parathion on almonds, plums, and prunes; and in Roca-Mahé and Moffitt 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-
tant class of such non-separable multiproduct technologies is the production of quality dif-
ferentiated outputs when product is sorted into lots of uniform quality that are sold at differ-
ent 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 regula-
tion 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 Lich-
tenberg, Parker, and Zilberman to such a mul-
iproduct 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 re-
lated markets will result in changes of relative prices and these signals will cause growers to
reallocate their crop between the different mar-

tets. These price incentives will affect all grow-
ers, those that are directly affected by the policy
and those that are only affected through the re-
sulting 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, and pesticides are
in many instances applied to protect the quality
of a crop. Price incentives to produce high qual-
ity fresh apples are considerable and the pre-
mium paid for apples that are sold in the high
value fresh market over apples sold to process-

4 In 1997, the USDA NASS/ERS Agricultural
Chemical Usage: Fruit Summary estimated that 130
different active ingredients of pesticides or growth reg-
ulants were applied in apple production. It reports use
data on 60 active ingredients. Overall, 96 percent of the
beating apple acreage is treated with inacaricides,
90 percent with fungicides, and 60 percent with her-
bicides. This amounts to 44 lbs of active ingredient
per acre. The survey covered California, Georgia,
Michigan, New Jersey, New York, North Car-
olina, Oregon, Pennsylvania, South Carolina, and
Washington.

ing 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 ap-
proach 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 tox-
ic action. Also children's risk exposure has be-
come 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 fa-
cilitates a reduction of the economic cost of the
regulation while meeting the risk-reduction ob-
jective.

Economic assessments of pesticide regula-
tion scenarios ask not only for an assessment of
production impacts but also of benefits that ac-
tue 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 monetized ben-

The paper continues with the description of
an economic model of regulation in quality differentiated markets. We start from a partial mar-
ket equilibrium model in which the cost struc-
ture acknowledges the non-separability of the
production technology. Changes in supply in re-
sponse to changes in the available technology
are derived for the different market segments
and losses of welfare analysis in long-run supply-
related markets are addressed. We apply the model
to the case of pesticide regulation in the U.S.
apple industry. After presenting the data enter-
ing the assessment, we report results on esti-
mated welfare changes for four pesticide-control
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 im-
portant. 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 pro-
cessed market and, in this sense, orchards are
 modeled as joint-product firm. Generally apple
orchards do not exclusively produce for fresh or
 the processed utilization. In this way they differ
from other fruit and vegetable production pro-
cesses, for example tomato production, where
 firms grow tomatoes either for fresh consump-
tion or for processed consumption but not for
both (Davis et al. ). The fresh market for apples
 pays a considerable premium and a denomination
of quality is modeled as a binary in the share of
 fruit allocated to the fresh market. The mar-
ginal welfare analysis suggested by Lichtenberg,
Putler, 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 ap-
proximated 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 regional-
ized, 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 \( \lambda \).
Some groups of growers do not use the pesticide
in question, and their technology is independent
of \( \lambda \).

More specifically, producers are grouped into
 sets of users and non-users of a pesticide in five
 distinction production regions. The groups are or-
dered such that \( j = 1, \ldots, k \) identify the pro-
ducers who are affected by a change in tech-
nology \( \lambda \), and \( j = k + 1, \ldots, J \) denote the
producers groups that are not affected by the
change. Let \( P_U \) denote prices and let \( Q \) signify
quantities, where subscript \( j \) identifies region and
superscript \( UR \) of \( P \) signifies fresh and
processed, respectively. The equilibrium in the
markets is described by the following set of
equations:

\[
\begin{align*}
\text{(1.1) Supply User:} & \quad P_U = MC_i(Q^U), \quad Q^U = \sum_i Q_i, \\
\text{(1.2) Supply Non-User:} & \quad P_N = MC_i(Q^N), \\
\text{(1.3) Regional Pricing:} & \quad P_i = (P_U, P_N), \\
\text{(1.4) Demand:} & \quad D_i(P_i, \lambda) = P_i, \\
\text{(1.5) Net Imports:} & \quad Q_I = MC_i(\sum_i Q_i, P^I), \\
\text{(1.6) Market Clearing:} & \quad \sum_i Q_I = Q_I = P_i, \quad P_i.
\end{align*}
\]

