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Welfare Impacts of the Mexico Potato Quarantine

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Under the North American Free Trade Agreement (NAFTA) tariffs on U.S. potato imports to Mexico were phased out by 1993. Citing phytosanitary issues, in 1996, the Mexican government placed quantitative restrictions on U.S. potato imports and restricted their import only to designated border areas. This article estimates the welfare cost of restricting U.S. potato imports into Mexico. We find that removing trade restrictions may lead to over 1.8 million tons of new imports into Mexico, a gain of consumer surplus of 4.0 billion pesos per year, and a loss of 2.9 billion pesos of producer surplus.

Key Words: international trade, non-tariff barriers, potatoes, quarantine, sanitary and phytosanitary barriers, welfare loss

JEL Classifications: F13, L13, Q13, Q17, C35

Potato consumption in Mexico grew from 1.08 million metric tons (MT) in 1994 to over 1.77 million MT in 2004, an increase of some 65.0% in a decade (Food and Agricultural Organization, 2008). Over the same period, however, imports have grown more quickly, from 165.8 thousand MT to 421.9 thousand MT (154.0%). Although the rise in imports is notable, it is perhaps more surprising that import volumes have not risen further yet, given the relatively high price of potatoes in Mexico. Despite the implementation of NAFTA, which abolished all tariffs and tariff-quotas on potatoes by 2003, trade in fresh potatoes between the United States and Mexico continues to be restricted by phytosanitary regulations. Mexican trade officials argue that U.S. potatoes are infested with pests and diseases that are not present in Mexico, so U.S. potato imports are limited to a 26 km exclusion zone adjacent to the U.S. border. This research investigates the welfare effects of restricting trade in U.S. potatoes from a Mexican consumer perspective.

In the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) reached as part of the Uruguay Round of the World Trade Organization in 1995, member nations agree to be bound by a set of protocols governing the use, and abuse, of SPS regulations on traded agricultural products (Roberts and Krissoff, 2004). One of these protocols allows for the use of a limited set of regulations that are designed to reduce the likelihood of a food, plant, or animal health incident. Although not a violation of the letter of the SPS agreement, U.S. potato growers and trade officials are concerned that Mexican SPS regulations are being used as a tool of commercial policy, rather than legitimate means of

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protecting their own producers or consumers. From an economist perspective, efficient trade policy requires regulators to restrict trade in the name of SPS only to the extent that the value of protecting either producers or consumers is greater than the cost of giving up lower-cost imports (Orden and Romano, 1996).

Although most research on SPS trade restrictions find them to be welfare-reducing (Calvin and Krissoff, 1998; Peterson and Orden, 2008), the one study that specifically addresses this issue finds the opposite (Tecnologico de Monterrey, 2007). Welfare-enhancing SPS trade barriers are theoretically possible if domestic producers increase supply in the absence of a threat from contamination. However, these benefits must be weighed against the cost of higher domestic prices. Ultimately, therefore, resolving the question is an empirical matter. This study attempts to do so by developing an empirical model of Mexican potato supply, demand, and economic welfare.

In the next section, we present some background and additional details on the nature of Mexican potato imports, and the policy governing them. In the second section, we describe a simple economic model of trade in which a small country imposes SPS restrictions, or technical barriers to trade (TBT), on imports from a large country. We use this model to derive some expected results, which are tested in the empirical analysis that follows. The third section describes the econometric model used to estimate the trade and welfare effects of relaxing the technical barriers to trade, while the fourth provides a brief description of the data used to estimate the model. In the fifth section, we summarize the econometric estimation and welfare simulation results and discuss the implications that follow. The final section concludes and draws some important caveats to our findings.

Background on Mexico Potato Import Policy

From the signing of the NAFTA agreement until full implementation, exports of U.S. and Canadian potato products to Mexico still faced tariff-based restrictions. Under the tariff-rate quota system that began in 1993, U.S. exporters could sell 15,000 tons into Mexico tariff-free with a tariff of 272% applying to all amounts above the quota level (Table 1). To gradually move toward completely tariff-free imports, the quota rose to 19,000 tons per year by 2002, with a tariff-rate of 51.6% applying to all over-quota amounts. Throughout the transition period, however, actual U.S. imports were significantly under the quota level each year. Beginning in 2003, there were no quotas or tariffs in place as per the NAFTA agreement, however, SPS regulations established in 1996 were still in place.

