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# Effect of Liberalized U.S.-Mexico Dry Onion Trade: A Spatial and Intertemporal Equilibrium Analysis

Stephen Fuller, Melanie Gillis, and Houshmand A. Ziari

## ABSTRACT

A spatial, intertemporal equilibrium model of the North American dry onion economy is constructed to analyze the impact of liberalized U.S.-Mexico trade. In a free-trade environment, exports of Mexican onions to the U.S. are projected to increase about 50%, while Mexico's share of the U.S. market increases from 8.7 to 12.8%. Farm-level prices in the U.S. are projected to decline 8.9%, while production declines 2.4%. The effect of free trade on U.S. producers is disproportional across regions. Northwest storage onion producers experience the greatest decline in production; however, analysis suggests that improved storage methods may offset a portion of the unfavorable impacts of liberalized trade on these producers. In spite of the unfavorable impact of free trade on U.S. dry onion producers, the industry would not be economically devastated.

**Key Words:** dry onion, NAFTA, spatial and intertemporal model.

Selected imports of horticultural products from Mexico compete with U.S. production, but historically U.S. seasonal tariffs have mitigated much of this competition (Hanrahan). The North American Free Trade Agreement (NAFTA), with its scheduled phaseout of these tariffs, is generating concern among U.S. producers. Because of low labor costs in Mexico and the relatively important contribution of the labor input in horticultural production, U.S. producers argue that their ability to compete in the U.S. market is dramatically reduced with the removal of these tariffs. Others contend that the inefficient marketing and distribution systems in Mexico make that country a marginal supplier to the

U.S. market, and that without investment in technology and infrastructure, Mexico cannot effectively compete (Sanderson).

The objectives of this study are to identify the effects of NAFTA on (a) U.S. dry onion imports from Mexico, and (b) regional dry onion prices, production, and consumption in the United States. Dry onions for the fresh market are the focus of this study, since this product is a leading vegetable crop in the United States. The U.S. Department of Agriculture's (USDA's) *Agricultural Statistics* reflects an annual value of nearly \$500 million for this crop (USDA/Statistical Reporting Service). Historically, Mexico has supplied about 7% of fresh dry onion consumption in the United States. Although Mexico's annual share of the U.S. dry onion market is modest, its exports are concentrated in several months. While approximately 97% of the imports arrive during December through May, the arrival of nearly three-fourths of these imports is concentrated in the months of March and April. During

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The authors are professor, research associate, and visiting assistant professor, respectively, all in the Department of Agricultural Economics, Texas A&M University, College Station. Senior authorship is not assigned.

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this period, spring/summer (nonstorage) and late summer (storage) onion producers in the United States compete with Mexico for market share. Leading storage onion shipping states are Colorado, Idaho, Michigan, New York, Oregon, and Washington, while Arizona, California, Georgia, New Mexico, and Texas dominate spring/summer onion shipments [USDA/Agricultural Marketing Service (AMS), *Fresh Fruit and Vegetable Shipments by Commodities, States, and Months*].

Under provisions of NAFTA, the U.S. onion tariff is being phased out over a 10-year period, and because onions have been identified as sensitive to imports from Mexico, a "safeguard" in the form of a tariff-rate quota (TRQ) has been established at 2,881 thousand cwt. The TRQ is in effect during the phaseout; under this arrangement, within-quota imports during the January 1–April 30 period are subject to the applicable NAFTA preferential rate, while over-quota imports are subject to the pre-NAFTA tariff of \$1.75/cwt. The TRQ includes both dry and green onions, and is permitted to increase annually at a 3% compounded rate as the within-quota preferential duty is phased downward over the 10-year period. The over-quota tariff will be eliminated along with the remaining within-quota tariff at the end of the 10-year period in 2004 (USDA/Foreign Agricultural Service 1992, *Horticultural Products Review*).

## Review of Literature

Shonkwiler and Emerson measured the effect of Mexican tomato imports on the production decisions of Florida's winter tomato producers. Their empirical findings were consistent with the rational expectations hypothesis that producers respond to market information in its entirety when making acreage decisions. Taylor and Wilkowske examined the relationship between the growth in Florida producers' productivity and their ability to compete in the U.S. winter market. The study concluded that productivity growth has been a major determinant of Florida's competitive position. In a later investigation, Kalaitzandonakes and Taylor found that fresh winter vegetable crops in Florida which face competitive pressure exhibit significantly higher productivity growth than vegetable crops that face minimal competitive pressure. Simmons and Pomareda developed a mathematical program-

ming model of winter vegetable production in northwest Mexico to evaluate the possibility for further expansion into the U.S. market. Rising wage rates and tighter supply controls were projected to halt Mexico's expansion of export winter vegetables.

Several studies examining U.S.-Mexico trade have focused on market behavior, tariffs, and the impact of trade on U.S. markets. A model of international rent-seeking activities by producers was developed by Bredahl, Schmitz, and Hillman and applied to the fresh vegetable trade between the United States and Mexico. According to their findings, past coalitions to impede trade have failed, and there is free trade in winter vegetables between the two countries. Hammig and Mittelhammer showed the quantity of tomatoes supplied by U.S. producers was sensitive to changes in the tariff during the winter quarter. Eliminating the tomato tariff would reduce U.S. shipments by 23.7%, while doubling the tariff would increase shipments by 18.6%. Fuller et al. developed a structural model of the spring onion economy to analyze forces affecting Texas onion producers. They found a decline in the real exchange rate (pesos/\$) and that the U.S. tariff encouraged dry onion imports from Mexico; however, imports from Mexico were largely offset by revised market order provisions. Krissoff and Sharples simulated the impact of the NAFTA tariff phaseout with a static trade model. Their analysis suggests that U.S. producers of horticultural products would incur small income losses, and U.S. production would decrease about 2% as a result of liberalized horticultural trade.

