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By

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ECONOMIC IMPACTS OF THE ELIMINATION OF AZINPHOS-METHYL ON THE APPLE INDUSTRY AND WASHINGTON STATE*

Andrew J. Cassey, Suzette P. Galinato, and Justin Taylor†

Abstract

The Environmental Protection Agency has declared the organophosphate pesticide azinphos-methyl (AZM) cannot be used in the production of apples after September 30, 2012. We estimate the change to sales, price, and employment to the Washington State apple industry from using the likely AZM alternative had this ban been in effect in 2007. Furthermore, we estimate the effects of this ban as it ripples through the overall Washington State economy. We find the ban will bring a relatively modest change to sales (-0.8%), prices (0.2%), and employment (0.1%) in the apple industry, with negligible impacts on the overall Washington State economy.

Key Words: apples, azinphos-methyl, economic impact, computable general equilibrium

JEL Classification: C68, D58, Q18, Q52, R11

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I. Introduction

The U.S Environmental Protection Agency (EPA) has mandated the nationwide elimination of the pesticide Azinphos-methyl, also known as AZM or Guthion, by September 30, 2012 (Federal Register 2009; EPA 2009). AZM belongs to the organophosphate (OP) class of pesticides and since the late 1960s, it has been the most used pesticide by apple growers in Washington State (Brunner et al. 2007). As of 2008, 80% of Washington apple growers used AZM (Washington State University 2010), primarily as a control for codling moth, the leading pest in Western apple orchards. (See appendix table 1 for historical AZM usage in Washington.)

The EPA's mandate is the result of concerns about the risks of OPs to the health of farm workers and the quality of local water and aquatic ecosystems. Details about the toxicity of AZM and other supporting data that guided the agency's decision are provided in the EPA's Ecological Risk Assessment (EPA OPPT 2005) and Organophosphorus Cumulative Risk Assessment (EPA OPP 2006).

Because most growers are expected to shift to an AZM-alternative Integrated Pest Management (IPM) strategy rather than relying solely on non-chemical methods or quitting production (Brunner 2009), the EPA regulation challenges the apple industry to control the codling moth while transitioning to a combination of safer, AZM-alternative pesticides.[1] Though an AZM-alternative IPM program is more worker- and environmentally-friendly, it requires different timing and more precise spray applications than AZM. Furthermore an additional spray of new pesticides is required to maintain yield and quality since the alternative pesticides do not

[1] Integrated Pest Management is an encompassing phrase describing a combination of mating disruption, field monitoring for targeted pesticide use, and new pesticides to protect against pests. It is endorsed by the Washington State University Tree Fruit Research & Extension Center (n.d.). Many growers already use an OP-based IPM program and need to switch to an OP-alternative IPM scheme (Brunner 2009). Details of various alternatives to AZM can be found in Brunner *et al.* (2007), but the most likely alternative includes (among others) the OP-alternative pesticides Altacor (chlorantraniliprole) and Delegate (spinetoram).

have as long-lasting residues (Brunner 2009). Therefore the alternative codling moth treatment is more costly per acre than using AZM because both the unit price and the quantity needed increases.

We estimate the economy-wide impact of eliminating AZM in favor of a new pest management alternative in apple production in Washington State. In particular, we estimate the change in sales (value of activity produced), prices, and employment for Washington's apple industry and for the Washington economy. We study Washington because it accounts for 58% of U.S. apple production in 2007 (USDA NASS 2009) and 65–75% of the fresh market (Pollack and Perez 2005). Furthermore, Washington is particularly vulnerable to the AZM ban because: (a) in 2007, AZM was used on 66% of Washington's apple bearing acres (USDA NASS 2008) and (b) apples are the leading agricultural commodity in Washington, with sales accounting for more than 70% of the market value of Washington's $2+ billion fruit industry (USDA NASS 2009).

We use a computable general equilibrium (CGE) model to estimate the impacts of the AZM ban on Washington's apple industry and other upstream and downstream economic sectors within the state. We estimate the increase in the per acre expenditure of switching to a non-AZM pesticide scheme that ensures the same volume and quality of apples produced as before. We consider the apple industry's response to this cost increase by allowing growers to change the amount of the various inputs (such as labor or pesticides) into production thus resulting in a change to output. The economic effects we study are changes to sales, prices, and employment for the apple industry, industries that supply inputs to the apple industry, industries using apples as an input, household income, and profit per acre of Washington apples. Unlike other methodologies, CGE analysis accounts for inter-sector relationships and price changes.

We estimate that the ban has a relatively modest negative impact on the Washington State economy. We find a change in apple sales of -0.8%, price of 0.2%, and employment of 0.1%. This results in a decrease of $16 million in profit for the Washington apple industry, or $101 per acre. Other impacted industries experience relatively small changes to sales, price, and employment as well. Taken as a whole, if the AZM ban had been in place in 2007, the Washington economy would have had 0.003% less sales and 0.001% more employment leading to an overall $2.3 million decrease in Gross State Product. These findings suggest that the AZM ban, though not pleasant for the apple industry, will not be dire, and will not have large consequences for Washington.

Previous research on the economic consequences of an AZM ban does not use CGE analysis and does not consider the larger economic impacts. Williams and Hinman (1999) use an enterprise budget to estimate the profitability of producing Red Delicious apples in Washington under conventional practices and when OPs are eliminated from the insect control program. The study estimates a 320% decline in the grower's profit if either all OPs are eliminated or all but one OP is eliminated. The large decline in estimated profits is due to a higher cost of orchard maintenance, increased insect damage, and losses in yield and quality. However, the Williams and Hinman study does not consider the possibility that growers will switch to other non-OP pesticides, and it does not consider the wider economic impacts.