In 1996 the Mexican government established an "... external quarantine aimed to prevent introduction of potato-related pests..." aimed at excluding potatoes that may carry a number of possible diseases including golden nematode, potato virus Y, potato yellow dwarf virus, and a number of others (Senasica, 2008). This quarantine banned all potato imports from the major growing regions in the United States (primarily the Pacific Northwest) and limited imports from other states to a 26 km zone along the United States/Mexico border.[1] Although the zone includes many large Mexican cities and some 6.5 million residents, it nonetheless effectively prevents most Mexican consumers from buying potatoes imported from the United States. Mexican agricultural authorities maintain that these pests do not exist in Mexican production regions, and if they were to become established, control costs would rise and impose significant economic damage on domestic potato producers. U.S. authorities from United States Department of Agriculture Animal and Plant Health Protection Service have continually challenged the scientific basis of the quarantine, arguing that the pests claimed in the regulation were already present in Mexico (Qaim, 1998). In 2003, Mexican and U.S. agricultural officials signed an agreement in which Mexico agreed to permit imports from any U.S. state into Mexico and to

[1] In the context of the Mexican trade policy, "quarantine" refers to a policy of excluding all imports deemed to be at risk for contamination to an agricultural zone in which potatoes are not produced. Note that this usage differs from the typical use of the term quarantine.

Table 1. Tariff and Tariff-Rate Quota Schedule for Mexican Imports of U.S. Potatoes

Year	Ad Valorem Tariff Rate (%)	Dollar/Kg Tariff Rate	Quota (MT) U.S.	Quota (MT) Canada	Actual Imports from U.S. (MT)
1992					2,091
1993	272.0	0.354	15,000	4,000	2,767
1994	261.1	0.339	15,450	4,120	3,565
1995	250.2	0.325	15,814	4,244	2,728
1996	239.3	0.311	16,391	4,371	881
1997	228.4	0.297	16,883	4,502	83
1998	217.6	0.283	17,389	4,637	508
1999	206.7	0.269	17,911	4,776	4,296
2000	155.0	9.201	18,448	4,920	6,485
2001	103.3	0.134	19,002	5,067	4,747
2002	51.6	0.067	0	0	2,110

Source: Tecnologico de Monterrey, 2007 and FASOnline (United States Department of Agriculture, Foreign Agricultural Services, 2008).

relax the 26 km zone restriction within 2 years. Although potatoes can move from any state into Mexico, the 26 km zone regulation has not been removed.

The market for fresh potatoes in Mexico is potentially lucrative for U.S. growers, but is highly complex. First, the Mexican market is better described as a number of regional markets, each with its own unique preferences and locally competing production. Although residents in the southern part of Mexico tend to consume more corn (in the form of tortillas) and rice, potato consumption is more common in the temperate northern states. Consumption and local supply tend to be highly correlated—22 states in Mexico grow potatoes—but the primary production regions lie along or near the Pacific Coast with 35% of total production in Sinaloa and 26% in Sonora. Other important producing states are Guanajuato (Central Mexico), Veracruz in the Gulf of Mexico, and Chihuahua in the North. Although Americans tend to think of the typical Mexican carbohydrate as either rice, corn, or perhaps beans, potato consumption forms a significant part of the daily diet at approximately 37.4 lbs per capita per year (Barquera et al., 2006). Domestic Mexican potatoes, however, are different from the U.S. potatoes that are exported to Mexico. Mexican growers primarily produce the alpha variety, which are smaller, rounder, and have a thin skin and yellow flesh compared with the large, white, thick-skinned U.S. imports. Alpha potatoes account for 60% of total production, whereas red potatoes make up 15% and 25% are other varieties (Santiago-Cruz and Salazar, 2000). Despite their dominance of the fresh market, alpha potatoes are not particularly well-suited for deep-frying, however, so the vast majority of Mexican processed and processing needs are imported from the United States. Although Mexico imported 55.9 thousand metric tons of fresh potatoes in 2007, it imported over 85.3 thousand metric tons of frozen potatoes (United States Department of Agriculture, Foreign Agricultural Services, 2008). Of the total Mexican potato output in 1999, 73% went to fresh usage, 14% to potato chips, and 13% to seed, leaving very little for domestic frozen production (Jabalera et al., 2000). Given that the population of Mexico now exceeds 100 million, the market potential for U.S. potato exporters is clear.