## The Model

For this study, a spatial, intertemporal equilibrium model was developed to analyze the impact of NAFTA on U.S. onion markets. The model was formulated to depict the North American dry onion sector and was specified as a quadratic programming model of the type developed by Takayama and Judge. The following is a mathematical representation of the model. To simplify the presentation, domestic demand and supply regions are not distinguished from foreign demand and supply regions. Equation (1) is the objective function which is maximized subject to constraints (2) through (8):

- $$\begin{aligned}
(1) \quad & \sum_d \sum_m \int P_{dm}(D_{dm}) dD_{dm} \\
& - \sum_o \sum_s \sum_m \int P_{osm}(S_{osm}) dS_{osm} \\
& - \sum_o \sum_s \sum_d \sum_h \sum_m c_{sdhm} T_{osdhm} \\
& - \sum_e \sum_s \sum_m sc_{esm,m+1} I_{sem,m+1}; \\
(2) \quad & \sum_d \sum_h T_{osdhm} \leq S_{osm}, \quad \forall s, m, \text{ and } o = 1; \\
(3) \quad & \sum_e E_{esm} \leq S_{osm}, \quad \forall s, m, \text{ and } o = 2; \\
(4) \quad & E_{esm} \leq f_{se}, \quad \forall s \text{ and } m; \\
(5) \quad & I_{sem,m+1} + M_{esm} = \rho_{esm} I_{es,m-1,m} \\
& + E_{esm}, \quad \forall e, s, \text{ and } m; \\
(6) \quad & \sum_d \sum_h T_{osdhm} \leq \sum_e M_{esm}, \quad \forall s, m, \text{ and } o = 2; \\
(7) \quad & \sum_{m \leq m_1} \left( \sum_{s=MEX} S_{osm} + G_m \right) \leq b(1+r)^y, \\
& \quad \quad \quad \forall m_1 \text{ and } o = 1; \\
(8) \quad & \sum_o \sum_s \sum_h T_{osdhm} \geq D_{dm}, \quad \forall d \text{ and } m.
\end{aligned}$$

Here,  $D_{dm}$  denotes the quantity of onions consumed in region  $d$  in month  $m$ ;  $P_{dm}(D_{dm})$  denotes the inverse demand equation for region  $d$  in month  $m$ ;  $S_{osm}$  denotes the quantity of onions of type  $o$  ( $o = 1$  represents nonstorage, and  $o = 2$  represents storage onions) supplied by region  $s$  in month  $m$ ;  $P_{osm}(S_{osm})$  denotes the inverse supply equation for type  $o$  onions in region  $s$  in month  $m$ ;  $T_{osdhm}$  denotes type  $o$  onion shipments from region  $s$  to region  $d$  via transportation mode  $h$  in month  $m$ ;  $I_{sem,m+1}$  denotes the quantity of storage onions carried forward from month  $m$  to month  $m + 1$  in region  $s$  at storage site  $e$ ;  $E_{esm}$  denotes the quantity of storage onions in region  $s$  that enters storage site  $e$  ( $e = 1$  represents farm storage, and  $e = 2$  represents commercial storage) in month  $m$ ;  $M_{esm}$  denotes the quantity of storage onions shipped from storage site  $e$  in region  $s$  in month  $m$ ;  $c_{sdhm}$  denotes the per unit transportation cost from supply region  $s$  to demand region  $d$  using transportation mode  $h$  (truck or railroad) in month  $m$ ;  $sc_{esm,m+1}$  denotes the storage cost at storage site  $e$  in supply region  $s$  from month  $m$  to month  $m + 1$ ;  $f_{se}$  denotes the storage capacity at site  $e$  in

supply region  $s$ ;  $\rho_{esm,m+1}$  denotes the spoilage rate at storage site  $e$  in region  $s$  in month  $m$ ;  $m_1$  represents the months in which the safeguard provision is in effect;  $G_m$  denotes Mexico's green onion imports in month  $m$ ;  $y$  denotes NAFTA's phaseout periods ( $y = 1, \dots, 10$ );  $b$  denotes base year TRQ level; and *MEX* represents Mexico.

The objective function maximizes the integral under linear demand equations, minus the integral above linear supply equations, minus the transportation cost, minus the storage costs subject to equations (2)–(8). Equation (2) forces the total quantity of nonstorage onions shipped from each supply region to all demand regions by all modes of transportation in month  $m$  to be less than or equal to the total quantity of nonstorage onions produced in the region in month  $m$ . For each supply region  $s$  and month  $m$ , equation (3) allocates the harvested storage onions among storage sites. Equation (4) sets an upper bound on the quantity of storage onions placed in storage at each storage site. Equation (5) balances the inflow and outflow of storage onions at each storage site. For each supply region and month, equation (6) requires the quantity of storage onions shipped to all demand regions by all modes of transportation to be less than or equal to the sum of the storage onions shipped from storage site  $e$  in period  $m$ . Equation (7) incorporates NAFTA's safeguard provision and requires Mexico's exports of dry and green onions in month  $m_1$  to be less than the safeguard quota designated for that year. Equation (8) requires that the quantity of nonstorage and storage onions shipped from all supply regions satisfy monthly regional demands.

