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An Analysis of the Impact of a Ban of Methyl Bromide on the U.S. Winter Fresh Vegetable Market

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ABSTRACT

This study evaluates the economic impact of a ban on methyl bromide on the U.S. winter fresh vegetable market for six major crops: tomatoes, green peppers, cucumbers, squash, eggplant, and watermelons. Florida is the primary domestic supplier of these products. Mexico and Texas are the competing suppliers of the five vegetable crops and peppers, respectively. Leontief technologies represent both monocrop and double-crop production systems; linear inverse demand functions represent four demand regions in the U.S. and Canada. By increasing production costs and reducing yields, a ban on methyl bromide decreases Florida's FOB revenues by 54% and increases those of Mexico by 65%. Price increases to U.S. fresh vegetable consumers range from near zero to over 10%, depending upon the commodity and location.

Key Words: fresh vegetables, methyl bromide, pesticide, quadratic programming, spatial equilibrium.

Methyl bromide is a broad-spectrum pesticide used in the production and marketing of a wide array of fruit and vegetable crops. It has been designated as a Class I ozone depleter and, as such, must be phased out of use by the year 2000. The purpose of this study is to present an economic analysis of the impact of the proposed methyl bromide ban on the U.S. winter fresh vegetable market. Florida is the primary domestic supply source for fresh vegetables in the winter in the U.S., with Mexico the major competitor.

According to the U.S. Department of Agriculture/National Agricultural Statistics Service (USDA/NASS) pesticide use study, methyl bromide is used on tomatoes, peppers, and eggplant in Florida. Because cucumbers, squash, and watermelons may be grown as second crops in a double-cropping system, these crops are also included in the analysis. The most common production practice is to inject methyl bromide into the soil during land preparation. The ground is covered with a plastic film which aids in preventing escape of methyl bromide and will later serve as "mulch." Methyl bromide is effective both as a pre-emergent herbicide and as a nematicide, and is, to date, the only effective chemical against nutsedge. It is usually mixed with chloropicrin, and is an effective control for many fungus-related diseases. After an interval of time (usually 10–14

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days), holes are punched into the plastic mulch and transplants are planted. Depending upon the condition of the plastic mulch and market conditions, a second crop may be produced using the same mulch. The usual practice in Florida is a first crop consisting of tomatoes, peppers, or eggplant, followed by a second crop of shorter maturity such as cucumbers, squash, or watermelons.

Florida and Mexico are the dominant suppliers of many vegetable crops to the U.S. market during the November through May period. Analysis of USDA data for 1989–92 reveals that Florida and Mexico jointly account for 94.6% of tomatoes, 86.4% of peppers, 99.8% of eggplant, 91.1% of cucumbers, and 97.5% of squash marketed during the November through May period (USDA/Agricultural Marketing Service). Florida is the sole supplier of watermelons during April and May. Thus, a ban on methyl bromide in the U.S. would not only affect Florida vegetable producers, but would also impact U.S. consumers of fresh fruits and vegetables. Consequently, it is necessary to conduct the analysis at the market level accounting for possible import substitution from Mexico.

The Montreal Protocol is an international group which deals with the issue of ozone depletion. The scientists who consult with the Montreal Protocol have determined that methyl bromide is a Class I ozone-depleting compound. The Clean Air Act of 1990 requires that all Class I ozone-depleting compounds be completely banned in the United States by the year 2001. Currently, the United States is the only country in the world which has announced its intentions for a total ban of methyl bromide. Although the United Nations has recommended a 25% reduction in methyl bromide use, to date, this proposal has not been implemented.

While methyl bromide was not widely used in the Mexican vegetable industry at the time this research was conducted, under present policy of the Mexican government, the use of methyl bromide by Mexican vegetable growers would be unaffected by the proposed ban in the United States. Interestingly, current phytosanitary regulations imposed on Mexican citrus exporters to the United States require that all exports of fresh citrus be fumigated with methyl bromide under the supervision of a USDA inspector.

Previous Work

A comprehensive study of the agricultural use of methyl bromide in the United States was conducted in 1994 by Ferguson and Padula under the auspices of the National Agricultural Pesticide Information and Assessment Program (NAPIAP) of the USDA. This study was national in scope and examined both preplant and post-harvest uses of methyl bromide. Included in the Ferguson-Padula investigation was the identification of those crops and states which most widely use methyl bromide. The fresh fruit and vegetable industry in Florida was identified as being vulnerable to a ban of methyl bromide. That finding provided the primary reason for conducting the research reported here.