Observed price differences between imported U.S. potatoes and domestic Mexican potatoes suggest that, despite the partial liberalization in 2003, trade is still far from free. Clearly, there is an equilibrium price differential that can only be maintained with some sort of regulatory prevention of arbitrage. The relevant question, therefore, becomes one of finding the level of trade that would be consistent with Mexican prices equaling world market prices for potatoes.

Economic Model of Quantitative Trade Restrictions

The barriers to U.S. potato imports used by the Mexican government constitute "regulatory protection" in that they insulate Mexican potato growers from U.S. competition (Josling, 1997). Regulatory protection implies that the existing regime of geographic quarantines effectively shifts the excess supply curve backward at all price levels. As Baldwin (1991) explains, such trade barriers can be conceptualized in many different ways, depending upon their impact on exporters. Paarlberg and Lee (1998), Petry, Paarlberg, and Lee (1999), and Peterson, Paggi, and Henry (1988) explain recent examples of cases involving foot-and-mouth disease, porcine reproductive and respiratory syndrome, and European Union (EU) restrictions on hormone use in imported products, respectively, while Sumner and Lee (1997) describe a model of trade restrictions on the import of rice by East Asian nations. Beyond agriculture, Hickock (1985) applies a similar, partial-equilibrium model to the evaluation of U.S. trade barriers on clothing, sugar, and steel. The Mexican potato case is somewhat unique in that it both imposes costs on U.S. exporters in terms of meeting inspection and handling protocols for potatoes that move into the 26 km zone, and imposes an outright ban on movement beyond. Consequently, the quarantine can be thought of as increasing the cost of exporting to the border zone, and creating a dual market within Mexico. Because the border zone does not fully comprise any particular state, it is not possible to completely distinguish the demand for U.S. and Mexican potatoes from publicly available data as in the U.S. avocado ban example discussed by Peterson and Orden (2008) and Orden and Romano (1996). However, consumers in the border zone are free to consume either potatoes imported from the U.S., those produced locally, or brought in from areas outside the quarantine zone. Therefore, this intermingling of U.S. imports and domestic product ensure that price arbitrage, subject to inherent price differences due to differentiation and transport costs, must exist. Any difference between the price of U.S. imports, adjusted for differentiation and transport, and the domestic price of Mexican potatoes must be attributed to the cost of the TBT.[2] In effect, the quarantine drives a wedge between the world (U.S.) price and the domestic Mexican price and reduces trade volumes (Beghin and Bureau, 2001; Calvin and Krissoff, 1998; Josling, 1997). Because the quarantine constitutes a TBT that causes observed consumer prices in Mexico to be higher than import prices from the United States, the "price wedge" model is appropriate in this case. Similar to other price wedge studies (Calvin and Krissoff, 1998; Yue, Beghin, and Jensen, 2006), we assume all of the difference between the domestic Mexican price and the world (U.S.) price is represented by a "tariff-equivalent" value, or the shadow price of constrained U.S. imports in the Mexican market. Therefore, we write the relationship between the two prices (assuming trade is not zero so we are not at a corner solution) under the law of one price as:

$$(1) \qquad p_m = p_u(1 + \tau),$$

where p_m is the domestic Mexican consumer price, p_u is the price in Mexico (in pesos, appropriately converted using a real exchange rate, after freight costs and insurance) of U.S. (imported) potatoes, and τ is the amount of a hypothetical tariff that would achieve the same trade volumes as the ban placed by the Mexican government.

Typically, price wedge studies assume the domestic and imported products are perfect substitutes. In the U.S./Japan apple case, however, Yue, Beghin, and Jensen (2006) argue that agricultural practices and other factors mean that Japanese and U.S. apples, even those of the same variety, are perceived as significantly different to consumers. Similarly, Mexican and U.S. potatoes differ in both visual and eating attributes. Although the Mexican alpha potato is small, round, and has yellow flesh, the primary U.S. export is the Russett Burbank, which is larger, has a rougher brown skin and white

[2] The Mexican policy is not equivalent to a quota because importers within the 26 km zone are free to import all they wish.

flesh. For this reason, we account for the differentiated nature of U.S. exports to explain some of the departure from the arbitrage condition shown in Equation (1) above.