Equation (1.1) represents the supply func-
tion for pesticide users and equation (1.2) is
the supply function for non-users. The mar-

ginal-cost functions (MC) reflect the multi-
product nature of production and depend on pro-
duction to the fresh (Q^F) and processing sector (Q^P). 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. \( P \) is the U.S. level price and so demand is mod-
eled 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 (Roos-
en). Therefore dependence in the consumption of fresh and processed apples is not considered in the demand function. The demand functions are parameterized by \( \lambda \) 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. de-
mand via regional pricing equations presented by \( h(P) \) in equation (1.3). Net imports (Q^N) are modeled in equation (1.5) and the last equation (1.6) imposes the market clearing 
conditions.

Totally differentiating this system, we de-
rive the equilibrium impacts of a change in technology (the loss of a pesticide) parame-
terized as a shift in \( \lambda \).

\[
\begin{align*}
(2.1a) \quad f^{\delta \lambda}_{\pi} & P^\lambda_\lambda + f^{\delta \lambda}_{\pi} P^\lambda_\lambda - dP^\lambda_\lambda = \frac{\partial MC^\lambda}{\partial \lambda}, \quad j = 1, \ldots, k, \\
(2.1b) \quad f^{\delta \lambda}_{\pi} P^\lambda_\lambda + f^{\delta \lambda}_{\pi} P^\lambda_\lambda - dP^\lambda_\lambda = \frac{\partial MC^\lambda}{\partial \lambda}, \quad j = 1, \ldots, k, \\
(2.2a) \quad f^{\delta \lambda}_{\pi} P^\lambda_\lambda + f^{\delta \lambda}_{\pi} P^\lambda_\lambda - dP^\lambda_\lambda = 0, \quad j = \kappa + 1, \ldots, l, \\
(2.2b) \quad f^{\delta \lambda}_{\pi} P^\lambda_\lambda + f^{\delta \lambda}_{\pi} P^\lambda_\lambda - dP^\lambda_\lambda = 0, \quad j = \kappa + 1, \ldots, l.
\end{align*}
\]

In system (2), \( f^\delta \) denotes the flexibility of the price of good K with respect to the quan-
tity of good L produced, where \( j \) indexes the region. The demand flexibilities are expressed as \( f^\delta, \quad i = Fs, \quad Pr \) for fresh and processed apples, respectively. For net imports \( c_{\text{imp}} \) and \( c_{\text{exp}} \) indicate the elasticities of net exports with respect to U.S. price level and U.S. production for the respective market \( k \). System (2) is equivalent to system (2) in Lichtenberg, Park-
et, and Zilberman, but for the cross-price flex-
ibilities. These enter the system to account for marginal cost changes of producing fresh (pro-
cessed) apples caused by changes in the pro-
duction 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, \( \lambda^\lambda \), can now shift the demand function as pre-

dented in (2.4). We use this shift to estimate the WTP premium necessary to neutralize the adverse surplus effects of a pesticide ban. Sys-
tem (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 as assum-
ing, as in Lichtenberg, Parket, and Zilber-
man, that shifts in supply curves can be ap-
proximated by linear shifts. This assumption
is suitable if shifts are relatively small which is an adequate assumption for the scenario consolidated 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 grower flexibility to substitute inputs once the orchard is planted is rather limited. In many instances the number of substituting pesticides available is small so that at the regional level it is a suitable approximation to assume that the marginal cost function of all costs in one regime shifts in a parallel manner.