As part of the discussion to eliminate AZM in agricultural production, the EPA conducted an economic assessment of the AZM ban on apple growers (EPA BEAD 2005). Their analysis gives cost estimates for the elimination of AZM separately for the Eastern and Western regions of the United States. The study estimates the impacts on growers by comparing the net revenues (total revenue minus operating cost) of the current practice of using AZM to the estimated net revenues of three alternative pest management scenarios. For the Western U.S. region, the EPA estimates the net revenues of growers currently using AZM will decline between \$8.7 and \$50.1 million, a 4–23% reduction in profit. While these estimates put into perspective the potential economic consequences of eliminating AZM, the analysis does not necessarily reflect the impacts on Washington growers specifically, and the range of impacts is large. Brunner (2006) criticizes these results for not using realistic costs to implement AZM-alternative pesticides. Furthermore, these results do not capture the economic significance of the ban as it ripples through the larger Washington economy.

II. Computable General Equilibrium Modeling and Methodology

CGE modeling is a general strategy to estimate macroeconomic impacts. It is widely used to study impacts from topics as diverse as implementing or removing agricultural subsidies and production incentives (e.g., Doroodian and Boyd 1999; Razack et al. 2009), trade restrictions and liberalizations (e.g., Philippidis and Hubbard 2005; Burfischer et al. 2002; Mai 2008), and environmental standards (e.g., Rendleman et al. 1995; Cassells and Meister 2001). Kehoe and Kehoe (1994) give a relatively simple introduction to the theory of CGE analysis as well testing—and passing—the reliability of this methodology.

Zilberman et al. (1991) use general equilibrium techniques to examine the ban of certain pesticides on selected fruits, vegetables, and field crops in California.[2] The study indicated that the availability of effective substitutes is important to mitigate the effects of a ban (along with research and development and supply and trade conditions). Their findings support our choice to

[2] Ethyl parathion is an example. All registered uses of products containing ethyl parathion were cancelled on October 31, 2003(Federal Register 2005).

explicitly consider other pesticides in the alternative scenario instead of pesticide-free management.

Model Development

We model the reactions of the economy in two alternative scenarios. The 2007 base case or benchmark is where AZM is used as the predominant insecticide to control codling moth in Washington apple production. As the benchmark is the primary production practice in 2007, we use actual 2007 data without modification. The second scenario is the counterfactual in which there is a complete AZM ban in 2007.

The CGE model consists of equations describing the relationships between subsectors in the economy, elasticities describing the behavior changes in response to a shock to the economy, and a Social Accounting Matrix (SAM). A SAM is data on the actual flows of economic transactions in the economy under study for a single year. We first calibrate the model to find the parameters needed for the model data to perfectly replicate the actual 2007 data. Then we apply these calibrated parameters to the counterfactual to estimate what would have happened if AZM were banned in 2007. The results from the CGE model will be the estimated percent difference in economic variables such as sales, price, and employment from the actual 2007 economic data and that estimated by the model in the counterfactual.

Our model is a modification of the Washington State CGE developed by Holland, Devadoss, and Stodick (n.d.), which is an enhancement of Löfgren et al. (2002). Given prices, endowments, and technology, producers maximize profit and consumers maximize utility. Labor is mobile across activities, but capital is specific and fixed. Supply is perfectly elastic and foreign savings are variable. We use Walrasian competitive equilibrium, including the government and a foreign sector, as our solution concept. All markets, except possibly the labor market, clear in equilibrium. Numerically, the model is constructed using GAMS software and calibrated with the PATH solver.

The first step to constructing the CGE model is to convert data from an input-output table to a SAM. A SAM is similar to an input-output table but contains additional information on the interrelations between production accounts and consumption, government, investment, and other accounts. An example of this additional information is the ownership of factors of production. The advantage of using a CGE model over an input-output model is the CGE model's ability to incorporate price changes into its estimates on the impact to the economy.

Our construction of the SAM from the IMPLAN data is straightforward using the IMPLAN software (MIG, Inc. 2004). Data on the interactions between the 440 sectors of the Washington State economy are obtained from the IMPLAN database (see *Data Sources* in the appendix) and aggregated into 23 sectors. This reduction in sectors is done for computational reasons. We do not aggregate the upstream and downstream sectors of the apple industry in order to study them in detail. Thus our sectors include (but are not limited to) Fruit, Pest Management, Nursery, Electricity, Utilities, Wholesale, Frozen, Can Dry, Other Food, and Transportation (see figure 1).

The second step is to separate the apple industry from the fruit sector. IMPLAN data comes at the sector level, so in order to model the apple industry specifically, we split the fruit sector with 71.5% to *apples* and the remaining to a separate *other fruit* industry (USDA NASS (2009). Also, we need the production costs for the apple industry. We use the Washington apple enterprise budget from Mon and Holland (2006) for this information (appendix table 4). We assume the AZM ban affects only the growers using AZM in 2007, so we scale the industry production costs to account for the fact that only two-thirds of apple producing acres used AZM.[3]

The SAM gives us a baseline and corresponds to the 2007 benchmark. We impose a change to the model replicating the change to the apply industry from the AZM ban and then trace the simulated impact on the apple industry, the industries that supply the apple industry, and the effect on households and other industries in that economy. Figure 1 illustrates the supply chain of the apple industry. We highlight the chemicals or agricultural pesticides in the figure since these are the inputs exogenously modified in our alternative IPM scenarios.