The model includes 22 U.S. demand regions and 20 U.S. supply regions. The major importing countries considered in this study are Canada and Japan, while Mexico is included as the principal exporter of dry onions to the United States. The model represents that portion of the onion crop year extending from October through June. The supply of storage onions generated in late summer that subsequently compete with Mexican imports during the winter and early spring are represented in the model, as are the spring and summer nonstorage onions harvested in the March–June period. Summer onion production in the United States does not compete with imports from Mexico since prices in Mexico often exceed those in U.S. wholesale markets during this period.

## Model Data

The above model requires the estimation of the following components: monthly regional demand equations, monthly regional supply equations for nonstorage onions, annual regional supply equations for storage onions, storage cost, spoilage rates, monthly foreign excess demand and supply equations, and transportation costs.

The monthly regional domestic demand equations for the United States were computed with average monthly regional wholesale price, monthly regional dry onion consumption, and a national own-price elasticity. Monthly regional wholesale prices were obtained from *U.S. Fresh Fruit and Vegetable Wholesale Prices in Selected Markets* (USDA/AMS). Regional dry onion consumption data compiled from the USDA's 1977-78 nationwide food consumption census, in combination with a national per capita consumption trend and regional population, were used to estimate monthly regional consumption. Unfortunately, because of small sample size and nonresponse problems, regional consumption estimates could not be taken from the USDA's 1987-88 nationwide food consumption census. Thus, it was necessary to use 1977-78 census data for the regional per capita consumption estimates. These estimates were obtained from the USDA/Human Nutrition Information Service regional household food consumption reports for 1977-78. The national per capita consumption trend was estimated with data taken from *Vegetables and Specialties: Situation and Outlook Report* (USDA/Economic Research Service). A national own-price dry onion elasticity of  $-0.2065$  was derived from Huang and used in estimation of regional demands. (The appropriateness of the assumed demand structure is discussed by Kutcher and by Koo.)

Spring and summer (nonstorage) onions are harvested and marketed within a monthly time frame. These relationships were estimated by using seasonal supply elasticities, monthly shipment data, and estimates of regional farm price. In contrast, storage onions are harvested and stored in late summer and then metered into the market throughout the subsequent storage season. Their monthly shipment pattern is determined by market prices, opportunity costs, storage costs, and shrinkage and loss. Therefore, it was necessary to estimate re-

gional annual supply equations that reflect late summer production rather than monthly supplies. Regional annual supply equations for storage onions were estimated by using supply elasticities, regional shipment data, and farm price estimates.

Supply functions were estimated for each onion class (spring, summer, and late summer or storage onions) and the elasticities derived from the estimated supply relationships.<sup>1</sup> The estimated long-run supply elasticity for storage onion production was 0.265, and the estimated supply elasticities for spring and summer production were 0.167 and 0.417, respectively.<sup>2</sup> Monthly regional shipments, in combination with the appropriate elasticity estimate and production and packing costs, were used to estimate monthly regional supply equations for spring and summer onions. Production and packing costs were used as a proxy for regional farm prices; these estimates were obtained from budgets developed by various extension service personnel in onion-producing states. Figures for monthly regional shipments of spring and summer onions were obtained from *Fresh Fruit and Vegetable Shipments by Commodities, States, and Months* (USDA/AMS). For storage onions, annual supply equations were estimated for each production re-

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<sup>1</sup> Conceptually, it seemed feasible to estimate a monthly supply relationship for each spring and summer onion producing region by merging seasonal average price by class with shipments from applicable states. Seasonal average price and production information by onion class was collected from *Vegetables Annual Summary* [USDA/National Agricultural Statistics Service (NASS)], while monthly shipments by state were taken from the USDA/AMS publication, *Fresh Fruit and Vegetable Shipments by Commodities, States, and Months*. Unfortunately, the merged data set yielded poor and unrealistic estimates of supply for all onion classes. Thus, it was necessary to base supply estimates on seasonal average price and production data (i.e., the NASS data). The inability to successfully estimate regional supply by month (nonstorage onions) and regional annual supply (storage onions) may not be significant. Cost budgets from different producing regions indicate similar production methods and technology across regions for onions within the same class. Further, based on conversations with extension personnel in leading spring and summer producing regions, production methods and technology are similar within a producing region's shipping season. This suggests similar production functions, and thus it appears appropriate to use elasticities that are based on equations estimated with seasonal average price and production data by onion class.

<sup>2</sup> The U.S. supply equations and further discussion are provided in the appendix.

gion, using data on historical shipments, an estimate of farm price, and the storage onion supply elasticity. Costs from extension service budgets served as an approximation of regional farm price, while production was estimated from shipment data. Monthly shipments throughout a producing region's shipment period were summed and adjusted upward by a regional spoilage rate to obtain regional onion production.

Mexico's monthly excess supply equations were estimated using Mexico's excess supply elasticity, monthly onion prices at the U.S.-Mexico border, and Mexico's monthly dry onion exports to the United States. The excess supply elasticity for Mexico was estimated using the following formulation (Houck; Shei and Thompson):

$$ES_e = S_e \left( \frac{P}{X} \right) - D_e \left( \frac{C}{X} \right),$$

where  $ES_e$  denotes excess supply elasticity,  $S_e$  denotes domestic own-price supply elasticity,  $D_e$  denotes domestic own-price demand elasticity,  $P$  is production,  $C$  is consumption, and  $X$  represents exports.

Mexico's domestic onion supply and demand elasticities were obtained from estimated equations that are based on model specifications found in Fuller et al. The estimated supply and demand equations had elasticities at the mean of 0.197 and  $-0.659$ , respectively. Mexico's excess supply elasticity for dry onions was estimated to be 5.5. (Refer to the appendix for Mexico's supply and demand equations and further discussion.)