Most analyses of trade in differentiated products use a variant of the constant elasticity of substitution (CES) demand model (Peterson and Orden, 2008, for example). However, the CES has the undesirable characteristic that elasticities are not affected by crowding the product space. Intuitively, we would expect that adding a product to a characteristic space of fixed size will lead to higher price elasticities, and hence lower prices, for all. Further, in a differentiated products context, consumers tend to buy only one of the range of available variants, not a small amount of each as the CES model assumes. Therefore, we follow Anderson, de Palma, and Thisse (1992) (ADT) and Anderson and de Palma (1992) and adopt a discrete choice model of demand. To our knowledge, this is the first application of the discrete choice approach to the analysis of TBT. Using a discrete choice approach has several advantages. First, the model yields relatively parsimonious, analytical solutions that are readily amenable to uncovering the equilibrium value of the TBT. Second, as ADT show, the discrete choice model can be equivalent to the more common CES approach, but is a more logically consistent description of consumer choice for differentiated food products. Third, the logit model used here does not impose the unrealistic assumption that substitution elasticities are invariant to the number of products in the market. Rather, as more varieties are introduced in the discrete choice model, the elasticity of each variant rises, and equilibrium prices fall, as theory would lead us to expect.

Preferences for a representative consumer, h, in a discrete choice model of demand are expressed in terms of a random utility model in which the indirect utility function for the consumer are given as:

$$(2) \qquad u_j^h = \gamma_j - \alpha p_j + \sum_k \beta_k x_{jk} + \xi_j + \mu\varepsilon_j^h,$$

where p_j is the price of choice j ($j = o$, m, and u for the outside, Mexican, and U.S. options, as well as r, b, and c for rice, beans, and corn, respectively), x_j is a $k \times 1$ vector of attributes of choice j, γ is a choice-specific preference parameter, α is the (constant) marginal utility of income, ξ is an error term that is unobservable to the econometrician (factors such as variations on potato quality, media information about either nutritional or safety attributes of potatoes, or other important demand-shifters that are fundamentally unobserved), and ε_j^h is an iid error term that is assumed to be double-exponentially distributed with scale parameter, $0 < \mu < 1$. In the potato context, μ represents the degree of heterogeneity between domestic and imported potatoes so that if $\mu = 0$, Mexican and U.S. potatoes are regarded as perfect substitutes by Mexican consumers, despite their obvious observable differences. Define the mean utility from choice j as: $\delta_j = \gamma_j - \alpha p_j + \sum_k \beta_k x_{jk} + \xi_j$, so that the probability of choosing j is written:

$$(3) \qquad P(j = 1) = \frac{e^{\frac{\delta_j}{\mu}}}{\sum_{i=0}^{I} e^{\frac{\delta_i}{\mu}}},$$

where $i = 0$ reflects the choice of an outside option, which yields utility that is normalized to zero. Aggregating over all representative consumers with this expression means that the aggregate market share of choice j is simply: $S_j = e^{\frac{\delta_j}{\mu}} / \sum_{i=0}^{I} e^{\frac{\delta_i}{\mu}}$.

To find the equilibrium value of τ, however, we must also take into account the expected response by Mexican potato suppliers to any change in their supply price. Assuming a fully integrated potato supply chain in Mexico, so that retailers and growers' interests are aligned, potato suppliers are faced with the following optimization problem:[3]

$$(4) \qquad \pi_m^r(p_m) = M[p_m - c_m(q_m(p_m))]S_m,$$

where M is the size of the total market for potatoes and potato substitutes. Assuming potato retailers compete in prices and marginal cost is convex in q_m, and substituting the arbitrage

[3] Clearly, this is a simplification of the true potato supply chain. Modeling retailers and growers separately, however, is not necessary for the conclusions we derive and does not affect the qualitative nature of our solution.

relationship in Equation (1) in the result provides an expression for τ that takes into account both demand and supply response for a differentiated product:

$$\tau = \frac{S_u(1 - S_u)(1 + \alpha(p_u - c_u)) + S_m(1 + S_m)(1 - (p_u - \varphi c_m))}{\alpha S_m(1 - S_m)} \tag{5}$$

where: φ is the product of the elasticity of supply and elasticity of cost with respect to quantity (marginal cost curve slope).[4] The value of the TBT on U.S. potatoes, therefore, is a function of the price of each type of potatoes, preferences for each, the marginal cost of production, and the response of domestic Mexican suppliers.