Assumptions

We look at the economic impact of the AZM ban in apple production in comparison to the next best alternative insecticides and management systems. Based on Brunner et al. (2007), we assume that the next best alternative is an IPM program using an assortment of new AZM-alternative insecticides. Though not all of the new pesticides expected to replace AZM were available in 2007, the counterfactual assumes that these alternatives were available. We estimate what the per acre cost of using these alternative pesticides would have been if they were available in 2007 in order to maintain the same volume and quality. Then we enter the increase in cost (as the percent difference from actual 2007 costs) into the model by decreasing the technical coefficient of pesticides for apple production. This forces the apple industry to react to a situation where the effectiveness of per unit pesticide is less than before by choosing different levels of production inputs such as labor or pesticides, resulting in changes to apple output. Because the increase in the per acre pesticide expenditure to maintain previous yield and quality is not the same as the technical coefficient (which is independent of price), we make an

[3] GAMS code for the model is available in the online appendix at http://www.ses.wsu.edu/People/faculty/Cassey/Webpage/.

assumption on how pesticide expenditure relates to pesticide productivity (apple yield per unit of pesticide).

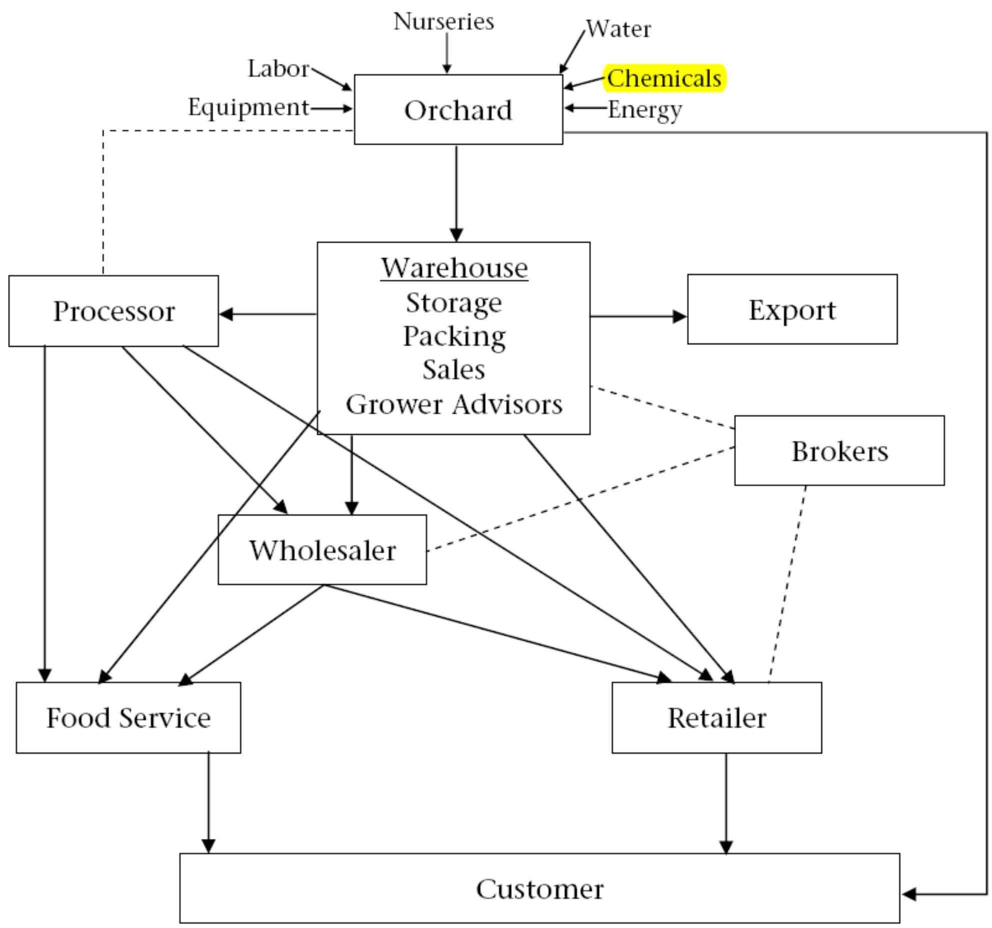

Figure 1. Supply chain of the Washington apple industry.

Source: Reprinted from Schotzko and Granatstein (2004), page 27, except for our highlighting.

We decrease the technical coefficient on pesticides in the apple activity by the same amount we calculate to be the increase in pesticide expenditures needed to maintain yield and quality. This assumption errs on the high side—in reality the decrease to the technical coefficient will be less than the increase in expenditure—because both the price and quantity of the AZM-alternative pesticides increases compared to AZM in the expenditure calculation. But the change to the technical coefficient is, by definition, the change in yield from using the same amount of the alternative management scheme. Thus the change to the technical coefficient must be a quantity change only and so can be no greater than the expenditure change (%Δ Expenditure = %Δ Price + %Δ Quantity). We do not have enough information to identify this quantity change separately from expenditure. Therefore we use our expenditure estimate for our technical coefficient knowing the resulting economic impact estimate will be an upper bound.

Because our pesticide expenditure estimate is based on the cost needed to maintain the yield and quality of the apple crop at the benchmark level, we assume that there will be no economic impacts from loss in quality. All impacts come from extra costs associated with increased prices and quantities for the new OP-alternative pesticides and correct spray and timing issues that are included in our budget estimates. Our costs for the counterfactual include an additional spray application and its associated use of extra chemicals, labor hours, and tractor use. Though non-AZM IPM programs require precise timing of applications that can take time for the grower to learn, our counterfactual assumes that growers have already learned the best application methods.

We assume that there are no differences in the costs of monitoring between the AZM-based IPM and the AZM-alternative IPM. AZM-alternative IPM requires more precise spraying and timing of applications than the conventional scheme. Most growers, however, use a pesticide consultant to organize their pesticide use. In most cases of switching away from AZM, the service of the pesticide consultant is provided by the pesticide distributor, without additional charge, conditional on the grower using pesticides from the manufacturer (Brunner 2009). Thus we assume any additional costs due to more precise monitoring and application procedures using the new pesticides are either explicitly given in the quoted price of the pesticide or are captured in the number of spray applications.