Our approach takes a major departure from the Ferguson and Padula investigation. In their study, the fresh vegetable market in the United States is treated as a single market, and no attempt is made to disaggregate the market by regions or seasons. Thus, because Florida is a seasonal supplier of fresh vegetables, the estimated economic impacts of a ban of methyl bromide on selected fruits and vegetable crops presented in Ferguson and Padula are not applicable to Florida.

An additional study on methyl bromide regulation was conducted in California, and reported in Yarkin et al. in 1994. California is another state identified by Ferguson and Padula as a major user of methyl bromide. Among the crops identified as major users of methyl bromide were almonds, grapes, nectarines, peaches, strawberries, fresh tomatoes, and walnuts. With the exception of strawberries, Florida and California do not directly compete in the market for these crops. The market window for Florida's winter fresh vegetable crop ends as California enters the market in June.

A Mathematical Model of the North American Winter Vegetable Market

The North American winter fresh vegetable market can be characterized as a spatial equilibrium problem. We focus on those months in which Florida is an important supplier of fresh vegetables to the North American market. The model is also limited to those commodities which utilize methyl bromide as a preplant fumigant.

To state the model mathematically, let i, j, k, and m index the I supply regions, the J demand regions, the K commodities, and the M months included in the model, respectively. Many producers in Florida utilize double-cropping systems in which two different commodities are produced on the same acre. Let l_i index the L_i cropping systems employed in supply region i. Then define W_{l_i} as the number of acres planted to cropping system l_i in region i. Next, let d_{l_ikm} be the per acre yield of commodity k in month m from cropping system l_i, so that $U_{l_ikm} = d_{l_ikm}W_{l_i}$ is the production of commodity k in region i and month m from cropping system l_i. Let $c1_{l_i}$ denote the per acre preharvest production cost of cropping system l_i, so that $c1_{l_i}W_{l_i}$ is the total preharvest production cost associated with cropping system l_i.

The total supply of commodity k from supply region i in month m is

$$Z_{ikm} = \sum_{l_i} U_{l_ikm};$$

that is, the total production of commodity k in region i and month m is the sum of the production of that commodity from each cropping system.

Let $c2_{ik}$ denote the per unit harvest and postharvest cost associated with commodity k in region i. The parameter $c2_{ik}$ includes harvest cost, costs for hauling to the packing plant, packing costs, and shipment to a distribution point.[1] Note that postharvest costs are assumed to be invariant to the month of harvest. Then $c2_{ik}Z_{ikm}$ is the postharvest cost associated with commodity k produced in region i and month m.

The demand side of the model is delineated by defining

$$P_{jkm} = a_{jkm} - b_{jkm}Q_{jkm}$$

as the inverse demand for commodity k in demand region j and month m, where P_{jkm} and Q_{jkm} denote the per unit price and quantity consumed, respectively, of commodity k in demand region j and month m, and the parameters a_{jkm} and b_{jkm} are both assumed to be nonnegative.

Let X_{ijkm} be the quantity of commodity k shipped from supply region i to demand region j in month m, and let $c3_{ijkm}$ denote the per unit transportation cost from supply region i to demand region j for commodity k in month m.

With these definitions, a quadratic programming model can be written as follows:

$$\begin{aligned}\text{Max} &\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{m=1}^{M}(a_{jkm}Q_{jkm} - 1/2\, b_{jkm}Q_{jkm}^2)\\ &- \sum_{i=1}^{I}\sum_{l_i=1}^{L_i} c1_{l_i}W_{l_i} - \sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{m=1}^{M} c2_{ik}Z_{ikm}\\ &- \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{m=1}^{M} c3_{ijkm}X_{ijkm}\end{aligned}$$

subject to:

$$U_{l_ikm} = d_{l_ikm}W_{l_i},$$

$$l_i = 1, \ldots, L_i, \qquad i = 1, \ldots, I,$$

$$k = 1, \ldots, K, \qquad m = 1, \ldots, M;$$

$$Z_{ikm} = \sum_{l_i=1}^{L_i} U_{l_ikm},$$

$$i = 1, \ldots, I, \qquad k = 1, \ldots, K,$$

$$m = 1, \ldots, M;$$

$$\sum_{j=1}^{J} X_{ijkm} \leq Z_{ikm},$$

$$i = 1, \ldots, I, \qquad k = 1, \ldots, K,$$

$$m = 1, \ldots, M;$$

$$\sum_{i=1}^{I} X_{ijkm} \geq Q_{jkm},$$

$$j = 1, \ldots, J, \qquad k = 1, \ldots, K,$$

$$m = 1, \ldots, M;$$

$$Q_{jkm}, W_{l_i}, Z_{ikm}, U_{l_ikm}, X_{ijkm} \geq 0$$

$$\forall\ i, j, k, m, l_i.$$

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[1] In the case of Mexico, a charge is included for hauling from the production area in Sinaloa to Nogales, Arizona, and the tariffs and inspection charges incurred as the shipment crosses the border into the U.S.

The optimal solution to this model provides the equilibrium consumption of each commodity in every month in each demand region (Q_{jkm}), the optimal level of shipments between each supply area and each demand area by commodity and month (X_{ijkm}), the optimal acreage of each cropping system by production area (W_{l_i}), and the quantity of each commodity produced in each supply region by month (Z_{ikm}). The optimal dual solution provides market clearing prices in each demand area by month and commodity.

This model is a variant of the spatial equilibrium model presented by Takayama and Judge. It incorporates the use of a fixed proportions technology to generate supply. This is the so-called implicit supply model as discussed by McCarl and Spreen. The model is simplified in that the price of each commodity is a function of its own quantity alone. This simplifying assumption eliminates the integrability problem addressed by McCarl and Spreen, and by Peters and Spreen. This approach is often employed in multi-commodity price endogenous models (Hazell and Norton, p. 169).

The other important simplification imposed on the model is that all parameters are assumed to be nonstochastic. It is well known that per acre yields of fresh vegetable crops are highly variable. The lack of time-series data from Mexico required that a deterministic model be constructed.

Empirical Specification

The data requirements of the proposed model are large. In this section, the data used to specify the model empirically are presented.

One notable omission from the quadratic programming model is any resource constraints imposed by land availability, labor, or machinery. Although limited land is available for fresh vegetable production, especially along the east coast of Florida, it could not be established that effective resource requirements restrict the production of fresh vegetables in Florida, Mexico, or other U.S. supply areas. The fruit and vegetable crops included in this analysis accounted for approximately 41% of the harvested acreage for fresh produce in Florida in the 1991–92 season [Florida Agricultural Statistics Service (FASS)]. In several of the regions studied, the fruit and vegetable crops included here compete with other fresh produce crops (such as potatoes, beans, and sweet corn, as well as citrus) for land, labor, and other resources. Given the price-endogenous specification of the model, relative profitability is likely the more important consideration in planting decisions for winter fresh vegetable production.

The Empirical Demand Structure

The inverse demand equations employed in the model are based upon the work of Scott. In his study, an inverse Rotterdam system of four equations of winter fresh vegetable demand in the U.S. was estimated for tomatoes, bell peppers, cucumbers, and green beans. The demand system estimated by Scott was extended here to include squash, eggplant, and watermelons.

As the inverse demand equations in the mathematical programming model reflect aggregate demand, it was necessary to adjust the intercepts of the demand equations. This adjustment was accomplished by first dividing the U.S. and Canada into four demand regions. New York, Chicago, Atlanta, and Los Angeles were selected as the corresponding terminal markets. Using 1990 census figures (U.S. Department of Commerce/Bureau of the Census), the population in each region was computed. There is no information to suggest that fresh winter vegetable demand is highly differential across the four demand regions, and so it was assumed that aggregate consumption is proportional to population.

The winter fresh vegetable market is assumed to encompass the months of November through May. Florida and Mexico account for over 90% of the supply to the fresh market of the commodities included in this study in those months. Based upon analysis of shipments data, it was determined that Texas should be included in the pepper market for November and December. No region could be identified as a viable alternative to Florida for watermelons in May.

Monthly shipments by crop were allocated to the four demand regions by population. Monthly prices by crop and market were computed by averaging the 1988–89 through 1990–91 monthly average prices. Using the estimated flexibilities, monthly shipments, and monthly prices, a system of inverse linear demand equations was derived to represent the demand structure for the four demand regions, six commodities, and seven months in the model.