The United States' monthly dry onion imports from Mexico were obtained from *Fresh Fruit and Vegetable Shipments by Commodities, States, and Months* (USDA/AMS). Because reliable data on border prices were not available, cost of onion production in Mexico and the associated marketing cost to U.S. border locations were assumed to be representative of prices. Cost of onion production in exporting regions in Mexico and the costs of transporting and marketing to U.S.-Mexico border locations were taken from a Mexican study conducted at Universidad Autonoma Chapingo (Cruz, Rindermann, and Sepulveda) and cost budgets published by Mexico's national union of producers of fruits and vegetables (Union Nacional de Organismos de Productores de Hortalizas y Frutas). The

onion tariff (\$1.75/cwt) and fees associated with inspection, brokerage, and unloading at U.S. warehouses comprise the majority of the marketing costs associated with exporting to U.S.-Mexico border locations. Total production and marketing costs varied from \$9.90/cwt to \$14.25/cwt.

The U.S.'s annual exports of dry onions comprise about 4% of fresh shipments, and historically over three-fourths of these exports have been to Canada (51%) and Japan (25%). Excess demand relationships for Canada and Japan were based on elasticities of  $-0.40$  and  $-2.25$ , respectively (Fuller, Gutierrez, and Capps). Data on monthly imports into Canada from the United States and Mexico were taken from *Vegetable Market Review* (Agriculture Canada), as were Canadian wholesale prices. Monthly imports of U.S. onions by Japan and the rest of the world were obtained from various issues of *Horticultural Products Review* (USDA/Foreign Agricultural Service), as were the values of these exports.

An estimated rate function was used to calculate all appropriate motor carrier rates; data to estimate the relationship came from *Fruit and Vegetable Truck Rate and Cost Summary* (USDA/AMS). Railroad rates were obtained for shipments from California, Idaho, Oregon, and Washington to central and eastern U.S. demand regions, since historical shipment data showed significant quantities shipped over these routes (USDA/AMS, *Fresh Fruit and Vegetable Shipments by Commodities, States, and Months*).

In the storage onion producing regions, temporary on-farm storage is available in October at a cost of \$.17/cwt. Charges for commercial storage (\$.87/cwt) are invariant with time in storage, but these costs are impacted by length of storage due to shrinkage and loss, and opportunity cost associated with the inventory of storage onions (Gillis). Shrinkage and loss data for each storage onion producing region were taken from the USDA/NASS publication, *Vegetables Annual Summary*, while opportunity cost was based on regional production cost, inventory, and a 10.5% interest rate.

### Model Validation and Procedure

To validate the model, historical data were compared with model-projected values. In particular, production of dry onions by supply region, imports

**Table 1.** Historical and Projected Dry Onion Production by U.S. Supply Region (1,000 cwts)

Supply Region	Historical	Projected
Nonstorage: <sup>a</sup>		
Arizona	480.6	475.2
California	2,443.7	2,438.8
Georgia	381.7	419.0
New Mexico	719.0	803.6
Texas	3,049.9	3,042.7
Washington	149.7	156.0
Storage: <sup>b</sup>		
California	732.1	747.0
Colorado	2,534.1	2,829.9
East Oregon/Idaho	5,864.5	5,824.0
Michigan	1,046.7	1,178.8
Minnesota	105.3	116.7
New York	2,273.7	2,541.1
Ohio	106.4	121.6
Oregon	764.6	760.2
Utah	491.6	589.1
Washington	1,854.3	1,837.0
Wisconsin	249.3	278.4

<sup>a</sup> Nonstorage represents shipments.<sup>b</sup> Storage represents shipments plus shrinkage and loss.

of Mexican onions, and consumption of dry onions by demand region were compared. The mean absolute error between historical production of dry onions by supply region and estimated production was 7.2% (table 1). In addition, estimated production by supply region was contrasted with the region's historical mean and standard deviation. The comparison showed each region's estimated production to be within one standard deviation of the historical mean, except for New York, which had a mean historic production of 2,274 thousand cwts, a standard deviation of 213 thousand cwts, and projected production of 2,541 thousand cwts.

Estimated dry onion imports from Mexico during October through June were 1,940 thousand cwts (table 2); historical imports averaged 1,843 thousand cwts. The mean absolute error was 5.3%, and the projected imports were within one standard deviation of the historical mean. Further, the regional distribution of dry onion imports among U.S. demand regions closely approximated that suggested by arrival data at selected terminal markets (USDA/AMS, *Fresh Fruit and Vegetable Ar-*

*rival Totals for 23 Cities*). Estimated monthly consumption of dry onions in the 22 demand regions closely approximated projected consumption, with a mean absolute error of 1.3%. Although model-projected values in most cases were not identical to historical averages, they were within one standard deviation of the historical values in virtually all comparisons. Based on this validation effort, the model was judged adequate to carry out the study objectives.