Finally, it is not apparent now whether the use of new pesticides will result in more or less labor costs on net. The more rigorous application that the new pesticides require to be effective increases labor costs. But workers can return to the crop one day after spraying compared to 14 days for AZM. This enhanced worker flexibility likely decreases labor costs. We settle on no change to labor efficiency in the apple industry, though we do a robustness check in the appendix.

Rather than project the accumulated costs of switching from AZM to the next best alternative from the phase-out period (2007 to 2012) and onwards, we estimate the economic impacts if AZM could not be used in 2007. We assume the next best alternative to be an AZM-alternative IPM using an assortment of new pesticides that are safer but costlier. Though other OPs such as Lorsban (chlorpyrifos), Dianizon, and Imidan (phosmet) are legal as of this writing, increased EPA scrutiny leads us to predict all OP usage will be curtailed in the future. Therefore we do not consider switching from AZM to another OP to be a realistic option.[4] We assume that the Washington apple growing industry reacts to the AZM ban by choosing the amount of alternative pesticide and other inputs to production given the decrease in the technical coefficient. Finally, we assume that no foreign countries prevent the importation of Washington apples due to the alternative pesticide despite 30% of Washington orchard owners and managers fearing such a ban (Washington State University 2010). Any substantial international restrictions put in place for the AZM-alternative pesticides will increase the economic impacts beyond what we estimate.

[4] As of this writing, Lorsban is restricted to use before bloom in the spring, when codling moth are not active. Diazinon is not effective against codling moth. Imidan is therefore the only OP-based alternative that could be used for codling moth control.

Though AZM is a pesticide used to control codling moth, the ban will affect apple growers' control of other pests, such as the leafroller, to some degree. Therefore, there will be changes to the percent of acres sprayed with other pesticides. We account for changes to the use of other pesticides as a result of the AZM ban.

Our economic impact estimate does not include economic changes from a healthier work force and healthier communities or changes to income or employment from the end of sales of AZM (produced by Bayer CropScience, Gowan Co., and Makhteshim Agan) and their replacement by alternatives. Also we do not consider the additional costs facing the American consumer from potential increased apple prices. Finally we do not consider any impact from either the State government or Federal government-provided education programs to inform apple growers about the ban and how to effectively manage it.

Costs of Pest Management

The insect management program costs are one piece of the total production costs of apples obtained from the enterprise budget of Mon and Holland (2006). In the 2007 benchmark, 66% of apple producing acres used AZM along with pheromones for mating disruption and the pesticides Intrepid and Rimon to make up an IPM program. There is no one-for-one replacement for AZM, so in the 2007 counterfactual, three pesticides—Delegate, Altacor, and Assail—substitute for AZM. The use of pheromones and chemicals for other pests like mites, leafrollers, and aphids are the same across the two cases, though the acres sprayed change.

Table 1 gives the projected costs of an insect control program in 2007 for the two scenarios. *Input cost per acre* is the quoted purchaser price of the pesticide times the number of sprays times the percent of acres sprayed. *Application cost per acre* is the cost of the labor, fuel, and depreciation to spray an acre once (assumed to be $30) times the number of sprays times the percent of acres sprayed. *Total cost per acre* is the sum of the input cost and application cost per acre. Brunner (2009) provides the costs for the pesticides and their use.

Table 1: 2007 Insect Control Program Costs, Benchmark (with AZM) and Counterfactual, $/acre

Compound	Trade Name	Benchmark			Counterfactual		
		Input	Application	Total	Input	Application	Total
Oil	Oil	20.40	25.50	45.90	20.40	25.50	45.90
Miticides	Miticides	12.00	6.00	18.00	12.00	6.00	18.00
azinphosmethyl	**AZM-Guthion**	**42.07**	**47.52**	**89.59**	**-**	**-**	**0.00**
phosmet	**Imidan**	**3.12**	**3.12**	**6.24**	**-**	**-**	**0.00**
methoxyfenozide	**Intrepid**	**7.78**	**5.61**	**13.39**	**18.30**	**13.20**	**31.50**
spinosad	**Success**	**31.23**	**16.38**	**47.61**	**-**	**-**	**0.00**
imidacloprid	**Provado**	**3.40**	**-**	**3.40**	**0.84**	**-**	**0.84**
novaluron	**Rimon**	**12.17**	**5.85**	**18.02**	**4.06**	**1.95**	**6.01**
chlorpyrifos	**Lorsban**	**12.29**	**-**	**12.29**	**7.68**	**-**	**7.68**
thiacloprid	Calypso	1.49	0.99	2.48	1.49	0.99	2.48
Pheromones	Pheromones	78.40	21.00	99.40	78.40	21.00	99.40
diazinon	Diazinon	2.10	2.97	5.07	2.10	2.97	5.07
AZM alternatives:							
rynaxypyr	Altacor	-	-	-	53.78	30.00	83.78
spinetoram	Delegate	-	-	-	67.12	36.00	103.12
acetampirid	**Assail**	**39.75**	**23.46**	**63.21**	**30.50**	**18.00**	**48.50**
	Total	*266.19*	*158.40*	*424.59*	*296.65*	*155.61*	*452.26*

Sources: USDA NASS (2008); Brunner (2009).

Notes: See appendix tables 2–3 for more details and sources. Changes from the benchmark to the counterfactual appear in bold. Numbers are rounded to nearest hundredth. Total cost per acre is the sum of input cost per acre based on the price of the pesticide times the number of sprays times the percent of acres sprayed and the application cost per acre which is the cost of the labor, fuel, and depreciation to spray an acre once (assumed to be $30) times the number of sprays times the percent of acres sprayed.