On the supply-side, Mexican producers face choices as well. Although other trade studies may explicitly recognize the differentiated nature of product demand (Yue, Beghin, and Jensen, 2006), few consider the options available to suppliers in the domestic industry. Therefore, we adopt a multiproduct supply model that describes output allocation and supply response in a manner consistent with the theory of the firm. Specifically, we model the supply of alpha-type Mexican potatoes using a Generalized Leontief (GL) profit function approach (Diewert, 1971; Shumway and Lim, 1993) in which suppliers distribute potatoes, corn, beans, and rice for the domestic market. Applying Hotelling's Lemma to the GL profit function provides a system of output supply functions of the form:

$$\begin{aligned} q_i(p_1, p_2, \ldots, p_n) = \gamma_{i0} + \gamma_{ii}\left(\frac{1}{p_i}\right)^{\frac{1}{2}} + \sum_{j=1}^{n-1} \gamma_{ii}\left(\frac{p_j}{p_i}\right)^{\frac{1}{2}} \\ + \sum_k \tau_{ik} X_k, \qquad i = 1, 2, \ldots n, \end{aligned} \tag{6}$$

where p_i is the price of netput i, q_i is the quantity supplied, and $\boldsymbol{X}$ is a vector of exogenous supply factors, which we model empirically below as including annual differences in production conditions and seasonal variation in supply. With this specification, the elasticity of supply (ε_s) is given by:

$$\begin{aligned} \varepsilon^s = \frac{\partial q_i}{\partial p_i}\frac{\partial p_i}{\partial q_i} = -\left(\frac{1}{p_i}\right)\left(\gamma_{ii}\left(\frac{1}{p_i}\right)^{\frac{1}{2}} \right. \\ \left. + \sum_{j=1}^{n-1} [\gamma_{ij}\left(\frac{p_j}{p_i}\right)^{\frac{1}{2}}\right), \qquad i = 1, 2, \ldots, n], \end{aligned} \tag{7}$$

which, once estimated, can be used to calculate the value of the TBT in Equation (5) above.

The difference between the aggregate supply of domestic potatoes implied by Equation (6) and demand implied by Equation (3) at the value of τ given by Equation (5) determines the impact of removing the quarantine on Mexican producer and consumer welfare. More trade, however, does not necessarily mean that all stakeholders in the importing country are better off. To estimate the gains from trade due to removing the SPS trade restrictions, it is necessary to calculate the change in both consumer and producer surplus. The change in consumer surplus (ΔCS) is found by calculating the total amount of CS at a price $p_u + \tau$ and subtracting the total CS without trade restrictions (at price p_u), or:

$$\begin{aligned} \Delta CS &= (p_u + \tau - p_u)q_d^0 + \left(\frac{1}{2}\right)(q_d^1 - q_d^0)\tau \\ &= \left(\frac{1}{2}\right)\tau(q_d^0 + q_d^1), \end{aligned} \tag{8}$$

where q_d^0 is the quantity demanded before removing the trade regulation and q_d^1 is the hypothetical or counterfactual quantity demanded without the trade restriction. The potential change in producer surplus (ΔPS), on the other hand, is the difference between the price received in the market and production cost, or:

$$\begin{aligned} \Delta PS &= (p_u + \tau - p_u)q_S^1 + \left(\frac{1}{2}\right)(q_S^0 - q_S^1)\tau \\ &= \left(\frac{1}{2}\right)\tau(q_d^0 + q_d^1). \end{aligned} \tag{9}$$

where q_S^0 and q_S^1 are defined analogously to the demand values above. Producer surplus is thus

[4] Without data on the marginal cost of producing potatoes in Mexico, we assume the marginal cost elasticity is 1.0, so the value of φ is equal to the supply elasticity.

easily calculated once the quantity supplied at each point is estimated. Note in both of these cases, however, that the calculations are linear approximations to the true demand and supply functions. To the extent that the actual curves are nonlinear in the region of the price change contemplated here, these estimates will imply a small error in approximation. Given that the change in price is relatively small, this error will not affect the qualitative nature of our conclusions.

Implementing Equation (5) to find the amount by which trade is reduced by SPS regulations requires: (1) the estimation of ε_D, (2) the estimation of ε_S, and (3) the calculation of τ. Although we describe how the elasticities of supply and demand are estimated below, determining the appropriate value of τ is typically more problematic as it requires accurate data on domestic and world (border) prices for the imported good. The cost-insurance-freight world price, which includes transportation and insurance costs, is, in theory, the most appropriate value to compare with the domestic price. By including all transit costs, the gap between domestic and world price is assumed to include only tariff and the implicit value of nontariff barriers (NTBs). In this sense, once explicit tariffs are taken into account, the value of all NTBs becomes a residual that is imputed from observed price data. The implicit value of the NTB, or its tariff-rate equivalent, is the value of the implicit tariff that would restrict trade to the level implied by the NTB.

