Environmental Regulation and Regional Economy:
Economic Impacts of the Elimination of Azinphos-methyl on
the Apple Industry and Washington State

Andrew J. Cassey[a], Suzette P. Galinato[b], and Justin L. Taylor[c]

[a] *Assistant Professor, School of Economics Sciences, Washington State University, PO Box 626210, 101 Hulbert Hall, Pullman WA 99164. Phone: 509-335-8334, Email: cassey@wsu.edu*

[b] *Research Associate, School of Economics Sciences, Washington State University, Email: sgalinato@wsu.edu*

[c] *Owner, 2L Data Solutions LLC, Email: taylor@2ldsolutions.com*

Abstract

The Environmental Protection Agency declared the pesticide azinphos-methyl must not be used in apple production after September 2012. We use this ban to contribute to the debate on environmental regulation versus industrial output. We use a computable general equilibrium model to estimate the change to sales, price, and employment in the Washington apple industry and the statewide economy had this ban existed in 2007. We estimate the ban decreases profit per acre by $101; changes sales by -0.8%, prices by 0.2%, and employment by 0.1% in the apple industry; but has negligible impacts on the Washington economy.

Keywords: apples, azinphos-methyl, CGE, economic impact, environmental regulation

There is an ongoing debate in academia, government, and industry on determining the extent to which environmental and health regulation is costly to the production output of the economy. This debate is flaring once again because 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 (2009; EPA 2009). We use this case to contribute to the debate on the economic impacts of environmental regulation. And it is a very heated debate. For example, Williams and Hinman (1999) write "…it is rather obvious that producers will suffer significant economic losses…." whereas a commenter writes that small economic impacts are "a sufficiently obvious outcome that it doesn't merit highlighting…"[1] These opposing quotes, both professing their views are "obvious," show how unsettled this debate is, and the need for our research.

We estimate the statewide impact of eliminating AZM in favor of a new pest management alternative in apple production in Washington. In particular, the economic effects we study are changes to sales (value of activity produced), 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.

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 for two reasons. First, since the late 1960s, AZM has been the most used pesticide by apple growers in Washington, primarily as a control for codling moth, the leading pest in Western apple orchards (Brunner et al. 2007). In 2007, AZM was used by 80% of Washington apple growers (Granatstein et al. 2010) and applied to 66% of Washington's apple bearing acres (USDA NASS 2008). Second, apples are the leading agricultural commodity, with sales accounting for more than 70% of the market value of Washington's $2+ billion fruit industry and 22% of all Washington farm receipts (USDA NASS 2009).

AZM belongs to the organophosphate (OP) class of pesticides, and 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).

The EPA regulation challenges the apple industry to control the codling moth while transitioning to a combination of safer, AZM-alternative pesticides. Though an AZM-alternative Integrated Pest Management (IPM) program is more worker- and environmentally-friendly, it requires different timing and more precise spray applications than AZM.[2] Furthermore, an

---

[1] This anonymous comment was forwarded to the author in a personal communication from Gary Brester. (Brester, G. W. 2010. Montana State University, Bozeman, MT, August 17.)

[2] 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 the OP-alternative pesticides Altacor

additional spray of new pesticides is required to maintain yield and quality since the alternative pesticides do not have as long-lasting residues (Brunner 2009). Therefore, for the same output, the alternative codling moth treatment is more costly per acre than using AZM because both the unit price and the quantity needed increases.

We use a computable general equilibrium (CGE) model to estimate the impacts of the AZM ban because we are interested in both quantity and price changes for Washington's apple industry as well as other upstream and downstream economic sectors. Furthermore, we like the CGE model's discipline and data requirements. Unlike a partial equilibrium approach or other methods, CGE analysis accounts for inter-sector relationships and price changes.

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. We then consider the apple industry's response to this cost increase by allowing growers to change the quantity of output by altering the amount of the various inputs (such as labor or pesticides) used in production. Our model accounts for the two biggest fears of apple growers: the increased cost of non-AZM pesticides and that more of the non-AZM pesticide is required for the same protection as AZM (Granatstein et al. 2010).