The total cost of the insecticide program is $425 per acre when AZM is used to control codling moth compared to $452/acre when AZM alternatives are used. Thus we estimate a 6.5% increase in the cost of pesticides—and therefore a 6.5% decrease in the technical coefficient of pesticides in the apple activity—in the counterfactual.[5] The per acre cost in the counterfactual is greater because the non-AZM pesticides are more expensive per acre and an additional spray is required to match the protection of AZM (from 1.58 applications of AZM per acre to 2.80 applications of AZM alternatives per acre).[6] Provado and Lorsban do not have application costs because we assume these pesticides are always mixed with other pesticides. Note that these budgets include the cost of controlling other insects. The cost of codling moth control alone is $211/acre (AZM + phosmet + pheromones + half sprays of Intrepid and Rimon) in the benchmark and $354/acre (Delegate + Altacor + Assail + pheromones + half sprays of Intrepid and Rimon) in the counterfactual. The cost differences between the two scenarios are attributed not only to the cost of AZM and AZM alternatives but also to the resulting change in chemicals that control other pests.[7]

III. Results and Discussion

The results for sales, prices, and employment are listed in table 2. The benchmark is the 2007 data with AZM. The counterfactual is the model's estimates for what would have occurred in 2007 if AZM had been banned. The percent change = ((counterfactual – benchmark) / benchmark)*100.

Apples are the featured industry and so those results are given in the first row of table 2. We impacted the apple industry by decreasing the technical coefficient of pesticide in the

[5] By comparison, the loss in productivity from organic techniques is about 10% (Brunner 2009).
[6] We cannot calculate the decrease in the technical coefficient from per acre application counts because of the interaction of other pesticides in control.
[7] Chlorpyrifos – use of this product decreases due to other chemicals that control both leafrollers and codling moth (Altacor, Intrepid and Delegate). Methoxyfenozide – use increases for leafroller control because of the reduced use of Lorsban (chlorpyrifos); Spinosad – the product is replaced by Delegate (spinetoram) in the counterfactual; Imidacloprid – use decreases because Assail (acetampirid) provides control of aphids, which is the primary use of Provado (imidacloprid); and Novaluron – use declines due to concerns with disrupting pest mites. Thiaclorpid and acetamiprid are used for codling moth and aphids control.

production of apples by 6.5% reflecting the increase in the total cost per acre of pesticide in that industry. The model estimates that the change in apple sales would have been -0.8% or -$11.6 million. The corresponding price change to Washington consumers would have been an increase of 0.2% and a decrease in production by 0.8%. Employment in the apple industry is estimated to be 22 workers larger in the counterfactual. This is because the model is compensating for the decrease in pesticide efficiency by substituting more labor.

Though the AZM ban does affect the apple industry, the economic impact is relatively mild for apple industry sales, prices, and employment. Our findings are much less severe than those estimated by Williams and Hinman (1999) because those authors do not allow apple growers to switch to an alternative pesticide when AZM is banned. Because we do, the model's apple growers can choose to mitigate the damage done from loss in quality, an important consideration as shown by Zilberman et al. (1991). Our industry profit estimate, however, is within the lower range of the EPA (EPA BEAD 2005). We estimate that the aggregate Washington apple industry would have had $16 million less profit in 2007 if AZM had been banned, about $101 per ace, due to the increase in pesticide expenses and decrease in sales.

The rows immediately following apples are the horizontal industries: other fruit and other crops. Because the AZM ban will affect all crops and not just apples, we decrease the technical coefficient of pesticides in the *other fruit* industry by 0.55%. Otherwise the model responds to the AZM ban by increasing the production of other fruit to offset the decrease in apple sales. This is not a realistic scenario since AZM will not be allowed on other fruit or crops. The results show a slight increase in the consumer price of other fruit (0.203%), though unlike apples, there is also a slight increase in overall sales (0.038%). The *other crops* sector shows a slight increase in price, but with a very small increase in sales.

Table 2: Results for Sales, Employment, and Domestic Consumer Price

	SALES (VALUE OF ACTIVITY PRODUCED)			EMPLOYMENT			WASHINGTON CONSUMER PRICE
	Benchmark (Millions)	Counterfactual (Millions)	Percent Change (%)	Benchmark	Counterfactual	Percent Change (%)	Percent Change (%)
Apples	1545.96	1534.36	-0.751	15857	15879	0.139	0.203
Other Fruit	614.11	614.34	0.038	7811	7822	0.141	0.203
Other Crops	3599.81	3599.90	0.002	34523	24527	0.010	-0.006
Upstream Ind.							
Pest Management	100.69	100.35	-0.335	61	60	-0.764	-0.394
Nursery	401.18	401.19	0.002	3819	3819	0.004	-0.001
Electric	5916.96	5916.96	-0.004	21851	21850	-0.005	-0.002
Utilities	1644.18	1644.18	-0.004	2316	2316	-0.008	-0.001
Downstream Ind.							
Wholesale	25174.77	25174.28	-0.002	136000	136000	-0.002	-0.001
Frozen	990.43	989.73	-0.071	7277	7272	-0.077	0.015
Can Dry	2205.53	2204.91	-0.028	3447	3446	-0.055	0.006
Other Food	12088.83	12087.42	-0.012	28174	28169	-0.016	0.004
Transportation	16891.14	16890.92	-0.001	111000	111000	-0.001	-0.001
Other Sectors	476831.34	476829.16	-0.000	3511530	3511529	-0.000	—
Total	548004.93	547987.36	-0.003	3882668	3882689	0.001	—

Notes: Percent Change = ((Counterfactual – Benchmark) / Benchmark) * 100. Values are rounded. Sales = quantity of activity x price of activity and are the revenue received by the producer. Employment is the quantity demanded of labor by activity. Washington consumer price is the market demand price for the commodity produced and sold within Washington to consumers or intermediate producers and includes indirect taxes and transaction costs.