The validated model served as the base model (pre-NAFTA) which was subsequently manipulated to reflect the liberalized trade environment. Phaseout of the U.S. tariff was incorporated into the base model by manipulating Mexico's monthly excess supply equations, while the quota was included as an upper-bound constraint. Analysis focuses on (a) 1999, or year 5 of the 10-year tariff phaseout, and (b) complete tariff removal (free trade) at the end of year 10 (2004). The monthly excess supply equations were adjusted downward to reflect a tariff of \$.875/cwt, or half of the pre-NAFTA tariff (\$1.75/cwt) in the 1999 scenario and complete removal of the tariff in the 2004 scenario. The dry onion quota in the initial year of the tariff phaseout (1994) was estimated to be 1,940 thousand cwts, but as a result of NAFTA provisions that annually increase the quota by 3%, the quota becomes 2,176 thousand cwts in the 1999 scenario and zero in 2004 (table 2). The estimated quota on dry onions in 1994 of 1,940 thousand cwts represents about two-thirds of the established quota on green and dry onions; historically, dry onions have represented about two-thirds of all onion imports during the quota period. The likely impact of trade liberalization was determined by contrasting the base model solution with solutions that reflect tariff phaseout in combination with the quota in year 5 (1999) and complete tariff removal (free trade) in 2004.

## Empirical Results

Results focus on (a) year 5 of the phaseout period in 1999 (50% reduction in tariff with TRQ), and (b) the removal of the tariff and TRQ (or free trade) in 2004. In addition, analysis is carried out to evaluate strategies to offset the unfavorable impact of NAFTA on U.S. onion producers.

Table 2. Effect of Liberalized U.S.-Mexico Dry Onion Trade on Regional U.S. Wholesale Prices, Quantities Consumed, and Imports from Mexico

Region	Pre-NAFTA			Year 5 of Phaseout (1999)			Free Trade (2004)		
	Price (\$/cwt)	Quantity Consumed (1,000 cwt)	Imports from Mexico (1,000 cwt)	Price (\$/cwt)	Quantity Consumed (1,000 cwt)	Imports from Mexico (1,000 cwt)	Price (\$/cwt)	Quantity Consumed (1,000 cwt)	Imports from Mexico (1,000 cwt)
Northeast	16.17	5,068.5	13.9	15.94	5,086.8	0.0	15.24	5,141.0	241.6
Midwest	14.97	4,822.6	668.6	14.73	4,838.7	732.9	14.02	4,885.7	987.2
South	15.60	5,121.8	1,173.2	15.36	5,140.5	1,108.5	14.64	5,195.8	1,269.4
Central	14.12	2,767.4	50.0	13.88	2,777.4	238.2	13.17	2,806.2	252.0
Mountain	12.98	1,233.0	22.9	12.76	1,237.4	49.6	12.08	1,250.3	40.0
West	12.72	3,264.9	11.9	12.49	3,277.0	47.3	11.84	3,311.0	111.5
	14.84 <sup>a</sup>	22,278.2 <sup>b</sup>	1,940.5 <sup>b</sup>	14.61 <sup>a</sup>	22,357.8 <sup>b</sup>	2,176.5 <sup>b</sup>	13.91 <sup>a</sup>	22,590.0 <sup>b</sup>	2,901.7 <sup>b</sup>

<sup>a</sup> Weighted average U.S. wholesale price.

<sup>b</sup> Total quantity consumed or total imports from Mexico.

*NAFTA Effects*

Imports from Mexico are projected to increase approximately 12% (236 thousand cwts) in year 5 of the phaseout (1999), whereas complete removal of tariff and TRQ (free trade) will increase imports by 961 thousand cwts, or about 50% (table 2).<sup>3</sup> Because imports do not exceed the predetermined quota in 1999, all dry onions enter at the preferential NAFTA rate. Mexico's share of the U.S. market increases from the current 8.7% to 9.7% in year 5 of the phaseout (1999), and to 12.8% under free trade (2004). About two-thirds of the absolute increase in Mexican imports is concentrated in March (46%) and April (18%), with over three-fourths of the increase in imports marketed in the combined north-east (23%), midwest (33%), and central (21%) regions of the United States.

Study results show modest declines in dry onion wholesale prices in the domestic consuming regions (table 2). The national average wholesale price declines about 1.5% (from \$14.84 to \$14.61/cwt) in 1999, and 6.3% (from \$14.84 to \$13.91/cwt) with complete removal of the tariff and TRQ in 2004 (free trade). Wholesale prices decline similarly in all regions (table 2). Domestic dry onion consumption increases modestly as a result of lower prices, from 22,278 thousand cwts in the pre-NAFTA period to 22,357 thousand cwts in 1999. Under free trade, consumption increases to 22,590 thousand cwts, or 1.4% above consumption in the pre-NAFTA period. Lower dry onion prices and increased consumption increase consumers' surplus by 0.7% (\$5.2 million) in year 5 of the phaseout (1999) and by 2.8% (\$20.9 million) with free trade (2004).

Farm-level prices for nonstorage onions decline from an average of \$9.52/cwt in the pre-NAFTA period to \$9.32/cwt in 1999 (a decline of 2.1%), and to \$8.72/cwt under free trade in 2004 (a decline of 8.4%) (table 3). The decline in regional farm-level prices ranges from about 3% in Washington and New Mexico to slightly over 10% in Texas and the Imperial Valley of California. In Texas, the

weighted seasonal average price declines from \$9.99/cwt in the pre-NAFTA period to \$9.74 and \$8.89 per cwt in year 5 of the phaseout and under free trade, respectively. Nonstorage onion shipments decrease from 7,335 thousand cwts in the pre-NAFTA period to 7,224 thousand cwts with free trade. Texas shipments decline about 55 thousand cwts, representing half of the total decline in nonstorage onion shipments. Lower farm-level prices and nonstorage onion production reduce U.S. producers' surplus by 0.7% (\$1.4 million) in year 5 of the phaseout (1999) and by 3.1% (\$5.9 million) under free trade (2004).