We find a decrease of $16 million in profit for the Washington apple industry, or $101 per acre. This is a sizable impact, but given the size of Washington's $1.5 billion apple industry, the relative impact is small. We find a change in apple sales of -0.8%, price of 0.2%, and employment of 0.1%. The change in employment is due to growers substituting labor for pesticides. Other impacted industries experience changes to sales, price, and employment that are small relative to the size of the industry as well. Taken as a whole, if the AZM ban had been in place in 2007, the Washington economy would have had 0.003% fewer sales and 0.001% more employment leading to an overall $2.3 million decrease in Gross State Product.[3] Thus, for the particular case of the banning of AZM in Washington apple production, our estimates indicate that this new environmental regulation is not particularly damaging to the regional economy, but that the fears of apple growers are plausible.

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). The study estimates the impacts on growers by comparing the net revenues of the current practice of using AZM to 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 range of impacts is too large to be useful. 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 net effects of the ban as it ripples through the larger Washington economy.

(chlorantraniliprole) and Delegate (spinetoram). Growers are not expected to quit production entirely or switch to organic or other non-chemical pest control systems in large numbers (Brunner 2009).

[3] Washington GDP was $325.5 billion in 2007 and the crop and animal production sector accounted for 1.25% of that (BEA 2010). Although the value of the apple industry is only about .46% of state GDP, the industry is an important part of the agricultural economy since its value is 36.76% of the crop and animal production sector.

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 (from positive profit to a loss) 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 (1999) study does not consider that growers could switch to other non-OP pesticides. Also, it does not consider the wider economic impacts.

Modeling Approach

CGE modeling is a general strategy to estimate economy-wide 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; 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 as testing—and passing—the reliability of this method.

Zilberman et al. (1991) establish the precedence of using CGE modeling in the context of a pesticide ban. They use general equilibrium techniques to examine the ban of certain pesticides such as ethyl on selected fruits, vegetables, and field crops in California.[4] The study indicates that the availability of effective substitutes is important to mitigate the effects of a ban. Their findings support our choice to explicitly consider other pesticides in the alternative scenario instead of pesticide-free management.

Strengths of the CGE Method Over Alternative Methods

Perhaps the best evidence of the soundness of the CGE modeling method is that this approach has been used in applied work for more than 30 years in a wide-range of contexts, including pesticide bans. The reason CGE is so popular is that there are many benefits from using it for estimating the economic impacts of a regulation compared to input-output or partial equilibrium methods. First, using a conventional apple enterprise budget allows us to construct an apple production function with data agreed upon by apple-growers themselves. We convert this enterprise budget into an input-output accounting production function and scale it up to state- level production using AZM for the benchmark year. We then insert the scaled budget into the statewide Social Accounting Matrix (SAM). The SAM is data on regional industry sales to, and purchases from, other industries and income and expenditures of regional households and government. The SAM can be used to capture the extent to which the state's total industry sales and jobs are dependent on the fruit industry. We make the necessary adjustments to the rest of the fruit industry to get back a balanced SAM. The fact that the benchmark and counterfactual SAM must balance is a key strength of CGE modeling—absent in other methods—because it enforces the discipline that total commodity

---

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

supply equals total commodity demand for every commodity in the regional economy The model's results are net changes to the variables of interest rather than gross changes.

Compared to an input-output approach, CGE is preferred for this context because it endogenizes the growers' response to the ban by allowing the growers to make profit- maximizing quantity adjustments. The input-output method forces all adjustment to occur through industry-wide quantities whereas adjustment in our CGE method occurs through both quantity and price in all commodity markets. The assumptions needed for an input-output model are more restrictive than a CGE model and thus our results are more appropriate for short-run predictions and analysis (Cassey et al. 2011).

We do not use a partial equilibrium approach for two reasons. The first reason is we want to model the net impacts of the ban on the Washington economy and not just in the direct and indirect industries that would be modeled in partial equilibrium. That means we consider changes in the secondary price effects that are held fixed in partial equilibrium. The second reason is practical. We do not have sufficiently long time-series data for the partial equilibrium model's parameters to be econometrically estimated with meaningful precision. Instead we have a Washington SAM and have estimates for the free parameters in the CGE model that are specifically for Washington.