The next group is the upstream industries. Besides apples and other fruit, *pest management* is, not surprisingly, the sector most affected by the AZM ban. The increase in the cost of pesticides results in a decrease in total sales. Here too, the economic impact of the ban is relatively mild. Both the *electric* and *utility* sectors decrease slightly in sales because of the decrease in apple production. Since the change to apples is small, the change to these upstream industries is small also.

The downstream industries are also not much affected by the AZM ban. The downstream industry most impacted by the AZM ban is the *frozen* sector. But even here, sales are estimated to have been only $704,000 less in the counterfactual and resulting in six less employees. The remaining sectors were aggregated because of their weak economic connections with the apple industry. And the ban has negligible impact on them.

The overall Washington economy is not strongly affected by the AZM ban. This is because though the apple industry is large in the state economy, the small impact in the apple industry creates even smaller ripples to the upstream and downstream industries. We estimate that Washington would have had 21 more workers in employment if the AZM ban had been in effect in 2007 and overall state sales would have been 0.003% smaller. The fact that there are not large impacts to the overall economy is consistent with theoretical results on tax increases to specific intermediate inputs and sector-specific factor taxes (Sue Wang n.d.). We estimate the change to indirect taxes and state government revenue to be negligible.

Other estimates from our simulation of the AZM ban include that household income does not change appreciably and there is no macroeconomic change to wages. But we estimate a change in household consumption of apples by -0.122%. This is due to the slight, but nonetheless positive change in the price of apples. This reduction in apple consumption means there could be a very minor negative health consequence for consumers offsetting the health benefits to orchard workers and their families. This conjecture is, however outside of our formal model.

IV. Conclusion

Because of the size of the apple industry in Washington's economy, the EPA's ban on AZM could have resulted in large economic impacts to the apple industry, causing ripples through the upstream and downstream industries, and the overall economy. We use realistic prices for the likely AZM alternative IPM system to estimate the percent increase in expenditure for spraying an acre of apple orchard if the AZM ban had been in effect in Washington in 2007. We enter this cost estimate into a CGE model of the Washington economy by decreasing the technical coefficient of pesticides in the apple activity by 6.5%. Then we simulate the Washington economy in 2007 with the ban in effect. We estimate that though the apple industry would have had multimillion-dollar decreases in sales and profit, the direct impact of the ban is not large relative to the more than $1.5 billion size of the industry. Because the direct impact is small, the economic ripples through the general economy are also small. We estimate a negligible change to the sales and employment of Washington due to the AZM ban.

We use CGE methodology to assess the economic impacts of the AZM ban because we are interested in price changes and the inter-sector spillovers. There are, however, some limitations from this approach. First, we cannot assess the economic impact on any particular apple grower, demographic of grower, or geographic region of the state, only the industry overall. Second, because we use a CGE model, we cannot allow growers to quit production and use their land for other purposes as VanSickle and NaLampang (2002) do for the phase out of methylbromide. Thus we do not allow for the AZM ban to cause a shift in apple production away from Washington State. Because the ban is nationwide, we do not consider this a serious limitation. Third, we assume that the new AZM alternative IPM systems can be thought of as maintaining apple crop volume and quality at increased cost and decreased efficiency. Therefore we do not consider any economic impacts from a reduction in quality or yield beyond those embedded in our cost estimate. Fourth, we do not model the AZM ban in other U.S. apple producing states. If we were to do this, the impact on Washington would be smaller than we estimated since doing so would increase the price of apples from the rest of the United States (but not the rest of the world) and thereby decreasing consumers desire to substitute Washington apples for these other apples. Fifth, we are not able to estimate the long-term health consequences from workers being exposed to fewer OPs and Washington consumers eating fewer apples. Finally, we estimate the economic impact from the AZM ban for one year only, 2007. Therefore the economic impact to the apple industry and the Washington economy will be larger if considered over a period of years.

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Appendix

Historical AZM Usage in Washington

Appendix table 1. Azinphos-methyl Usage in Apples, Washington, 1991–1997.

Year	Area Applied (%)	Number of Applications	Rate per Application (lb/ac)	Rate per Crop-Year (lb/ac)	Total Applied (1,000 lbs)	Bearing Acreage (1,000 acres)
1991	90	2.8	0.88	2.44	345.0	157
1993	81	3.3	0.91	3.02	357.9	147
1995	94	3.3	0.99	3.30	474.4	153
1997	91	2.9	0.95	2.77	390.2	155
1999	78	2.3	0.96	2.31	309.3	172
2001	73	2.0	0.94	1.96	241.4	168
2003	78	2.2	1.01	2.29	289.2	162
2005	72	1.8	0.97	1.75	196.4	155
2007	66	2.4	0.96	2.27	236.3	158

Source: *Agricultural Chemical Usage—Fruits,* USDA NASS (1992–2008). For 2007 data see p. 28 and 50 of the 2008 edition.

Notes: The *area applied* is the percent of crop acres receiving one or more applications of AZM. Application rates refer to the average number of pounds of AZM applied to an acre of land. *Number of applications* is the average number of times a treated acre received AZM. *Rate per application* is the average number of pounds applied per acre in one application. *Rate per crop year* is the average number of pounds applied per acre counting multiple applications.

Data Sources

Washington fruit and apple data. We use USDA NASS (2009) *Agri-Facts* for Washington (http://www.nass.usda.gov/Statistics_by_State/Washington/Publications/Agri-facts/agri1jul.pdf) to calculate the ratio of the value of apple production to the total value of fruit production. We then apply this ratio to the value of production in the Washington fruit industry given by 2007 IMPLAN data (see next subsection). We use USDA NASS (2008) *Agricultural Chemical Usage 2007 Field Crops Summary* (http://usda.mannlib.cornell.edu/usda/nass/AgriChemUsFruits//2000s/2008/AgriChemUsFruits-05-21-2008.pdf) for apple bearing acres and pesticide and AZM use in Washington.