In 1999, or year 5 of phaseout, farm-level storage onion prices decline about 2.4%; with removal of all trade constraints in 2004, prices decline 9% (table 3). Under free trade, prices are reduced by approximately 7% in New York, Michigan, Ohio, Wisconsin, and western Oregon, but near 11% in eastern Oregon/Idaho and Washington. Shipments of storage onions in the base model of 14,744 thousand cwts are reduced to 14,646 thousand cwts in 1999, and to 14,325 thousand cwts with free trade in 2004. Producers' surplus declines 1.5% (\$3.6 million) in year 5 of the phaseout (1999), and 5.7% (\$13.6 million) under free trade (2004).

Interregional trade flows show Mexico will make gains in the northeast, midwest, and central U.S. markets under free trade. To a considerable extent, these gains are associated with corresponding losses by northwest storage onion producers (tables 2 and 3). Further, in reaction to the substantial increase in Mexico's exports during March and April under free trade, northwest storage onion producers adjust their intertemporal shipment pattern by increasing shipments in the fall and early winter months and reducing shipments in the spring. However, due to the inelastic demand for dry onions, a modest increase in shipments by these producers dramatically lowers price, thus limiting additional quantities that may be shipped in the fall and early winter. The adjustment in interregional and intertemporal flow patterns by northwest storage onion producers suggests their vulnerability to free trade because of their high storage costs in the peak of Mexico's shipping period (March–April) and relatively high transportation costs to major markets.

Liberalized U.S.-Mexico trade lowers domestic farm-level price, which generates a modest increase in exports. Exports are projected to increase from

<sup>3</sup> Conversations with Ing. David Andrade, Coordinator Maestria Administracion de Empresas, Universidad Autonoma de Tamaulipas, indicate that land and water resources in Tamaulipas would not constrain the projected increase in dry onion production.

**Table 3.** Effect of Liberalized U.S.-Mexico Dry Onion Trade on Regional U.S. Farm Prices and Quantities Shipped

Region	Pre-NAFTA		Year 5 of Phaseout (1999)		Free Trade (2004)	
	Price (\$/cwt)	Quantity Shipped (1,000 cwts)	Price (\$/cwt)	Quantity Shipped (1,000 cwts)	Price (\$/cwt)	Quantity Shipped (1,000 cwts)
Nonstorage:						
South <sup>a</sup>	10.26	3,461.7	10.01	3,447.5	9.17	3,399.9
West <sup>b</sup>	8.86	3,873.6	8.72	3,861.2	8.31	3,824.1
	9.52 <sup>f</sup>	7,335.3 <sup>g</sup>	9.32 <sup>f</sup>	7,308.7 <sup>g</sup>	8.72 <sup>f</sup>	7,224.0 <sup>g</sup>
Storage:						
Northwest <sup>c</sup>	9.73	7,892.0	9.47	7,840.0	8.75	7,648.5
Mountain <sup>d</sup>	10.69	3,074.6	10.44	3,051.7	9.74	2,984.0
North <sup>e</sup>	13.11	3,777.8	12.86	3,754.3	12.14	3,692.5
	10.80 <sup>f</sup>	14,744.4 <sup>g</sup>	10.54 <sup>f</sup>	14,646.0 <sup>g</sup>	9.83 <sup>f</sup>	14,325.0 <sup>g</sup>

<sup>a</sup> Includes Georgia and Texas shipments.<sup>b</sup> Includes Arizona, California, New Mexico, and Washington shipments.<sup>c</sup> Includes California, Idaho, Oregon, and Washington shipments.<sup>d</sup> Includes Colorado and Utah shipments.<sup>e</sup> Includes Michigan, Minnesota, New York, Ohio, and Wisconsin shipments.<sup>f</sup> Weighted average farm price.<sup>g</sup> Total quantities shipped.

1,500 thousand cwts in the pre-NAFTA period to 1,619 thousand cwts with free trade, a 7.9% increase. During year 5 of the phaseout (1999), exports increase about 2.1%. The principal producing sectors that benefit from the increased exports are in the northwest, which supplied over 70% of U.S. exports. The modest increase in exports by the northwest only partially offsets that region's loss in the domestic market. Other significant exporting regions were California, New York, Texas, and New Mexico.

#### *Effects of Reduced Production Costs and Shrinkage/Loss*

About 80% of the projected decline in U.S. dry onion output under free trade in 2004 (531 thousand cwts) is associated with storage onion production. To evaluate the feasibility of offsetting the unfavorable impact of NAFTA on storage onion producers, scenarios are analyzed which involve lower production costs and reduced shrinkage and loss while in storage. Regional production costs vary between \$6

and \$7.50/cwt. Scenarios are evaluated which involve \$.50 and \$1/cwt reductions in these costs. Nationally, about 20% of U.S. storage onion production is lost through shrinkage and loss during the storage season (USDA/NASS, *Vegetables Annual Summary*). Because improved controlled storage environments hold promise of reducing shrinkage and loss, scenarios are evaluated which involve 20 and 50% reductions. Scenario results are contrasted with the free-trade solution to identify the effectiveness of the various strategies in improving producers' welfare.

Reductions in production costs have the expected effect on storage onion producers. With lowered production costs, the farm-level prices decline, storage onion production increases, imports from Mexico are reduced, and U.S. producers' surplus decreases. A \$.50/cwt reduction in storage onion production cost lowers average farm price from \$9.83/cwt to \$9.70/cwt, increases producer shipments by 220 thousand cwts (from 14,325 thousand cwts to 14,545 thousand cwts), reduces imports from Mexico by 167 thousand cwts (from 2,901

thousand cwts to 2,734 thousand cwts), and lowers producer surplus by \$8.8 million. A \$1/cwt reduction in production cost is projected to lower farm price to \$9.57/cwt, increase storage onion shipments to 14,797 thousand cwts, reduce imports from Mexico to 2,538 thousand cwts, and decrease storage onion producers' welfare by \$17.4 million.