To derive the welfare implications for producers we start from the profit maximizing problem of the grower who chooses the optimal quantities $Q^P$ and $Q^G$ according to

$$\max_{Q^P, Q^G} \pi_P = \Pi_P(Q^P) + \Pi_G(Q^G) - C(Q^P, Q^G; x).$$

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 solution of $Q^P$ and $Q^G$ are denoted as $Q^P_0$ and $Q^G_0$. Abstracting from fixed costs, producer surplus is defined as $S_P = \Pi_P(Q^P_0) + \Pi_G(Q^G_0) - C(Q^P_0, Q^G_0; x)$. Assuming that output $I$ is a necessary input, the change in producer surplus for the non-users of a pesticide is defined as

$$\Delta S_P = \int_{h_0}^{h_0} [\Pi_P(\cdot) + \Pi_G(Q^G_0) - MC_0(Q^G_0; x)] \left( \frac{\partial \Pi_P}{\partial h} \right) dh^P - \int_{h_0}^{h_0} MC_0(Q^G_0; x) \left( \frac{\partial \Pi_P}{\partial h} \right) dh^P - \int_{h_0}^{h_0} \left( \frac{\partial MC_0(Q^G_0; x)}{\partial h} \right) dh^P$$

for $i = 1, \ldots, k$.

Equivalence to (4) and (5), the changes in producer surplus can be calculated in each market separately employing the partial-equilibrium supply curves $Q^P(P); Q^G(P), i = Fr, Pr$. 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 realization of production and supply between the markets is an important aspect of this study, the latter approach was chosen.9

In the 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

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9 See discussion at Jasti, Muth, and Schmitz the two approaches and in general the approach in empirical applications. The approach taken has the advantage that the assumption of necessity of the markets 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 envi-
ronmental benefits. Therefore the demand func-
tions do not shift and the change in con-
sumer surplus can be described by the differ-
ence in the consumer surplus before and after a
change in pesticide availability. It is calcu-
lated as $-\partial Q_e^b/\partial Q_e + dQ_e/2$ 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 prefer-
ence for stricter pesticide regulation in the
market. Blend and von Ravenswaay, for ex-
ample, estimate the demand for ecabeled ap-
plies and, among those, apples produced under
reduced pesticide use. Using a telephone sur-
vey they found that 72.6 percent of their sam-
ple would buy ecabeled apples at a zero
price premium and that, at a $0.10 price pre-
mium, this purchase probability would de-
crease by only 9 percent. In a study on the
Alar crisis, von Ravenswaay and Hoehn esti-
imated 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 scenar-
ios 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 sig-
nificant and positive. Here we estimate the
WTP premia necessary to offset the negative
production effects of a pesticide cancellation.3

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 as-
sessed.

The WTP shift calculated here presents an aver-
age 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 rela-
tive to imports will change due to the change in pes-
cicide regulation. Would the consumer shift consump-
tion 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.

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 hu-
man 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 changes for the producer
groups $j = 1, 2, \ldots, k$. In system (1) we
suppose that a grower chooses the profit-max-
imizing level of production for the fresh and
processed market using the technology de-
scribed by the cost function $C(Q_f^b, Q_p^b; \lambda)$.
According to the profit-maximization problem
(3), the grower will choose the level of pro-
duction that equates the marginal cost of pro-
ducing 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, $Y_f$
and the optimal share of fruit going to the
fresh market, $a_f$, according to

\[
\max_{a_f, Y_f} \Psi(Y_f, a_f; \lambda) = \psi(Y_f, a_f) + \lambda \left[ a_f P_f^b (1 - a_f) P_p^b Y_f - \Psi(Y_f, a_f; \lambda) \right].
\]

We assume $\Psi(Y_f, a_f; \lambda)$ is the alterna-
tive cost function specification that equivalent to $C(Q_f^b, Q_p^b; \lambda)$ describes
the grower's available technology. We
assumne it to be convex in $Y_f$ and $a_f$. The
first-order conditions are stated as

\[
\Psi(Y_f, a_f; \lambda) = a_f P_f^b (1 - a_f) P_p^b Y_f. 
\]