Econometric Model of Trade Restrictions

In order to parameterize the welfare model described above, we estimate two econometric models: (1) Mexican potato demand, and (2) potato supply. The demand model reflects the fundamental difference between imported potatoes, those produced domestically in the U.S., and all other substitute options while the supply model reflects the alternative product opportunities available to Mexican growers.

Mexican potato demand is modeled using the representative consumer, discrete choice approach (Anderson and de Palma, 1992; Anderson, de Palma, and Thisse, 1992) described in Equation (3) above. Specifically, we assume consumer preferences are given by a random utility model with consumer heterogeneity described by an extreme value distribution function, from which we derive an estimable demand system for domestic and imported potatoes as well as all potato substitutes. To derive an estimable version of Equation (3), we follow Berry (1994) and linearize the aggregate share function so that the market share of each product is written:

$$\ln(S_j) - \ln(S_0) = \gamma_j - \alpha p_j + \sum_k \beta_k x_{jk} + \xi_j, \qquad i = 1, 2, \ldots, n. \tag{10}$$

and the unobservable error term, ξ_j, becomes the econometric error term. In a discrete choice demand model, each of the γ_j parameters are product-specific preference parameters. Although it would be preferable to have detailed product attribute, marketing mix, and other variables to include in the vector $\boldsymbol{x}_j$, in this application, we know very little detail about the products that are consumed so the vector of attributes consists of monthly and yearly binary variables. Including monthly binary variables is important because Mexican consumers rely primarily on domestic production for supply (and imports from the United States), so the potato market is subject to seasonal fluctuations both in availability and quality. The outside option is intended to reflect all other consumption possibilities available to Mexican consumers that may substitute for domestic potatoes, imported potatoes, or the rest of the products considered "inside" (Berry, Levinsohn, and Pakes, 1995). Therefore, we define the outside option as the per-capita volume of all food not committed to the starchy staples considered here as measured by a standard, nation-wide food consumption survey (Barquera et al., 2006). All quantities are measured in kg per capita, and prices in pesos per kg and represent national average values. Because the linearized logit model has a closed form solution, we estimate using standard instrumental variable techniques, specifically two-stage least squares (2SLS) and generalized method of moments (GMM).

The ability to use an instrumental variable estimator is important, because consumer prices are likely to be endogenous. In the demand model, valid instruments must be correlated with the endogenous potato price, but not with the residual in the demand equation. Input prices, prices of related products, and truly exogenous demand factors (demographics, socioeconomic indicators) are typical candidates. In the current example, given the relative lack of data from official Mexican sources, we use all exogenous variables, lagged values of endogenous variables, producer prices (a proxy for input costs), and a residual measure of technical progress. The resulting demand elasticity will be an unbiased estimate of the true market demand response.

On the supply side, we estimate Equation (6) using the same approach (GMM). In this case, however, the set of instruments includes all exogenous and predetermined variables that are likely to shift demand and thus identify the supply curve for each product. Per capita income, alternative product prices, aggregate population, seasonal and annual binary variables, and exchange rates are all effective in this regard. In monthly data, we model shipments out of inventory and not annual planting decisions. Output supply is a function of the expected output price, alternative product prices, expected input prices, seasonal variation, and the state of technology. The output price is the expected Mexican producer price, whereas alternative crops include rice, corn, and beans. We choose a GL functional form because it is inherently linear homogeneous, flexible and has been shown to perform well in general specification tests against alternative models of supply (Shumway and Lim, 1993). Symmetry and convexity are imposed globally during the estimation procedure.