Transportation Costs

Postharvest costs for Mexico include all charges incurred to place the product across the U.S.-Mexico border at Nogales, Arizona. In Florida, the city of Wildwood, which is located at the intersection of Interstate 75 and the Florida turnpike, was selected as the transshipment point for Florida produce.[2] Using the software program AUTOMAP (AUTOMAP, Inc.), the distance between each supply point and each demand point was computed.

An estimate of $1.3072 per mile was used as the transportation cost of a fully loaded refrigerated truck carrying 40,000 pounds of product (VanSickle et al.). This figure was multiplied by the appropriate distance and then adjusted to reflect the differences in weight per unit across commodities.

Production Costs

In Florida, four production areas were delineated: Dade County, Palm Beach County, southwest Florida, and the west central production area located near Ruskin and Palmetto. These four production areas are consistent with those used by the Florida Agricultural Statistics Service when reporting regional production in the state (FASS/*Vegetable Summary*). Using survey data, cropping systems were developed for each production area. It is assumed that all cropping systems that use methyl bromide are covered 100% by methyl bromide. The production budgets published annually by the University of Florida (Smith and Taylor) were adapted to provide preharvest cost of production. These figures are shown in table 1. It is important to note those

Table 1. Estimated Preharvest Production Cost by Cropping System and Production Area in Florida, with and without Methyl Bromide

	Cost ($/acre)	
Location/Cropping System	Baseline[a]	Without MB
Dade County		
Tomatoes	6,075	5,716
Squash[b]	2,037	2,037
Palm Beach County		
Tomatoes	6,250	6,311
Tomatoes/Cucumbers[c]	7,425	7,452
Peppers	4,800	5,149
Peppers/Cucumbers[c]	6,360	6,334
Eggplant	5,235	5,379
Southwest		
Fall tomatoes	6,256	6,672
Spring tomatoes	6,789	6,972
Tomatoes/Cucumbers[c]	7,542	7,481
Tomatoes/Squash[c]	7,290	7,290
Tomatoes/Watermelons[c]	8,319	8,283
Peppers	5,100	5,787
Peppers/Cucumbers[c]	6,259	6,770
Peppers/Watermelons[c]	7,286	7,572
Cucumbers[b]	2,208	2,208
Squash[b]	2,043	2,043
West Central		
Fall tomatoes	5,944	5,890
Spring tomatoes	5,500	5,380
Tomatoes/Cucumbers[c]	6,835	7,059
Tomatoes/Squash[c]	6,885	7,111
Tomatoes/Watermelons[c]	6,800	7,028
Fall peppers	4,801	5,052
Spring peppers	5,093	5,052
Peppers/Squash[c]	6,195	6,273
Peppers/Watermelons[c]	6,125	6,190
Cucumbers[b]	2,208	2,208
Squash[b]	2,043	2,043

[a] Production costs for baseline cropping systems were adapted from Smith and Taylor.

[b] Does not use methyl bromide.

[c] Double-crop systems list first crop produced, followed by second crop produced.

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[2] For peppers produced in Texas, the city of McAllen, Texas, is the supply point.

Table 2. Per Acre Yields of Crops by Cropping System and Production Area in Florida, with and without Methyl Bromide

	Dade		Palm Beach		West Central		Southwest	
Crop/Cropping System	Baseline	W/O MB	Baseline	W/O MB	Baseline	W/O MB	Baseline	W/O MB
Tomatoes/single[a]	1,300	1,040	1,300	780				
Tomatoes/fall single					1,100	880	1,400	1,120
Tomatoes/spring single					1,100	880	1,400	1,120
Tomatoes/Tomatoes-Cucumbers			1,300	780	1,100	880	1,400	1,120
Tomatoes/Tomatoes-Squash					1,100	880	1,400	1,120
Tomatoes/Tomatoes-Melons					1,100	880	1,400	1,120
Cucumbers/single[b,g]					400	400	400	400
Cucumbers/Tomatoes-Cucumbers			600	300	600	360	600	360
Cucumbers/Peppers-Cucumbers			600	300			600	360
Peppers/single[c]			1,000	650			1,050	892
Peppers/fall single					950	807		
Peppers/spring single					950	807		
Peppers/Peppers-Cucumbers			1,000	650			1,050	892
Peppers/Peppers-Squash					950	807		
Peppers/Peppers-Melons					950	807	1,050	892
Squash/single[d,g]	275	275			275	275	275	275
Squash/Tomatoes-Squash					275	220	275	220
Squash/Peppers-Squash					275	220		
Eggplant/single[e]			1,500	975			320	288
Melons/Tomatoes-Melons[f]					300	240	320	288
Melons/Peppers-Melons					300	240		

[a] Tomato yields are in 25-lb. cartons.
[b] Cucumber yields are in 55-lb. bushels.
[c] Pepper yields are in 28-lb. bushels.
[d] Squash yields are in 42-lb. bushels.
[e] Eggplant yields are in 33-lb. bushels.
[f] Watermelon yields are in cwt.
[g] Does not use methyl bromide.

cropping systems which do not utilize methyl bromide.