*Model Development and Calibration*

Our model is a modification of the Washington State CGE developed by Holland et al. (n.d.), which is an enhancement of Löfgren et al. (2002). The model's assumptions are that given prices, endowments, and technology, producers maximize profit and consumers maximize utility. We use Walrasian competitive equilibrium, with the government and a foreign sector, as our solution concept. The model closures are that 1) capital and land are activity specific and fixed, 2) labor is supplied perfectly elastically, is mobile, and unemployment or out-of-region migration are possible, 3) foreign and rest of the United States savings are variable, and 4) price level (CPI) varies to achieve the savings-investment closure. Closure 2 means the labor market is slack. There is an unspecified level of unemployment that cannot be separated from the possibility of migration into or out-of the region. The implications are that the sum of labor demand across all sectors leads to equilibrium quantity adjustment, but no change to wage. Numerically, the model is constructed using GAMS software and calibrated with the PATH solver.[5]

Our CGE model uses 2007 data because AZM was the predominant pesticide used in Washington that year and it was the last year when AZM could be used without restriction. Data on the interactions between the sectors of the Washington economy are obtained from the IMPLAN database (MIG 2004; see Data Sources in the appendix). We focus on 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. 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

---

[5] GAMS code for the model is available in the online appendix at
http://faculty.ses.wsu.edu/Cassey/Webpage/Appendix/Apples_OP/FinalModel.txt. Select equations available in the technical appendix.

exogenously modified in our counterfactual. We aggregate the remaining industries into 23 total sectors for computational reasons.

IMPLAN data come 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 as that is the split reported by the Washington Fact Sheets (USDA NASS 2009). We use the Washington conventional apple enterprise budget from Mon and Holland (2006) for production cost information. We assume the AZM ban affects only the growers using AZM, so we scale the industry production costs to account for the fact that only two-thirds of apple producing acres were sprayed with AZM in 2007 (Lehrer 2010).[6]
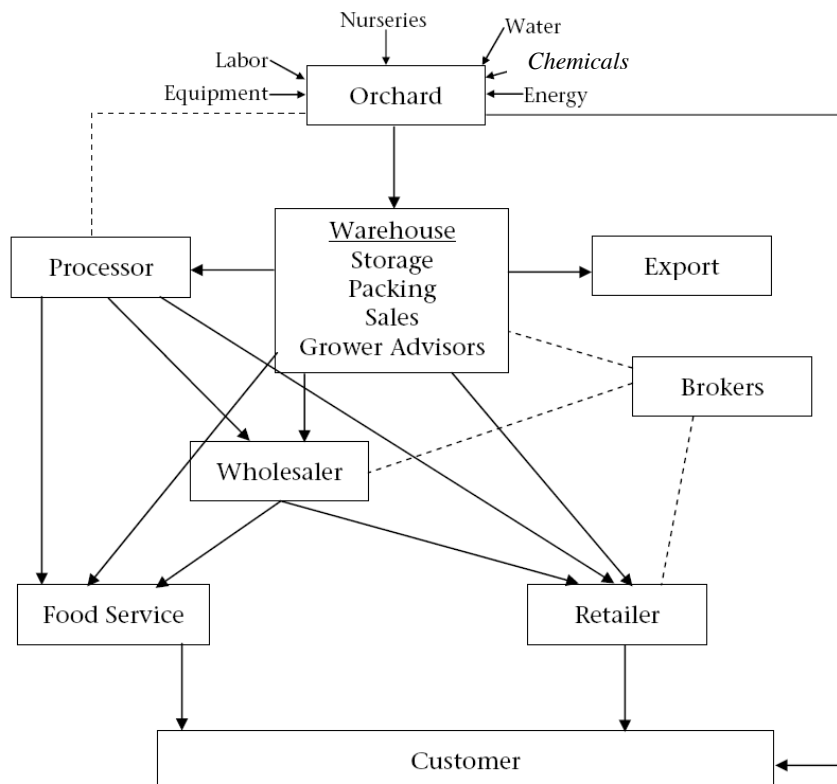
Figure 1. Supply Chain of the Washington Apple Industry
Source: Reprinted from Schotzko and Granatstein (2004, 27).