Following Lichtenberg, Parker, and Zilber-
man, we approximate locally marginal costs of yield and fresh fruit by their average costs. Denoting \( W_y \) the per-acre cost of production, we set \( \Psi_y = W_y \) and \( \Psi_y = \frac{W_y}{y} \). The change in technology, \( \delta \), impacts all three technology parameters: cost of production, \( W_y \), yield, \( Y \), and fresh share, \( a \). Totally differentiating the marginal-cost function with respect to these changes yields the changes in marginal cost for fresh and for processed apples as
\[
\Delta W_y = \left( \frac{1}{a \Psi_y} + 1 - a \right) \Psi_y W_y \Delta \Psi_y
- \left( \frac{\Psi_y}{a \Psi_y} + 1 \right) \Delta \Psi_y\Delta Y
- \left( \frac{\Psi_y}{a \Psi_y} + 1 \right) \Delta \Psi_y\Delta a.
\]
The denominator in (9) corrects for the point of evaluation where 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, \( \Psi_y \), refers to the cost of producing apples per bush and processed consumption.

For fresh production, the term \( \left( 1 - a \Psi_y / Y \right) \) in (8.1) corrects these costs upward by the part that would otherwise be implied for processed production. If the share of crop allocated to the fresh market increases, this upward correction will be reduced. Similarly, the downward correction of the marginal cost of fresh yield, \( \Psi_y / Y \), becomes 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 billion annual value of production at the farm level (1996). Production is concentrated on the two seed-boards 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 $1.7 billion, from apple production. Midwest, Northeast, and Mid-Atlantic are relatively similar in their importance, each with annual revenue of about $150 million, and the Southeast is the smallest production region with $39 million revenue coming from apple production.

Change in Cost of Production, Yield, and Quality

Dorn and also Rosenberg 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 Agricultural Chemical Usage: Fruit Survey, while implementation scenarios have been estimated using expert surveys. These data permit the calculation of changes in the cost of production using a partial-biased approach. Pesticide prices are taken from USDA/NASS agricultural price statistics (1996 for herbicides, 1997 for fungicides). The application costs are estimated using updated estimates from enterprise budgets (Clarke and Burdick; Fass et al.; Homan et al.; Keeney and Schneller; Parker et al.; Pennsylvania Agricultural Extension Service; Vossen et al.) and the cost of applying herbicides.

1This study is included in the following analysis account for 75.6 percent of U.S. apple production. Happens in remaining states are negligible in the overall impact and can safely be ignored in this analysis.

2The price for a particular pesticide is not published, chemical supplies in different geographical regions were contacted by phone and asked for the price at which the product would typically be sold to apple growers. Answers were used for our analysis. We cross-checked prices published by USDA-NASS with prices elicited from chemical suppliers and found only minor differences.
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<td>152.7</td>
<td>35.4</td>
<td>5400.0</td>
<td>3900.0</td>
<td>1500.0</td>
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<td>14.4</td>
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<td>21.3</td>
<td>30.4</td>
<td>0.41</td>
<td>0.209</td>
</tr>
<tr>
<td>KY</td>
<td>3.1</td>
<td>2.4</td>
<td>5.4</td>
<td>13.0</td>
<td>8.6</td>
<td>4.4</td>
<td>0.66</td>
<td>0.294</td>
</tr>
<tr>
<td>GA</td>
<td>2.9</td>
<td>2.4</td>
<td>9.8</td>
<td>26.0</td>
<td>9.3</td>
<td>16.7</td>
<td>0.36</td>
<td>0.287</td>
</tr>
<tr>
<td>TN</td>
<td>2.6</td>
<td>1.6</td>
<td>7.7</td>
<td>12.3</td>
<td>9.6</td>
<td>2.7</td>
<td>0.78</td>
<td>0.248</td>
</tr>
<tr>
<td>South-East</td>
<td>38.5</td>
<td>19.3</td>
<td>17.8</td>
<td>343.0</td>
<td>320.8</td>
<td>222.2</td>
<td>0.35</td>
<td>0.186</td>
</tr>
</tbody>
</table>

1 Regional averages are employed if a price is not available.
2 Prices received for fresh or processed apples are not recorded in these states.