Data Description

Potato production is defined as the total value of alpha potatoes, hybrid potatoes, and unclassified potatoes expressed in constant 2008 peso terms. Production value is converted into quantity (kg) values by dividing by the average grower price, which is defined as the average real price paid for potatoes grown in Mexico as reported by Sistema di Informacion Agroalimentaria de Consulta (SIACON) on a monthly basis. Potato imports from the United States are from FASOnline (United States Department of Agriculture, Foreign Agricultural Services, 2008) and are expressed in constant (June 2008) pesos, converted from U.S. dollars by multiplying by a real exchange rate. The real exchange rate is defined as the nominal, or observed exchange rate, multiplied by the ratio of the U.S. consumer price index (CPI) to the Mexican CPI. Both the exchange rate and CPI are from Bancomex. Under purchasing power parity, the real exchange rate is a constant so adjusting the nominal exchange rate in this way corrects for deviations in real purchasing power between the two countries. Import prices are unit value indices calculated by dividing the real monthly value of potato imports reported by FAS by the monthly quantities. Implicitly, therefore, these unit value indices assume that potatoes of constant quality are imported throughout the marketing year. Potato consumption is defined as apparent disappearance as it is calculated as a residual of production plus imports less exports. To maintain comparability between U.S. and domestic potatoes, all prices are measured at the wholesale level. We have no reason to believe that retail-wholesale margins should differ between the two types of potatoes in a systematic way, so using wholesale prices should not bias our demand estimates. All of the variables used in this study are summarized in Table 2 below.

Results and Discussion

This section presents the results obtained from estimating each of the econometric models and then simulation results from the trade- and welfare-effect models. In each case, we discuss the implications of our results for potential changes in trade policy.

We first examine whether or not domestic Mexican prices are indeed endogenous. For this purpose, we present three different sets of estimates, and conduct a specification test of the estimator that does not account for endogeneity (ordinary least squares). The three sets of estimates in Table 3 correspond to one estimator that is known to be inconsistent when prices are endogenous, and two that are consistent. A third, generalized method of moments is

Table 2. Summary of Data Used in Demand and Supply Models

Variable	Units	N	Mean	S.D.	Minimum	Maximum
Production	000 M tons	54	189.91	173.34	0.00	678.40
Imports	000 M tons	54	10.05	2.20	5.70	15.40
Exports	000 M tons	54	0.42	1.35	0.00	10.18
Price (pesos)	pesos/kg	54	7.35	1.39	5.40	11.50
Mexico price (dollars)	$/kg	54	0.30	0.06	0.22	0.48
Import price	$/kg	54	0.40	0.07	0.28	0.64
Population	millions	54	104.78	1.32	103.00	107.00
Exchange rate	pesos/$	54	10.96	0.28	10.33	11.52
Rice price	pesos/kg	54	6.25	1.42	5.00	11.90
Corn price	pesos/kg	54	2.79	0.53	2.20	3.87
Bean price	pesos/kg	54	10.56	1.88	7.00	16.25
Rice output	000 M tons	54	83.02	133.45	0.00	538.96
Corn output	000 M tons	54	8,973.80	10,441.00	0.00	40,379.00
Bean output	000 M tons	54	720.00	655.80	0.00	2,861.10

preferred under endogeneity because it produces estimates that are correct under a number of other known sources of inconsistency. We use a Hausman (1978) specification test to determine which set of estimates is preferred. According to the Hausman (1978) test, the estimator that is efficient and consistent under the assumption of no endogeneity, but inconsistent if prices are endogenous, is compared with one that is inefficient under the maintained hypothesis, but is consistent under the alternative hypothesis that prices are endogenous. For this purpose, we use the GMM estimator. The resulting test statistic is chi-square distributed with degrees of freedom equal to $k - 1$, where k is the number of explanatory variables in the model. Because the critical chi-square value for 5 degrees of freedom at a 5.0% level is 26.296 while the test statistic value is 83.590, we easily reject the null hypothesis of no endogeneity and conclude that the GMM estimator is consistent, but the ordinary least squares (OLS) estimator is not.

Focusing on the GMM model estimates, the results in Table 3 show each of the parameters of interest. First, a *J*-test of the overidentifying restrictions associated with the GMM estimator fails to reject the null hypothesis that the set of instruments are all truly exogenous (test value of 2.401 is less than the critical value $\chi^2_{16} =$ 15.339). Therefore, the GMM estimator is likely valid. Second, the logit scale parameter is 0.615. Because this parameter indicates the degree of substitutability among the set of products under consideration, and is greater than zero, the two types of potatoes and potato substitutes are clearly not regarded as perfect substitutes. Furthermore, because this value is significantly different from 1.0, they are not regarded as completely distinct products either. Finding a scale parameter that lies clearly between 0 and 1.0 provides some evidence that a differentiated-product approach is appropriate. Third, the own-price elasticity of demand is -0.599. This elasticity estimate means that consumers reduce potato purchases by approximately 0.60% for every 1.0% increase in prices. This is similar to other empirical studies (-0.48, Tecnologico de Monterrey, 2007), and not unreasonable given the staple nature of potatoes and the small quantity of potatoes consumed by the average consumer (and high prices). Fourth, the cross-price elasticity of demand is 0.011which is characteristically low for a logit model. Note, however, that the simple logit used here is subject to the independence of irrelevant alternatives property, which means that the cross-price elasticity is the same for all pairs of substitute products. Although often considered a weakness of the simple logit, it is of little consequence here because we are primarily interested in accurately estimating the own-price elasticity and not in the complete matrix of cross-price elasticities. Furthermore, the product-specific preference parameters suggest that, at