Per acre yields were also based on the work of Smith and Taylor. In some cases, yields were adjusted to reflect the per acre yields reported in the FASS *Vegetable Summary*. An extension specialist survey also provided information on per acre yields. The per acre yields included in the model are shown in table 2.

Per acre preharvest production costs and yields for Mexico and Texas are shown in table 3. The data for Mexico are based upon the production budgets found in VanSickle et al., and the pepper budget for Texas is based upon information from the Texas Cooperative Extension Service.

An assumption imposed on the model is that the total production from one acre of a particular cropping system is not concentrated in a single month. The enterprises included in the model are composites of all similar cropping systems in that production area. For example, tomatoes produced in Dade County, Florida, are harvested from November through March. This occurs because growers stagger plantings so that mature product will be available over several months. Instead of defining numerous enterprises with specific plant-harvest dates, the approach taken here was to define a single composite enterprise which depicts all production of similar enterprises in that production area. Hence, marketings from a particular cropping system are spread over

Table 3. Per Acre Production Costs and Yields for Selected Crops in Mexico and Texas

Location/Crop	Preharvest Cost per Acre	Yield per Acre	
		Baseline	Without MB
Mexico			
Tomatoes[a]	3,048	880	880
Peppers[b]	2,200	760	760
Cucumbers[c]	1,912	550	550
Squash[d]	614	220	220
Eggplant[e]	2,418	1,230	1,230
Texas			
Peppers[b]	1,325	400	400

Sources: VanSickle et al.; Texas Cooperative Extension Service.

[a] Tomato yields are in 25-lb. cartons.

[b] Pepper yields are in 28-lb. bushels.

[c] Cucumber yields are in 55-lb. bushels.

[d] Squash yields are in 42-lb. bushels.

[e] Eggplant yields are in 33-lb. bushels.

several months. Data compiled by the Florida Tomato Committee provided monthly marketings by production area for tomatoes. There are no similar data for the other crops included in this study. The FASS *Vegetable Summary* and survey information were used to arrive at monthly marketings of the other crops in the model.

Postharvest costs for Florida are based upon data derived from Smith and Taylor. These costs include harvesting, packing, marketing, and transportation from the production area to Wildwood, Florida. Postharvest costs for Mexico are based upon information provided in VanSickle et al., and include the costs of harvesting, packing, transportation to Nogales, Arizona, and all applicable tariffs and fees incurred as the product crosses the border into the U.S. Postharvest costs for peppers in Texas were provided by the Texas Cooperative Extension Service.

Empirical Results

The solution to the quadratic programming model[3] included equilibrium prices and quantity consumed by month and crop in each of the four markets, shipments by month and crop from each supply region to each market, and the acres planted to each cropping system in each supply region. The model performed reasonably well in replicating the observed pattern of shipments from each supply region. With a few exceptions, the model also performed well in the quantity of each crop produced.

The acres planted by cropping system and supply region for the baseline model are shown in table 4. Total acreage planted to tomatoes in Florida is 61,613, which is higher than the 50,000 to 55,000 acres typically planted in the state. Regional distribution of tomato production is fairly consistent with observed data. All four production areas in Florida produce tomatoes in the model. Mexican tomato acreage in the model is also higher than observed acreage. The market share allocated to Florida and Mexico for tomatoes corresponds closely to observed data.

The model replicates the production of the other crops reasonably well. Total acreages of peppers, eggplant, cucumbers, squash, and watermelons in the model correspond closely to observed data. The main problem with the acreage allocations in the base run of the model is the failure of southwest Florida to produce peppers. Southwest Florida is the largest production area for peppers in Florida. After numerous runs of the model, it is clear, given the pre- and postharvest costs and assumed monthly production distribution, that the model will not reflect production of peppers in southwest Florida.