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 it 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, 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 Carlsson have shown that this can be the case with regard to insecticide choices where apple producers incorporate variable costs such as worker...
Table 2. Elasticities (calculated at mean)\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Short Run</th>
<th>Long Run</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Year 1)</td>
<td>(Year 5)</td>
</tr>
<tr>
<td><strong>Northwest</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresh Production</td>
<td>0.306</td>
<td>0.623</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>(0.229)</td>
<td>(0.318)</td>
</tr>
<tr>
<td>Processed Production</td>
<td>-0.059</td>
<td>-0.006</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>(0.140)</td>
<td>(0.126)</td>
</tr>
<tr>
<td><strong>Southwest</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresh Production</td>
<td>-0.220</td>
<td>0.237</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>(0.660)</td>
<td>(0.387)</td>
</tr>
<tr>
<td>Processed Production</td>
<td>0.229</td>
<td>0.372</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>(0.325)</td>
<td>(0.263)</td>
</tr>
<tr>
<td><strong>Central</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresh Production</td>
<td>0.346</td>
<td>0.540</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>(0.149)</td>
<td>(0.229)</td>
</tr>
<tr>
<td>Processed Production</td>
<td>-0.225</td>
<td>-0.085</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>(0.110)</td>
<td>(0.169)</td>
</tr>
<tr>
<td><strong>East</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresh Production</td>
<td>0.858</td>
<td>0.981</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>(0.319)</td>
<td>(0.425)</td>
</tr>
<tr>
<td>Processed Production</td>
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<td>-0.369</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>(0.112)</td>
<td>(0.116)</td>
</tr>
<tr>
<td><strong>Consumption</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Year 1)</td>
<td>(0.290)</td>
<td>(0.370)</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>(0.105)</td>
<td>(0.108)</td>
</tr>
<tr>
<td><strong>Import</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Year 1)</td>
<td>0.638</td>
<td>0.708</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>(0.204)</td>
<td>(0.213)</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>-1.162</td>
<td>-0.157</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>(0.045)</td>
<td>(0.048)</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>0.465</td>
<td>-0.288</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>(0.132)</td>
<td>(0.249)</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>0.133</td>
<td>0.180</td>
</tr>
<tr>
<td>(Year 1)</td>
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<tr>
<td>(Year 1)</td>
<td>-0.374</td>
<td>-0.374</td>
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<tr>
<td>(Year 1)</td>
<td>(24.370)</td>
<td>(24.370)</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>-0.791</td>
<td>-0.791</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>(3.034)</td>
<td>(3.053)</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>-0.699</td>
<td>-0.479</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>(1.702)</td>
<td>(1.702)</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>-0.791</td>
<td>-0.791</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>(2.134)</td>
<td>(2.134)</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>-3.276</td>
<td>-3.276</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>(2.482)</td>
<td>(2.482)</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>-3.193</td>
<td>-3.193</td>
</tr>
<tr>
<td>(Year 1)</td>
<td>(45.557)</td>
<td>(45.557)</td>
</tr>
</tbody>
</table>

\(^a\) Numbers in parentheses report standard errors.

Elasticity Estimates and Market Data

Regional supply elasticities are estimated together with demand elasticities and import responses in an econometric model (Reference). 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 Willcox's 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 in the means of the data.

We report the resulting estimates in Table 2. A nonparametric bootstrapping method of 1,000 iterations was used to determine the statistical significance of the elasticity estimates and standard errors are reported in parentheses.

Safety or environmental benefits from their insecticide choice.\(^a\)

The problem with this approach is that such benefits might be large or they might also vary to a prohibitive for the marginal cost 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 gain 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 adjust by reallocating production between the fresh and processing sectors 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. 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 apple 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 inhibitors (PSIs). Fungicides are used to stave off 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 Etab fungicides. Human health concerns exist in particular for metiram and mancozeb, which belong to the group of ethylene-bis dithiocarbamate (EBDC). These breaks down to thioarsenic, a suspected carcinogen. Thioarei breaks down and