We model the reactions of the economy in two alternative scenarios. The 2007 benchmark is where AZM is the predominant insecticide to control codling moth in Washington apple production. The second scenario is the counterfactual in which there is a complete AZM ban in 2007. We first calibrate the model to find the parameters needed for the model data to replicate the actual 2007 data (including employment). Then we apply these calibrated parameters to the counterfactual to estimate what would have happened if AZM were banned in 2007. Our model does have free

---

[6] In 2007, 66% of Washington apple bearing acres were sprayed with AZM at least once. Ten percent of acres were in organic production. The remaining acres were managed with non-AZM pest control. According to Lehrer (2010), these non-AZM pest management programs are very similar to what we model in our counterfactual with the exception that not all of the non-AZM pesticides that we consider were actually available for commercial use in 2007.

parameters, mostly elasticities, whose value cannot be calibrated and so must be entered manually. We use parameter values specified for use in the Washington State CGE model (Holland et al. n.d.). (A list of free parameters, the values we use, and our source, is in Table A1 in the appendix.) Details of our calibration are available in the technical Appendix.

Assumptions Particular to the AZM Ban

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 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.[7] 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. The essence is that we counterfactually tell growers the increase in cost to achieve the benchmark output, but then let them decide to produce something other than the benchmark given the change in cost. Because our model adjusts the equilibrium price and quantity of other agricultural products as well, we account for reallocation of production to other crops.

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 assumption on how pesticide expenditure relates to pesticide productivity (apple yield per unit of pesticide). 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 (%ΔExpenditure = %ΔPrice + %ΔQuantity+ %ΔPrice*%ΔQuantity). 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. We have done a sensitivity analysis of these assumptions (not reported) and found that our results are the same qualitatively.

Our pesticide expenditure estimate is based on the cost needed to maintain the yield and quality of the apple crop at the benchmark level. All impacts come from how the apple industry responds to the increased prices and quantities for the new OP-alternative pesticides. Our costs for the counter-

---

[7] Technical coefficients refer to the portion of the total inputs of a sector that are required from another sector. These parameters represent direct backward linkages of an industry to other industries and constitute the recipe for production of that industry (Krumme 2010).

factual include an additional spray application and its associated use of extra chemicals, labor hours, and tractor use. This models the two biggest fears of apple growers (Granatstein et al. 2010). 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 decreases labor costs. We settle on no change to labor efficiency, 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. 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.[8] We assume that the Washington apple growing industry reacts to the AZM ban by choosing the amount of AZM-free 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.

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.

Costs of Pest Management

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.

---

[8] 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 .

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.

Table 1. 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	6.0	18.00	12.00	6.00	18.00
	AZM-Guthion		0				
azinphosmethyl		**42.07**		**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 online 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.

We account for that fact that only 66% of Washington's acres were sprayed with AZM at least one time (Lehrer 2010). Thus the other 33% of acres are not directly affected by the pesticide ban. *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.

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.[9] 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).[10] 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.[11]

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.

As seen in the first row, 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%. This price change occurs because we assume the Washington apple market is perfectly competitive and is imperfectly substitutable with outside apples. We treat the AZM ban as a negative supply shock, shifting the supply curve in. The decrease in production is 0.8%. We estimate employment in the apple industry 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.

---

[9] By comparison, the loss in productivity from organic techniques is about 10% of which most of the loss is due to fertilization and thinning techniques rather than pest control (Granatstein et al. 2010).

[10] We cannot calculate the decrease in the technical coefficient from per acre application counts because of the interaction of other pesticides in control.

[11] 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.