Modification of the Model to Account for the Loss of Methyl Bromide

An extensive survey of extension specialists and university faculty was conducted in an attempt to identify alternative production systems which do not utilize methyl bromide. It was generally agreed that the use of plastic

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[3] The model was solved using GAMS on a 486–50 microcomputer. Despite the large number of endogenous prices, the model was easily solved on the microcomputer.

Table 4. Acres Planted by Cropping System and Location, with and without Methyl Bromide

	Dade		Palm Beach		West Central		Southwest		Texas		Mexico	
Cropping System	Base-line	W/O MB	Base-line	W/O MB	Base-line	W/O MB	Base-line	W/O MB	Base-line	W/O MB	Base-line	W/O MB
Single tomatoes	8,279										55,068	100,598
Single peppers			6,981		14,747	17,994	15,819				12,236	18,895
Fall peppers									5,865	14,258		
Spring peppers					6,362	7,800						
Single cucumbers							5,950	5,152			13,720	14,738
Single squash	6,085	9,692									14,491	13,531
Single eggplant			2,598								1,916	4,277
Tomatoes/Cucumbers			8,029				1,710	6,527				
Tomatoes/Squash							3,160					
Peppers/Melons					4,420							
Tomatoes/Melons							9,869	9,340				

mulch would be retained and alternative fumigants would be utilized. Preharvest costs by cropping system and production area in Florida under a methyl bromide ban are shown in table 1. The alternative production systems utilize the fumigants Telone and Vapam as replacements for methyl bromide. Tillam would also be used as a preplant herbicide because the specialists agreed that Telone would not provide the level of weed control given by methyl bromide. Table 1 reveals that the preharvest production costs per acre differ little between the methyl bromide and no methyl bromide systems.

The main impact of the loss of methyl bromide is on yield per acre. The replacement fumigants combined with Tillam are predicted to provide less weed control compared to methyl bromide, especially for nutsedge. The horticultural scientists also believe that the loss of methyl bromide would make vegetable production more susceptible to ground-borne pests. In table 2, per acre yields are presented for those cropping systems affected by the loss of methyl bromide; these yields reflect the minimum of the range of possible yield reductions provided by the extension specialists and horticultural scientists. As such, the solution to the model under a methyl bromide ban reflects the most optimistic scenario, given the current information on alternative practices.

Another important point regarding the values in table 2 is the impact of the loss of methyl bromide on double-crop systems. In those systems, the yield adjustment imposed on the first crop ranges from 15–40%, depending upon location. The yield penalties imposed on the second crop were higher, ranging from 20–50%, with the exception of watermelons. The rationale for the larger yield losses on the second crop is that reduced weed control would adversely affect the integrity of the plastic mulch and hence lower second crop yields.

Yield losses in both Palm Beach and Dade counties resulting from a methyl bromide ban are projected to be larger than in southwest or west central Florida because of the lack of land in the east coast production areas. Producers located in southwest and west central

Florida have access to a larger land area and would be able to move production to mitigate "old land disease."

Model Solution Under a Methyl Bromide Ban

The acreages planted by cropping system and production area under a methyl bromide ban are shown in table 4. The results suggest that a ban on methyl bromide would have a sizable impact on the Florida fresh vegetable industry. Production of tomatoes, peppers, eggplant, and cucumbers would cease in Palm Beach County. Tomato production in Dade County would also be eliminated. Fresh vegetable production in both southwest and west central Florida would be adversely affected, although west central Florida would retain substantial tomato and pepper production. Florida's early season production of watermelons would decline significantly.

The Mexican fresh vegetable industry would gain much of the production lost in Florida. It is projected that tomato acreage in Mexico would nearly double, and that pepper and eggplant acreages would also show major increases.

Market share calculations confirm the impact suggested by the acreage adjustments that a methyl bromide ban will have on Florida. While Florida retains a majority share of the November, December, and May fresh tomato market, Mexico will control over 70% of the market in the January through April period. With the loss of tomato production in Dade and Palm Beach counties, Florida will essentially stop shipping tomatoes in January and February.

The impact of the methyl bromide ban on Florida's green pepper production is large. Shipments of green peppers from Florida will cease during the November through March period. Florida is projected to retain a majority share of the April and May market. Both Texas and Mexico are projected to gain market share, as neither production region is affected by the methyl bromide ban.