---

* Elasticities 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

<table>
<thead>
<tr>
<th></th>
<th>Acreage Treated Percent</th>
<th>Change in Cost ($/Acre)</th>
<th>Change in Yield Percent</th>
<th>Change in Fresh Shave Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Captain + Mancozeb + Metiram</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>31.2</td>
<td>6.4</td>
<td>0.0</td>
<td>−0.4</td>
</tr>
<tr>
<td>Midwest</td>
<td>100.0</td>
<td>76.8</td>
<td>0.0</td>
<td>−4.4</td>
</tr>
<tr>
<td>Northeast</td>
<td>100.0</td>
<td>57.9</td>
<td>0.0</td>
<td>−5.0</td>
</tr>
<tr>
<td>M-Atlantic</td>
<td>100.0</td>
<td>14.0</td>
<td>0.0</td>
<td>−5.6</td>
</tr>
<tr>
<td>Southeast</td>
<td>100.0</td>
<td>49.2</td>
<td>−2.5</td>
<td>−5.5</td>
</tr>
<tr>
<td>EBI-Fungicides</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>23.2</td>
<td>59.0</td>
<td>−3.2</td>
<td>−4.4</td>
</tr>
<tr>
<td>Midwest</td>
<td>50.5</td>
<td>30.1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Northeast</td>
<td>46.8</td>
<td>4.0</td>
<td>0.0</td>
<td>−0.3</td>
</tr>
<tr>
<td>M-Atlantic</td>
<td>30.9</td>
<td>11.4</td>
<td>−1.8</td>
<td>−2.6</td>
</tr>
<tr>
<td>Southeast</td>
<td>57.8</td>
<td>−12.7</td>
<td>−1.4</td>
<td>−1.3</td>
</tr>
<tr>
<td>Glyphosate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>64.8</td>
<td>6.8</td>
<td>−0.3</td>
<td>−8.9</td>
</tr>
<tr>
<td>Midwest</td>
<td>34.5</td>
<td>1.3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Northeast</td>
<td>40.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>M-Atlantic</td>
<td>17.1</td>
<td>4.9</td>
<td>−0.6</td>
<td>0.0</td>
</tr>
<tr>
<td>Southeast</td>
<td>85.0</td>
<td>9.5</td>
<td>−3.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Simatezine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>41.9</td>
<td>7.5</td>
<td>0.0</td>
<td>−9.3</td>
</tr>
<tr>
<td>Midwest</td>
<td>32.9</td>
<td>7.4</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Northeast</td>
<td>40.0</td>
<td>7.3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>M-Atlantic</td>
<td>35.3</td>
<td>4.5</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Southeast</td>
<td>40.0</td>
<td>0.4</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

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

The EBI fungicides are a group comprised of fenameto, myclobutanil, and triflumuron. 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 oftensuggested alternative parquat 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 Year on Captan, Metiram, and Mancozeb, in $ 000

<table>
<thead>
<tr>
<th></th>
<th>Fresh Apples</th>
<th>Processed Apples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>User</td>
</tr>
<tr>
<td></td>
<td>000 $</td>
<td>Non-User</td>
</tr>
<tr>
<td>West</td>
<td>840.0</td>
<td>970.7</td>
</tr>
<tr>
<td>Midwest</td>
<td>-35.9</td>
<td>11.7</td>
</tr>
<tr>
<td>Northeast</td>
<td>-974.3</td>
<td>-888.1</td>
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<tr>
<td>M-Atlantic</td>
<td>-413.0</td>
<td>-350.6</td>
</tr>
<tr>
<td>Southeast</td>
<td>-210.3</td>
<td>-180.4</td>
</tr>
<tr>
<td>South</td>
<td>-793.6</td>
<td>-538.9</td>
</tr>
<tr>
<td>East</td>
<td>-1631.4</td>
<td>-1516.5</td>
</tr>
<tr>
<td>Total</td>
<td>-2425.0</td>
<td>-2053.3</td>
</tr>
</tbody>
</table>

Results

Table 3 shows the direct production impacts for all four scenarios. The second column gives the percentage of apple acreage planted 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 carbohydrates, captan, metiram and mancozeb, Table 3 shows that large impacts are expected in the southeastern United States and in the West. The cost of production change only little and overall these fungicides are not widely used. Raising economic surplus changes are presented in Table 4 and all users except those in the West incur losses. There even arises benefits from the shortened supply for fresh apples, so that price increases outweigh the upward shift in costs and producer surplus increases.