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

	SALES (VALUE OF ACTIVITY PRODUCED)			EMPLOYMENT			CONSUMER PRICE
	Benchmark	Counterfactual	Percent Change	Benchmark	Counterfactual	Percent Change	Percent Change
	(Million $)	(Million $)	(%)	(Workers)	(Workers)	(%)	(%)
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	34527	0.010	-0.006
Upstream Ind.							
Pest Mgmt	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		-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		3511530	3511529	-0.000	—

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

Though the absolute magnitude of the AZM ban's impact is in the millions, the economic impact is relatively small given the size of Washington's apple industry. Our findings are much less severe than those estimated by Williams and Hinman (1999) because they do not allow apple growers to switch to an alternative pesticide when AZM is banned, an important distinction 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 acre, due to the increase in pesticide cost and decrease in sales. This is calculated by using the parameters of the CGE model to get counterfactual cost estimates that we then insert into the enterprise budget (and not from the CGE model itself where profit in terms of opportunity cost must be zero).

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. Otherwise the model responds to the AZM ban by increasing the production of other fruit to offset the decrease in apple sales. That is not a realistic scenario since AZM will not be allowed on other fruit or crops. In order to maintain the benchmark levels for other fruit, we decrease the technical coefficient by 0.55%. This is admittedly ad hoc and is a limitation if the AZM use on other crops differs from apples. However, our results are robust to our choice and thus we do not consider the necessity of this assumption to be a major limitation.

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.

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 as a percent of the industry. Both the electric and utility sectors decrease slightly in sales because of the decrease in apple production.

The downstream industries are also modestly affected by the AZM ban in percentage. 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 five fewer employees. The remaining sectors were aggregated because of their weak economic connections with the apple industry. The ban has negligible impact on them.

Though perhaps a surprise to industry representatives, the overall Washington economy is not strongly affected by the AZM ban relative to its overall size. This is because though the apple industry is one of the largest industries in Washington, it is still small compared to the statewide economy. 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 statewide economy is consistent with theoretical results on tax increases to specific inputs and sector-specific factor taxes (Wing 2004). 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. 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 Washington 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.

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 Washington apple prices. Finally we do not consider any impact from either the State or Federal government-provided education programs to inform apple growers about the ban and how to effectively manage it. However, our model does calculate equivalent variation by household and welfare. These may be found in Table A2 in the Appendix.

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, we estimate a negligible change to the sales and employment of Washington due to the AZM ban.

We use a CGE modeling method to assess the economic impacts of the AZM ban because we are interested in quantity and price changes and inter-sector spillovers for all industries in the state economy that cannot be achieved with other methods. Though the benefits of this method include modeling discipline and easily satisfied data requirements with actual apple budgets, there are some limitations as well. First, we do not assess the economic impact on any particular apple grower, demographic of grower, or geographic region of the state, only the industry overall. Second, though we allow apple growers to shift production to other crops, we do not estimate the change in acres used in apple or other crops production as VanSickle and NaLampang (2002) do for the phase out of methylbromide. Third, we follow Brunner (2009) in assuming 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 choose a middle ground on how we model the AZM ban's effect on other U.S. apple producing states. We do not put a negative shock to the apple industry in other U.S. states besides Washington because of the difficulty in estimating what that shock should be for the representative

26

"other" state. 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 decrease consumers desire to substitute Washington apples for these other apples. On the other hand, we also do not allow for the AZM ban to cause apple production to increase in other regions, because the ban is nationwide. 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 2007 only and we do not consider costs from transitioning from AZM to AZM-free states. These transition costs may be severe for some individual growers. Therefore the economic impact to the apple industry and the Washington economy will be larger if considered over a period of years.

The upcoming AZM ban is another salvo in the ongoing battle over the extent to which health and environmental regulation negatively impacts industry. Our paper informs academics, government agents, and industry representatives of the economic impact from this particular environmental regulation. We find that the Washington apple industry faces a profit loss that averages $101 per acre. But given the size of this industry and the regional economy, the relative overall industrial and statewide impacts are small. This is consistent with Benson and Shumway (2009) who ex post show that, though some experts predicted the death of the Washington bluegrass seed industry after the implementation of a burn ban, the industry actually grew by two-thirds. In the AZM case, the environmental remedy is not expected to have dramatic negative consequences for regional output, though the growers' fears of higher pesticide prices and an inability to pass costs on to the consumer are justified.

Acknowledgements

References

2005. "Ethyl Parathion; Notice of Receipt of Request to Voluntarily Cancel Certain Pesticide Registrations." Federal Register 70 (80): 21761–21763. http://www.epa.gov/fedrgstr/EPA-PEST/2005/April/Day-27/p8185.htm. [Accessed Feb. 1, 2010].