The impact of the methyl bromide ban on cucumber and squash production in Florida is much smaller. While Florida is projected to lose market share in cucumbers, the impact is much smaller compared to tomatoes and peppers. The quantity of cucumbers produced as a second crop after tomatoes or peppers is greatly reduced under a methyl bromide ban, but over 6,500 acres of tomatoes/cucumbers are still projected to be produced in southwest Florida. Projected production of squash in Florida expands slightly under a methyl bromide ban. Squash production in Dade County does not utilize methyl bromide. The impact of the methyl bromide ban is to eliminate squash as a double crop, but squash production in Dade County expands to more than compensate for the lost production in southwest Florida.

Under a methyl bromide ban, eggplant production in Palm Beach County is eliminated. In the specification of the model, Palm Beach was the only region in Florida that produced eggplant. Loss of eggplant production in Palm Beach County results in total loss of market share. It is possible that other regions in Florida could expand eggplant production.

In the specification of the model, Florida is assumed to be the sole supplier of watermelons in May. The impact of the loss of methyl bromide is to slightly reduce watermelon production after tomatoes in southwest Florida and eliminate watermelons as a second crop in west central Florida. Total watermelon production is reduced from 4,484,000 cwts to 2,690,000 cwts. This decline reflects reduction in production for the May market only. The model does not consider watermelon production for the June market.

Revenue Impacts

The impact of a methyl bromide ban on FOB revenues is based upon shipping point prices. Florida FOB revenues for the six crops included in this study are projected to decline from $1.029 billion to $481 million, or 53%. Most of the lost revenue in Florida will be gained by Mexico, where FOB revenues are projected to increase from $565 million to $933 million, an increase of 65%. FOB revenue from bell pepper production in Texas will

Table 5. Percentage Increase in Wholesale Prices in Regional Markets Resulting from a Ban on Methyl Bromide, by Commodity and Market, with Averages

	New York	Chicago	Atlanta	Los Angeles	Average
Tomatoes	4.4	3.1	4.5	3.1	3.8
Peppers	5.1	4.0	6.7	0.3	4.0
Cucumbers	10.8	9.7	11.7	0.2	8.1
Squash	1.0	0.7	1.1	0.9	0.9
Eggplant	12.0	5.5	12.8	3.2	8.4
Watermelons	11.4	11.3	12.9	9.1	11.2
Average	7.5	5.7	8.3	2.8	6.1

more than double, from $17 million to $41 million.

Price Impacts

Prices of all products in wholesale markets will increase as a result of banning methyl bromide, as shown in table 5. Seasonal wholesale price increases during Florida's shipping season range from 0.9% for squash to 11.2% for watermelons. The prices of those products in which Mexico currently competes significantly are projected to increase the least, because Mexico increases its shipments of these products.

The southeast and northeast markets would be the markets most adversely affected as average prices for the selected products are expected to rise 8.3% and 7.5%, respectively, while the midwest and west wholesale markets expect average price increases of 5.7% and 2.8%, respectively (table 5). The overall pattern across the four markets is roughly consistent with the relative transportation costs of produce from Mexico (via Nogales, Arizona).

Concluding Remarks

Methyl bromide is widely utilized by the Florida fresh fruit and vegetable industry. It has been designated as a Class I ozone depleter, and its production and importation into the U.S. is to be banned after the year 2000. In this study, a quantitative analysis of the impact of the proposed ban on Florida fruit and vegetable producers was presented. Since Florida and Mexico are the two dominant suppliers of fresh produce to the winter market in the United States, analysis of the ban entailed development of a spatial equilibrium model of the North American winter fresh vegetable market.

The empirical results suggest that a ban on methyl bromide would have a significant impact on Florida fruit and vegetable producers. Tomato production in both Dade and Palm Beach counties would cease. Pepper, eggplant, cucumber, and watermelon production in Florida would be greatly reduced. Mexico would gain much of the market lost to Florida. As the ban of methyl bromide has been unilaterally proposed by the United States, producers in Mexico would not be affected. U.S. consumers of winter fresh fruits and vegetables would face higher prices ranging from nearly zero to more than 10%, depending upon the commodity, month, and location of the market.

The results of the analysis are based upon the current state of knowledge regarding the alternatives to methyl bromide. Research results recently reported by the Pesticide Action Network of North America, Updates Service (PANUPS) suggest that fruit and vegetable producers in Europe have had some success in both strawberry and cucumber production in reducing or eliminating the use of methyl bromide. Further research on the role of methyl bromide and its possible substitutes may invalidate the results presented here.

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