Given the premiums 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 largest share of the cost. This result from the relativelyelastic demand for fresh apples (0.37) and the more inelastic 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 Barbado.

In our case not only the elasticities of demand are important in determining this effect; the responsiveness of net imports to price and some production changes is also consequential. The change in net imports depends on changes in 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 million, i.e., in the fresh market and by 2.9 million, i.e., 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 million in the fresh market and $9.4 million 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 non-negativity 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 condition on profit maximization requires that \(\frac{\partial^2 \pi}{\partial Q^2} - \frac{\partial^3 \pi}{\partial Q^3} \geq 0\) which is equivalent to \(\frac{\pi_{\text{emp}}}{\pi_{\text{gen}}} \geq 1\) given the assumption that \(\pi_{\text{emp}} \geq \pi_{\text{gen}}\). This condition can be approximated by \(\frac{\partial P}{\partial Q}\). 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 million, 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 theoretical 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.

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 Kerr 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

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<table>
<thead>
<tr>
<th>Region</th>
<th>Lower 5% Mean</th>
<th>Upper 5% Mean</th>
<th>Percent</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>West</td>
<td>840.0</td>
<td>319.0</td>
<td>4,392.0</td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>-35.9</td>
<td>-1,416.0</td>
<td>1,187.3</td>
<td></td>
</tr>
<tr>
<td>Northeast</td>
<td>-974.3</td>
<td>-1,560.9</td>
<td>375.1</td>
<td></td>
</tr>
<tr>
<td>M-Atlantic</td>
<td>-413.0</td>
<td>-593.8</td>
<td>402.6</td>
<td></td>
</tr>
<tr>
<td>Southeast</td>
<td>-210.3</td>
<td>-328.8</td>
<td>128.7</td>
<td></td>
</tr>
<tr>
<td>Prod.</td>
<td>-793.6</td>
<td>-2,266.4</td>
<td>521.9</td>
<td></td>
</tr>
<tr>
<td>Cons.</td>
<td>-1,631.4</td>
<td>-11,592.7</td>
<td>494.3</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>-2,425.0</td>
<td>-6,622.1</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>

The result can be obtained by noting that the system of flexibilities equals the inverse of the system of elasticities:

\[
\begin{align*}
\frac{\partial}{\partial Q} & \ln P = \frac{\partial}{\partial P} \ln Q = -\frac{1}{P} \\
\frac{\partial}{\partial P} & \ln Q = \frac{\partial}{\partial Q} \ln P = \frac{1}{Q} \\
\frac{\partial}{\partial Q} & \ln Q = \frac{\partial}{\partial P} \ln P = -\frac{1}{P} \\
\frac{\partial}{\partial P} & \ln P = \frac{\partial}{\partial Q} \ln Q = \frac{1}{Q}
\end{align*}
\]
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 become smaller.

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

For the EBIL 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 million, 57 percent of which occurs in the processed markets. Overall impacts result in an economic surplus loss of $4.4 million, half of which is borne by consumers. A WTP increase of 0.9 percent of market value in response to the cancellation of EBILs 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 million, most of which occur in the market for processed apples (Table 8). Impacts in other regions are compensated for by changes in the market environment.