2009. "Azinphos-methyl Notice of Receipt of Request for Label Amendments." Federal Register 74 (139): 36202.   http://www.epa.gov/fedrgstr/EPA-PEST/2009/July/Day-22/p17398.htm [Accessed Sept. 14, 2009].

Benson, A.G. and C.R. Shumway. 2009. "Environmental Regulation and Innovation Offsets in the Bluegrass Seed Industry." Review of Agricultural Economics 31: 231–246.

Brunner, J.F. 2006. "Summary of Assessment of EPA-BEAD Grower Analysis of Azinphosmethyl." Document ID: EPA-HQ-OPP-2005-0061-0187. http://www.regulations.gov. [Accessed June 14, 2009].

———. 2009–2010. Personal communication. Director, Washington State University Tree Fruit Research and Extension Center, Wenatchee, WA, various dates.

———, K.R. Granger, and M.D. Doerr. 2007. "Implementing OP-alternative Pest Management Programs in Washington Apple." Washington State University Tree Fruit Research and Extension Center. http://entomology.tfrec.wsu.edu/op-alternative/. [Accessed Sept. 14, 2009].

Cassells, S.M. and A.D. Meister. 2001. "Cost and Trade Impacts of Environmental Regulations: Effluent Control and the New Zealand Dairy Sector." Australian Journal of Agriculture and Resource Economics 45: 257–274.

Cassey, A.J., D. Holland, and A. Razack. 2011. "Comparing the Economic Impact of an Export Shock in Two Modeling Frameworks." Applied Economics Perspectives and Policy, 33:623–638.

Doroodian, K. and R. Boyd. 1999. "The Impact of Removing Corn Subsidies in Mexico: A General Equilibrium Assessment." Atlantic Economic Journal 27:150–169.

Granatstein, D., M. LaPierre, and N. Lehrer. 2010. "Organic Orchards: Needs and Priorities Survey." Washington State University Tree Fruit Research and Extension Center. http://csanr.wsu.edu/publications/presentations/Research_Priorities_WE_2010.pdf. [Accessed June 1, 2011].

Holland, D., L. Stodick, and S. Devadoss. n.d. "Documentation of the Idaho-Washington CGE Model."http://www.agribusiness-mgmt.wsu.edu/Holland_model/docs/DocumentionR.pdf. [Accessed March 1, 2009].

Kehoe, P.J. and T.J. Kehoe. 1994. "A Primer on Static Applied General Equilibrium Models." Federal Reserve Bank Minneapolis Quarterly Review 18 (1): 1–16.

Krumme, G. 2010. Economic Geography Glossary. University of Washington, Seattle, WA. http://faculty.washington.edu/krumme/gloss/t.html. [Accessed March 27, 2012].

Lehrer, N. 2010. Personal communication. Postdoctoral research associate, Pest Management Transition Project, Washington State University Tree Fruit Research and Extension Center, Wenatchee, WA, August 8.

Löfgren, H., R.L. Harris, and S. Robinson, with assistance from M. Thomas and M. El-Said, 2002. "A Standard Computable General Equilibrium (CGE) Model in GAMS." Microcomputers in Policy Research 5, International Food Policy Research Institute.

Mai, Y. 2008. "Removing Border Protection on Wheat and Rice: Effects on Rural Income and Food Self-Sufficiency in China." Australian Journal of Agricultural and Resource Economics 52: 113–131.

Minnesota IMPLAN Group (MIG). 2004. IMPLAN Pro Version 2.0: User's Guide, Analysis Guide, Data Guide, 3rd edition. MIG, Inc.: Stillwater, MN.

Mon, P.N. and D. Holland. 2006. "Organic Apple Production in Washington State: An Input– Output Analysis." Renewable Agriculture and Food Systems 21: 134–141.

Philippidis, G., and L. Hubbard. 2005. "A Dynamic Computable General Equilibrium Treatment of the Ban on U.K. Beef Exports: A Note." Journal of Agricultural Economics 56: 307–312.