Input-Output data. We use a 2007 IMPLAN (**IM**pact analysis for **PLAN**ning) input-output table for the Washington State economy. IMPLAN data files are sold by the Minnesota IMPLAN Group, Inc (MIG). MIG compiles input-output data from a variety of sources, but mainly the U.S. Bureau of Economic Analysis, Bureau of Labor Statistics, Census Bureau, Department of Agriculture and Geological Survey. See http://implan.com/index.php?option=com_content&task=view&id=86&Itemid=57.

Insect control costs. The cost estimates of an insect control program with and without AZM are obtained from Brunner (2009) and shown in appendix tables 2–3. Costs include the prices of some new products registered and sold in 2008. The cost of the labor, fuel, and equipment depreciation associated with a one acre-application is thought to be $30 (though we increase this in a robustness check below). Other management costs such as pruning, fertilization, weed and disease control, and harvest are treated in the model as a constant between the benchmark and counterfactual.

Appendix table 2. Cost of insecticide, 2008 prices.

Chemical	$/unit	units/acre	$/acre
azinphosmethyl	0.83	32.0	26.56
Intrepid	2.60	16.0	41.60
Success	5.72	10.0	57.20
Provado 1.6F	2.10	4.0	8.40
Rimon	1.56	40.0	62.40
Pheromone	0.28	400.0	112.00
Lorsban 4E	0.30	64.0	19.20
Dianizon	5.30	4.0	21.20
Altacor	11.95	4.5	53.78
Delegate	7.99	7.0	55.93
Assail	14.95	3.4	50.83
Calypso	7.50	6.0	45.00
Imidan	6.00	5.0	30.00

Source: Brunner (2009).

Appendix table 3a. Insect Control Program Costs Using AZM for Codling Moth Control

Compound	Trade Name	Area Treated (%)	Number of Applications	Acre Applications	Insect Control Program Cost		
					Input ($/acre)	Application ($/acre)	Total ($/acre)
Oil	Oil	85	1.0	0.85	20.40	25.50	45.90
miticides	Miticides	20	1.0	0.20	12.00	6.00	18.00
azinphosmethyl	AZM-Guthion	66	2.4	1.58	42.07	47.52	89.59
acetamiprid	Assail	46	1.7	0.78	39.75	23.46	63.21
thiacloprid	Calypso	3	1.1	0.03	1.49	0.99	2.48
phosmet	Imidan	8	1.3	0.10	3.12	3.12	6.24
methoxyfenozide	Intrepid	17	1.1	0.19	7.78	5.61	13.39
spinosad	Success	39	1.4	0.55	31.23	16.38	47.61
imidacloprid	Provado	27	1.5	0.41	3.40	-	3.40
novaluron	Rimon	15	1.3	0.20	12.17	5.85	18.02
pheromones	Pheromones	70	1.0	0.70	78.40	21.00	99.40
chlorpyrifos	Lorsban	64	1.0	0.64	12.29		12.29
diazinon	Diazinon	9	1.1	0.10	2.10	2.97	5.07
			Total	*6.33*	*266.19*	*158.40*	*424.59*

Appendix table 3b. Insect Control Program Costs Using AZM alternatives for Codling Moth Control

Compound	Trade Name	Area Treated (%)	Number of Applications	Acre Applications	Insect Control Program Cost		
					Input ($/acre)	Application ($/acre)	Total ($/acre)
HMO	Oil	85	1.0	0.85	20.40	25.50	45.90
miticides	Miticides	20	1.0	0.20	12.00	6.00	18.00
rynaxypyr	Altacor	40	2.5	1.00	53.78	30.00	83.78
spinetoram	Delegate	40	3.0	1.20	67.12	36.00	103.12
acetamiprid	Assail	30	2.0	0.60	30.50	18.00	48.50
thiacloprid	Calypso	3	1.1	0.03	1.49	0.99	2.48
methoxyfenozide	Intrepid	40	1.1	0.44	18.30	13.20	31.50
imidacloprid	Provado	10	1.0	0.10	0.84	-	0.84
novaluron	Rimon	5	1.3	0.07	4.06	1.95	6.01
pheromones	pheromones	70	1.0	0.70	78.40	21.00	99.40
chlorpyrifos	Lorsban	40	1.0	0.40	7.68	-	7.68
diazinon	Diazinon	9	1.1	0.10	2.10	2.97	5.07
			Total	*5.69*	*296.65*	*155.61*	*452.26*

Sources: Data on percent area treated of oil, miticides and methoxyfenozide are from Brunner (2009); the rest are from the 2007 Agricultural Chemical Usage—Fruit Report (USDA NASS 2008).

Notes: Input cost = number of acre applications times the cost of input/insecticide per acre. See appendix table 2 for the price of insecticides. Application cost = $30 x acre application. Application cost specific to the pesticide is not given because it is assumed that it is mixed in the same tank with another product.

Washington Apple Enterprise Budget.

Appendix table 4. Apple Production Function in Input-Output Accounting Framework.