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

<table>
<thead>
<tr>
<th></th>
<th>Froth Apples</th>
<th>Processed Apples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total $000</td>
<td>User $000</td>
</tr>
<tr>
<td></td>
<td>Non-User $000</td>
<td>Mill. Ib.</td>
</tr>
<tr>
<td>West</td>
<td>-2,163.7</td>
<td>-941.7</td>
</tr>
<tr>
<td>Midwest</td>
<td>52.9</td>
<td>-0.6</td>
</tr>
<tr>
<td>N-East</td>
<td>-64.6</td>
<td>-99.6</td>
</tr>
<tr>
<td>M-West</td>
<td>-46.1</td>
<td>-75.2</td>
</tr>
<tr>
<td>S-East</td>
<td>-5.3</td>
<td>-17.6</td>
</tr>
<tr>
<td>Prod.</td>
<td>-2,226.8</td>
<td>-1,534.6</td>
</tr>
<tr>
<td>Conn.</td>
<td>-2,180.7</td>
<td>-1,657.4</td>
</tr>
<tr>
<td>Total</td>
<td>-4,387.5</td>
<td>-2,792.0</td>
</tr>
</tbody>
</table>
Table 8. First-Year Economic Surplus Changes after a Ban on Glyphosate, in $ 000

<table>
<thead>
<tr>
<th></th>
<th>Fresh Apples</th>
<th>Processed Apples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total $</td>
<td>User $</td>
</tr>
<tr>
<td>West</td>
<td>-5,469.9</td>
<td>-2,006.3</td>
</tr>
<tr>
<td>Midwest</td>
<td>195.7</td>
<td>23.0</td>
</tr>
<tr>
<td>Northeast</td>
<td>228.5</td>
<td>0.0</td>
</tr>
<tr>
<td>M-Atlantic</td>
<td>165.4</td>
<td>35.8</td>
</tr>
<tr>
<td>Southeast</td>
<td>-26.8</td>
<td>-59.9</td>
</tr>
<tr>
<td>Prod.</td>
<td>-4,907.1</td>
<td>-1,867.5</td>
</tr>
<tr>
<td>Cons.</td>
<td>-4,104.6</td>
<td>-2,758.9</td>
</tr>
<tr>
<td>Total</td>
<td>-9,011.6</td>
<td>-4,726.4</td>
</tr>
</tbody>
</table>

ment, i.e., by price increases. Consumers would suffer large losses especially in the fresh market. Total losses amount to $9.0 million. 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 million. (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 million. 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 from $2.4 million and $9.0 million. In terms of value of production, losses in the order of 0.2 percent to 0.6 percent would be experienced. While these seen rather small, they are well within the range of impacts found by other empirical studies of single pesticide cancellations such as Bushy 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 var 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 Yoeck have estimated the WTP to avoid Alar in apples at up to 35 percent. Also Roso-

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

<table>
<thead>
<tr>
<th></th>
<th>Fresh Apples</th>
<th>Processed Apples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total $</td>
<td>User $</td>
</tr>
<tr>
<td>West</td>
<td>-4,607.4</td>
<td>-2,454.5</td>
</tr>
<tr>
<td>Midwest</td>
<td>133.5</td>
<td>25.8</td>
</tr>
<tr>
<td>Northeast</td>
<td>166.4</td>
<td>81.1</td>
</tr>
<tr>
<td>M-Atlantic</td>
<td>119.5</td>
<td>38.2</td>
</tr>
<tr>
<td>Southeast</td>
<td>-48.1</td>
<td>18.7</td>
</tr>
<tr>
<td>Prod.</td>
<td>-4,140.0</td>
<td>-2,290.6</td>
</tr>
<tr>
<td>Cons.</td>
<td>-3,357.0</td>
<td>-2,516.8</td>
</tr>
<tr>
<td>Total</td>
<td>-7,497.0</td>
<td>-4,807.3</td>
</tr>
</tbody>
</table>
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 a pesticide 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 assessing 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 in yields but 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 in one or all of the pesticide regimens in those regions are offset by gains accruing to non-users. In particular, a reduction in the supply from western states can have large impacts on prices and hence benefit 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 effects of stricter pesticide regulations. We estimated the minimum WTP premia necessary to make each cancellation scenario welfare improving. These values vary between 0.5 and 3.9 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, which is particular true if the improved environmental quality of a product can not be disassociated in the market through effective labeling policies. If exports or importers 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 substitution is reduced by only a fraction of production losses. Our analysis indicates that to the long-term regional and international distribution effects could become more important the disadvantage of regions that are far more 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.

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