Pollack, S. and A. Perez. 2005. "Fruit and Tree Nuts Outlook—Commodity Highlight: Fresh Market Apples." Economic Research Service, FTS 315, U.S. Department of Agriculture. http://www.ers.usda.gov/Publications/FTS/. [Accessed Sept. 14, 2009].

Razack, A., S. Devadoss, and D. Holland. 2009. "A General Equilibrium Analysis of Production Subsidy in a Harris-Todaro Developing Economy: An Application to India." Applied Economics 41: 2767–2777.

Rendleman, C.M., K.A. Reinert, and J.A. Tobey. 1995. "Market-based Systems for Reducing Chemical Use in Agriculture in the United States." Environmental Resource Economics 5:51–70.

Schotzko, R.T., and D. Granatstein. 2004. "A Brief Look at the Washington Apple Industry: Past and Present." Working paper no. 04-05, School of Economic Sciences, Washington State University. http://www.agribusiness mgmt.wsu.edu/ AgbusResearch/Apple _Industry.htm. [Accessed August 31, 2009].

U.S. Department of Agriculture—National Agricultural Statistics Service (USDA NASS). 2008. "Agricultural Chemical Usage—Fruits." http://usda.mannlib.cornell.edu/MannUsda/ viewDocumentInfo.do?documentID=1567. [Accessed Sept. 14, 2009].

———.2009. "Washington Fact Sheets." http://www.nass.usda.gov/Statistics_by_State/ Washington. [Accessed Sept. 14, 2009].

U.S. Department of Commerce—Bureau of Economic Analysis (BEA). 2010. Regional Economic Accounts. http://www.bea.gov/regional/. [Accessed May 26, 2011].

U.S. Environmental Protection Agency (EPA). 2009. "Summary of Azinphos-methyl Phase Out Final Decision." http://www.epa.gov/oppsrrd1/reregistration/azm/phaseout_fs.htm. [Accessed Sept. 14, 2009].

U.S. Environmental Protection Agency—Biological and Economics Analysis Division (EPA BEAD), 2005. "Grower Impact Assessment of Azinphos-methyl Use on Apples." Document ID: EPA-HQ-OPP-2005-0061-0043. http://www.regulations.gov. [Accessed June 14, 2009].

U.S. Environmental Protection Agency—Office of Pesticides Program (EPA OPP). 2006. "Organophosphorus Cumulative Risk Assessment." Document ID: EPA-HQ-OPP-2002-0302-0210. http://www.regulations.gov. [Accessed June 14, 2009].

U.S. Environmental Protection Agency—Office of Prevention, Pesticides and Toxic Substances (EPA OPPT). 2005. "Azinphos-methyl Insecticide: Ecological Risk Assessment for the Use of Azinphos-methyl on Almonds, Apples, Blueberries (Low- and Highbush), Brussels Sprouts, Cherries (Sweet and Tart), Grapes, Nursery Stock, Parsley, Pears, Pistachios, and Walnuts." Document ID: EPA-HQ-OPP-2005-0061-0037. http://www.regulations.gov. [Accessed June 14, 2009].

VanSickle, J. and S. NaLampang. 2002. "The Impact of the Phase Out of Methylbromide on the U.S. Vegetable Industry." International Agricultural Trade and Policy Center PBTC 02-1, University of Florida.

Washington State University Tree Fruit Research & Extension Center. n.d. Apple Pest Management Transition Project. http://pmtp.wsu.edu/. [Accessed Feb. 5, 2010].

Williams, K. and H. Hinman. 1999. "Impacts on the Elimination of Organophosphates and Carbamates from Red Delicious Apple Production in Washington." Agriculture and Food Policy Center, Policy Research Report 99-1, Texas A&M University. http://www.afpc.tamu.edu/pubs/2/171/rr99-1.pdf. [Accessed Jan. 22, 2010].

Wing, I.S. 2004. "Computable General Equilibrium Models and their Use in Economy-Wide Policy Analysis: Everything You Ever Wanted to Know (But Were Afraid to Ask)." Boston University and Massachusetts Institute of Technology. http://people.bu.edu /isw/papers/cge.pdf. [Accessed June 1, 2011].