Reduced shrinkage and loss during storage lowers the effective storage cost, reduces the level of production necessary to attain a particular level of shipments, and lowers opportunity cost. A 20% reduction in shrinkage and loss is projected to lower average storage onion price from \$9.83/cwt to \$9.74/cwt, increase onion shipments from 14,325 thousand cwts to 14,704 thousand cwts, lower Mexico's exports to the U.S. from 2,901 thousand cwts to 2,573 thousand cwts, and increase producer surplus by \$2.3 million. Reducing storage onion shrinkage and loss by 50% reduces average farm price to \$9.47, increases storage onion shipments to 15,322 thousand cwts, reduces imports from Mexico to 2,079 thousand cwts, and increases producer surplus by \$3.8 million. These results indicate that improved storage methods represent a superior alternative for offsetting the unfavorable influence of NAFTA on storage onion producers. Based on this outcome, additional research into storage systems and their economic feasibility appears to be warranted.

### Summary and Conclusions

A spatial, intertemporal model of the North American dry onion economy was developed to determine the impact of implementing the NAFTA provisions. Under these provisions, the U.S. tariff on dry onion imports (\$1.75/cwt) is phased out over a 10-year period. During this phaseout, a tariff-rate quota (TRQ) is instituted to provide protection to U.S. producers. This study evaluated the impact during the fifth year of the phaseout (1999) and after removal of the tariff and TRQ (with free trade in 2004).

Results indicate a large percentage increase in the importation of dry onions from Mexico as a result of reduced U.S. tariffs. A 50% reduction in the U.S. tariff (year 5 of phaseout, 1999) increases imports by 12%, whereas complete removal of tariff and TRQ (free trade) increases imports by about 50%. In spite of the dramatic increase in imports

(50%), Mexico's share of the U.S. dry onion market remains modest, increasing from 8.7% to 12.8%.

Farm-level prices in the U.S. decline as a result of increased imports; in particular, nonstorage onion prices decline about 8.4% under free trade in 2004, while storage onion prices decline about 9%. Shipments by nonstorage onion producers decline about 1.5% with free trade, and shipments by storage onion producers decline about 2.8%. With free trade, wholesale prices decline 6.3%, and domestic onion consumption increases a modest 1.4%. The lower farm-level prices that result from increased imports are projected to increase exports by 7.9%.

The effect of removing the dry onion tariff and TRQ is disproportional across producing regions. About half of the reduction in nonstorage onion production is projected to occur in Texas. Texas spring onion shipments commence in March and peak in April and May, while imports from Mexico peak in March and April, thereby creating considerable overlap in shipping patterns. Nearly 60% of the decline in storage onion shipments is located in the northwest states. The northwest region markets significant quantities of storage onions in March and April, and thus competes with Mexico's peak export period. Storage onion shipments during March and April have incurred substantial storage costs and, because this region ships to markets at extended distances (central and eastern U.S.), the region appears to be vulnerable to the projected increase in Mexican onion imports.

Scenarios were evaluated to determine the feasibility of offsetting the unfavorable impact of NAFTA on storage onion producers. Analysis showed reduced production costs (i.e., downward shifts in the regional supply functions) would lower imports from Mexico and increase dry onion shipments, but would lower farm prices and producers' surplus. The more promising alternative involved lowering of shrinkage and loss during the storage season. Improved storage methods would lower farm prices, lower imports from Mexico, increase storage onion shipments, and increase producers' welfare. A 20% reduction in spoilage and loss was projected to increase producers' surplus by \$2.3 million per year relative to the free trade outcome. However, the gain only partially restores the producers' \$13.6 million decline in surplus that results from free trade.

In conclusion, under free trade, modest declines

in dry onion prices and production are likely to occur, but the expected changes are less than the historical year-to-year variation in these variables. The analysis shows U.S. onion producers to be unfavorably impacted by the removed tariff, but not economically devastated. Regardless, the movement to free trade will force less efficient dry onion producers in the United States to exit the industry.<sup>4</sup>

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<sup>4</sup>This study fails to consider the possible dynamic processes which may occur over the TRQ phaseout. It would be possible to include projected adjustments in Mexico's onion demand that may occur as a result of changes in its income and population by modifying Mexico's excess supply equations. However, reliable projections of Mexico's highly variable per capita income are not available. Rather than confound the results with speculation about Mexico's future population and income, this study focuses on a period during which reliable information is available. If real per capita income in Mexico were to grow during this phaseout, increased domestic consumption of dry onions may limit that country's ability to export. In addition, the estimated supplies in the U.S. supply regions reflect historical shipment patterns and production technology. If these factors are modified during the phaseout, the projected production and prices are less likely. Finally, the analysis may under- or overestimate U.S. producers' response to lower dry onion prices. During the phaseout, relative domestic prices of horticultural products may be altered, thus impacting producers' incentives to produce onions as well as other horticultural products.