Sector Names	Apple Industry Output ($/acre)	Apple Industry Output, aggregated ($)[a]
Inputs		
Tape & twine	50.00	10,107,250.00
Fertilizer	48.91	9,886,911.95
Chemicals	670.40	135,508,008.00
Beehives	35.00	7,075,075.00
Pheromone dispensers	110.00	22,235,950.00
Custom hauling	187.50	37,902,187.50
Irrig/Electric charge	168.75	34,111,968.75
Equipment repair	227.74	46,036,502.30
Equipment fuel/lube	147.37	29,790,108.65
Total inputs	1,645.67	332,663,962.15
Value Added		
Employee compensation	1,403.59	283,728,700.55
Proprietary income[b]	166.52	33,661,185.40
Other property income[c]	666.08	134,664,741.60
Indirect business taxes	133.45	26,976,250.25
Total Value Added[d]	2,369.64	479,010,877.80
Total Industry Outlay[e]	4,015.31	811,674,839.95

Source: Reprinted from Mon and Holland (2006), page 137.

Notes: a – Assumed total apple acreage = 202,145; b – Incomes received by self-employed entrepreneurs. c – Earned by corporations rather than sole proprietors; d – Sum of employee compensation, other property income, proprietary income, and indirect business taxes; e – Sum of individual inter-industry input purchases and value added.

Robustness of Results

Because some of our assumptions have a degree of conjecture, we consider numerous *ad hoc* changes to the model to determine the extent to which these assumptions affect the results.

Changes to the cost of applying one spray on one acre. We assume that the cost of the labor, fuel, and depreciation to spray an acre once is $30 for both the benchmark and the counterfactual. This is based on anecdote. Therefore we check the difference in total pesticide cost in the two scenarios when this increases by 10% (to $33), 25% (to $37.50), and 50% (to $45). Note that this cost, whatever its value, is assumed to be the same in both the benchmark and counterfactual. By increasing this labor, fuel, and depreciation cost, the percent increase in the total cost of using AZM to AZM alternative decreases. Because the increase in total cost decreases, the estimates in the main text become even smaller and thus we do not separately report them.

Appendix table 5. Robustness Check on the Cost of Labor, Fuel, and Depreciation to Spray One Acre Once

Cost of labor & fuel, to spray one acre once ($)	Total Pesticide Cost		
	Benchmark ($/acre)	Counterfactual ($/acre)	Difference (%)
30.00	424.59	452.26	6.52
33.00	440.43	467.82	6.22
37.50	464.19	491.17	5.81
45.00	503.79	530.07	5.22

Changes to the production share of labor. There is currently no consensus about how switching from AZM to non-AZM alternatives will affect labor productivity. It is possible that labor efficiency in the apple industry decreases because of the greater need for monitoring and precisely timed applications of the AZM alternatives. But this is offset by the possibility that workers can return to the orchard much quicker after spraying the AZM alternatives compared to AZM. The main results assumed that these conflicting forces result in no change to labor efficiency.

We experiment by increasing the production function share parameter of labor in the apple activity. This means the apple industry needs to use more labor than before. We find the economic impact estimates for both the apple industry and the overall economy are very sensitive to this parameter. Changing this labor production share parameter by values smaller than 1% results in large consequences. We conclude that any large economic consequences from the AZM ban will be due to the as yet unknown changes to labor in the apple industry and not to the expenditure changes from alternative pesticides. The details of this experimentation may be found in the online appendix at http://www.ses.wsu.edu/People/faculty/Cassey/Webpage/.

Selected Equations and Code from the Model

Our model is a modification of the Washington State CGE developed by Holland, Devadoss, and Stodick (n.d.), which is an enhancement of Löfgren et al. (2002). The GAMS code is available as part of the online appendix available from http://www.ses.wsu.edu/People/faculty/Cassey/Webpage/. Below we include the equations from the model directly affected by our counterfactual change to the technical coefficient of the pesticide commodity for the apple activity. Note that the model is a system of simultaneous equations and therefore the equations below do not relate to each other sequentially.

For the counterfactual, we decrease the technical coefficient for the pesticide commodity in apple activity. The technical coefficient is the parameter ica(C,A) and is the quantity of commodity C as intermediate input per unit of activity A. It is defined by $ica(c,A) = QINTO(C,A)/QAO(A)$ where QINTO(C,A) is the initial quantity of intermediate use of commodity C by activity A and QAO(A) is the initial activity level. It is a term in the production shift parameter of activity A, ad(A). We code

```
ica("PESTMAN-C","APPLE-A")= .935*ica("PESTMAN-C","APPLE-A");
```

ica("PESTMAN-C","FRUIT-A")= .9945*ica("PESTMAN-C","FRUIT-A");

into GAMS.

The technical coefficient enters the model as a term in the production shift parameter of the apple activity. Given QFO(F,A), the initial quantity demanded of factor F by activity A, the indirect business tax rate, tb(A), and the Constant Elasticity of Substitution production function share parameter, δ(F,A), and exponent, ρ(A),

$$ad(A) = \frac{QAO(A)\left(1 - tb(A) - \sum_C ica(C,A)\right)}{\left(\sum_F \delta(F,A) * QFO(F,A)^{-\rho(A)}\right)^{\frac{-1}{\rho(A)}}}.$$

The technical coefficient is also a term in the intermediate input demand equation for commodity C in the production of activity A, $QINT(C,A) = ica(C,A) * QA(A)$, where QA(A) is the activity level of A and is calculated by

$$QA(A) = \frac{ad(A)}{1 - tb(A) - \sum_C ica(C,A)} * \left(\sum_F \delta(F,A) * QF(F,A)^{-\rho(A)}\right)^{\frac{-1}{\rho(A)}}.$$

Thus, changing the technical coefficient parameter directly impacts the intermediate input demand equation, which in turn changes the quantity supplied to domestic commodity demands (including intermediate producers), thus changing QF(F,A), the quantity demanded of factor F by activity A, and finally changing the quantity of activity A.

The activity price is $PA(A) = \sum_C PX(C) * \theta(A,C)$ where PX(C) is the producer (supply) price (of commodity C and θ(A,C) is the yield of output C per unit of activity A. For table 2, we calculate $Sales(A) = PA(A) * QA(A)$.