Zilberman, D., A. Schmitz, G. Casterline, E. Lichtenberg, and J.B. Siebert. 1991. "The Economics of Pesticide Use and Regulation." Science 253: 518–522.

Appendix 1

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/Agrifacts/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 (IMpact analysis for PLANning) 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.[12]

Insect Control Costs

The cost estimates of an insect control program with and without AZM are obtained from Brunner (2009) and available at the online appendix at http://faculty.ses.wsu.edu/Cassey/Web page/. 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.

Robustness of Results

Because some of our assumptions have a degree of conjecture, we consider two 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

---

[12] See http://implan.com/index.php?option=com_content&task=view&id=86&Itemid=57.

percent increase in the total cost of using AZM to AZM alternative decreases from 6.5% to 6.2%, 5.8%, and 5.2%. Because the increase in total cost decreases, the estimates in the main text become even smaller and thus we do not separately report them.

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.[13]

---

[13] The details of this experimentation may befound in the online appendix at
http://faculty.ses.wsu.edu/Cassey/Webpage/

Appendix 2

Technical Appendix

Free Parameters

GAMS and the PATH solver calibrate our CGE model's parameters except for thirteen free parameters that cannot be calibrated with the SAM. The values we use for the free parameters are commonly used in the literature. In particular, we use the default values provided by Holland et al. (n.d.) without modification. Interested readers may request from the authors the calibrations done in GAMS and the PATH solver.

Table A1. Free Parameters in CGE Model

Parameter	Description	Value	Notes
xed(C,T)	Elasticity of demand for world export function	-5.00	
esubp(A)	Elasticity of substitution for production	0.99	
esubd(C)	Elasticity of substitution (Armington) between regional output and imports	2.00	
esubs(C)	Elasticity of substitution (transformation) regional output and imports	2.00	
esube(C)	Elasticity of substitution (transformation) between RoW and RUS exports	2.00	
esubm(C)	Elasticity of substitution (Armington) between RoW and RUS imports	2.00	
ine(C,H)	Income elasticity	1.00	
income_ine(C)	Investment on commodities elasticity	1.00	
frisch(C)	Consumption flexibility: min subsistence level	-1.00	Zero minimum
ifrisch(C)	Investment demand flexibility: min investment level	-1.00	No minimum
efac(LAB)	Demand elasticity for labor	4.00	
efac(CAP)	Demand elasticity for capital	0.50	

Source: Holland, Stodick, and Devadoss (n.d.)

Equivalent Variation by Household and Welfare

Table A2 displays the household income and welfare impacts due to the AZM ban. There are nine categories of households based on the household's income range and they are: less than 10K, 10-15K, 15-25K, 25-35K, 35-50K, 50-75K, 75-100K, 100-150K, and 150K+. These ranges are denoted in the table by their last number.

Table A2. Average Net Income and Equivalent Variation by Household

	Average Net Household Income			**Equivalent Variation**
	Benchmark ($)	Counterfactual ($)	Percent Change (%)	(dollars / household)
10K	5397.55	5397.55	-0.000117	-0.001985
15K	4297.40	4297.39	-0.000170	-0.004282
25K	8952.98	8952.95	-0.000349	-0.025789
35K	11486.49	11483.95	-0.000371	-0.034301
50K	31045.46	31045.33	-0.000424	-0.100178
75K	56306.06	56305.77	-0.000520	-0.212274
100K	43073.57	43073.40	-0.000406	-0.094268
150K	37323.44	37323.32	-0.000323	-0.050530

Notes: Net income included taxes, savings, inter-household transfers, and overseas transfers. Households are ordered by their income range and are denoted by the last value in their range.

Selected Equations and Code from the Model

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.[14] 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 $ica(c, A) = QINTO(C, A) \times QAO(A)$ 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. 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, $\delta(F,A)$, and exponent, $\rho(A)$,

---

[14] The full GAMS code is available as part of the online appendix, http://faculty.ses.wsu.edu/Cassey/Webpage/ Appendix/ Apples_OP/FinalModel.txt.

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

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

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

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 price (of commodity C and θ(A,C) is the yield of output C per unit 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).*