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## Appendix

### U.S. Supply Equations and Discussion

It was hypothesized that dry onion supply was a function of lagged onion price, lagged onion production, an index of input costs, and time. The time variable was included as a proxy for changes in onion production technology. Recent research by Buxton and by Ornelas and Shumway suggests the expected price of other vegetables does not explain changes in onion production. Therefore, returns to a competing crop were not included in our specified onion supply equations. The estimated equations are based on the 1969–90 period. Historical price and production data were obtained from *Agricultural Statistics* (USDA/Statistical Reporting Service), and the index of prices paid by farmers for inputs was taken from the *Economic Report of the President* (Congress of the U.S., Council of Economic Advisors).

#### Spring supply equation:

$$\begin{aligned} \ln(Q) = & 8.6772 + 0.167 \ln(LPR) \\ & (3.005) \quad (3.005) \\ & - 0.125 \ln(IPC) + 0.01899T \\ & (-1.070) \quad (2.785) \\ \text{Adjusted } R^2 = & 0.93, \quad DW = 1.7908 \end{aligned}$$

#### Summer supply equation:

$$\begin{aligned} \ln(Q) = & 4.673 + 2.43 \ln(LPR) \\ & (2.09) \quad (2.795) \\ & - 0.1741 \ln(IPC) \\ & (-1.134) \end{aligned}$$

(continued)

$$+ \frac{0.418 \ln(LQ)}{(1.809)} + \frac{0.01959T}{(1.744)}$$

$$\text{Adjusted } R^2 = 0.71, \text{ Runs Test} = 1.0699$$

*Late summer or storage supply equation:*

$$\ln(Q) = \frac{4.9458}{(1.84)} + \frac{0.148 \ln(LPR)}{(2.595)}$$

$$- \frac{0.014 \ln(IPC)}{(-0.098)}$$

$$+ \frac{0.4426 \ln(LQ)}{(1.715)} + \frac{0.01739T}{(1.353)}$$

$$\text{Adjusted } R^2 = 0.93, \text{ Runs Test} = -0.2880$$

For the above equations, numbers in parentheses denote *t*-test values, and the variables are defined as follows:

$Q$  = total seasonal onion production (1,000 cwt);

$LPR$  = lagged weighted seasonal dry onion price (\$/cwt, with 1980 = 100);

$LQ$  = lagged total seasonal onion production (1,000 cwt);

$IPC$  = index of prices paid for inputs by farmers (1980 = 100); and

$T$  = time (with 1 = 1969, 2 = 1970, ..., 23 = 1990).

The estimated equations have relatively high goodness-of-fit measures, and signs on included variables are as expected. The exception was the spring supply equation, where the lagged production variable had an unexpected sign. However, this variable was insignificant at the 10% level; hence it was removed from the estimated spring onion supply equation. The Durbin-Watson test and the runs tests revealed no autocorrelation. For increased insight into the estimated equations, see Fuller, Gillis, and Ziari.

### *Mexico's Supply and Demand Equations and Discussion*

The specified demand and supply models for dry onions in Mexico were analogous to those presented by Fuller et al. Mexico's annual production of dry onions ( $MXP$ ) was specified as a function of Mexican price lagged one year ( $LMXPR$ ), exports to the United States in the previous year ( $LMXEX$ ), and a proxy of production cost ( $MXPC$ ). Mexico's average annual dry onion price ( $MXPRR$ ) was determined by apparent per capita consumption ( $MXC$ ), Mexico's exports to the United States ( $MXEX$ ), and real per capita income ( $MXPCI$ ). The following equations are based on 1971-92 data.

*Mexico supply equation:*

$$MXP = \frac{492150.0}{(3.190)} + \frac{596.22 LMXPR}{(3.055)}$$

$$+ \frac{3.7899 LMXEX}{(4.974)} - \frac{3810.0 MXPC}{(-4.974)}$$

$$\text{Adjusted } R^2 = 0.86, \text{ DW} = 1.892$$

*Mexico demand equation:*

$$MXPRR = \frac{262.43}{(-1.090)} - \frac{46.18 MXC}{(-2.457)}$$

$$+ \frac{0.00916 MXEX}{(1.135)} + \frac{19.45 MXPCI}{(3.188)}$$

$$\text{Adjusted } R^2 = 0.64, \text{ DW} = 2.195$$

For the above equations, numbers in parentheses denote *t*-test values, and the variables are defined as follows:

$MXP$  = Mexico's annual production (metric tons);

$LMXPR$  = lagged Mexico onion producer price (\$/metric ton, with 1978 = 100);

$LMXEX$  = lagged Mexico onion exports (metric tons);

$MXPC$  = Mexico production cost index (1978 = 100);

$MXPRR$  = Mexico onion retail price (\$/metric ton, with 1978 = 100);

$MXC$  = Mexico's apparent per capita onion consumption (kilograms);

$MXEX$  = Mexico onion exports (metric tons); and

$MXPCI$  = Mexico's per capita income (pesos, with 1978 = 100).

The estimated equations have relatively high goodness-of-fit values, and signs on included variables are as expected. All variables are significant at the 5% level, except Mexico exports ( $MXEX$ ) in the demand equation, and the Durbin-Watson tests indicate no autocorrelation. Mexico's onion production and producer price information were obtained from *Anuario Estadístico de la Producción Agrícola Nacional* (Secretaría de Agricultura y Recursos Hidráulico), while the *Indice de Precios, Cuaderno Mensual* (Banco de México) was the source for retail prices. The production cost index was the real wage rate, and real per capita income was based on gross domestic product, population, and the consumer price index; necessary data sets came from *International Financial Statistics* (International Monetary Fund). Data on dry onion exports to the U.S. came from *Fresh Fruit and Vegetable Shipments by Commodities, States, and Months* (USDA/AMS).