Table 3. Discrete Choice Demand Estimates: Potatoes, Corn, Beans, and Rice, Mexico

	OLS		2SLS		GMM	
	Estimate	t-Ratio	Estimate	t-Ratio	Estimate	t-Ratio
Domestic[a]	−1.352*	−2.713	3.792	1.872	3.255*	2.061
Imported	−5.486*	−11.980	−4.714*	−5.228	−4.773*	−5.883
Corn	−0.014	−0.254	−0.390*	−2.400	−0.299*	−2.052
Beans	0.112	0.842	0.604*	2.030	0.504	1.959
Rice	0.071	1.831	0.679*	3.042	0.609*	3.099
Price	−2.879*	−2.207	−37.610*	−3.065	−34.286*	−3.406
Jan	−2.226*	−8.320	−1.900*	−3.773	−1.984*	−4.343
Feb	−1.659*	−6.468	−1.133*	−2.246	−1.228*	−3.324
Mar	−1.164*	−4.531	−0.912	−1.903	−1.025*	−2.650
April	−1.498*	−5.817	−1.412*	−2.978	−1.562*	−4.314
May	−1.497*	−5.787	−1.330*	−2.778	−1.445*	−3.501
June	−1.989*	−7.690	−2.024*	−4.258	−2.034*	−5.378
July	−2.427*	−9.035	−2.763*	−5.446	−2.831*	−6.407
Aug	−1.556*	−5.780	−2.011*	−3.874	−2.030*	−4.585
Sept	−1.410*	−5.246	−1.687*	−3.356	−1.741*	−3.401
Oct	−0.396	−1.468	−1.016	−1.882	−0.946	−1.495
Nov	−0.063	−0.234	−0.641	−1.204	−0.578	−1.318
R^2	0.836		0.891		0.914	
D.W.	1.335		1.634		1.679	
μ	0.835		0.584		0.615	
Ed					−0.599	
G					128.762	
Hausman					83.59	

Notes: OLS is ordinary least squares; 2SLS is two-stage least squares; GMM is generalized method of moments.
[a] D.W. is the Durbin-Watson statistic used to test for first-order autocorrelation. Hausman is the value of a chi-square distributed test statistic that is used to test whether consumer prices are endogenous to the economic problem described here. Critical value of the Hausman statistic, which is chi-square distributed with $k - 1$ degrees of freedom, is 26.296.
* Indicates significance at a 5.0% level.

current prices, Mexican consumers prefer domestic potatoes over imported and tend to prefer rice and beans to corn or the outside option. Potato demand also exhibits significant seasonality, with large swings in potato market share between the summer and winter months. Finding the elasticity of demand in this way, however, provides only part of the information necessary to calculate the value of the tariff barrier (TB), τ, as it also depends upon the elasticity of domestic supply as well.

On the supply side, the Hausman (1978) specification test yields similar results to the demand case. Namely, we strongly reject the notion that prices are exogenous as the Hausman test statistic value of 826.216 is greater than the critical value of 54.572. Therefore, we again use a GMM estimator for the supply model. The GL supply function provides a good fit to the data, as evidenced by the high coefficient of determination and the relatively large number of significant explanatory variables. Because the GL supply model is highly nonlinear, the structural coefficients provide little direct information as to the sensitivity of Mexican growers to price. Therefore, we calculate the supply elasticity using the specification given in Equation (7) above. Evaluated at the means of all explanatory variables, the elasticity of supply is 0.409, which is reasonable and consistent with other empirical studies (Tecnologico de Monterrey, 2007). As expected, supply also exhibits significant seasonal variation as potato growing occurs throughout the country with production seasons often overlapping between several regions at any given time (Table 4).

The demand and supply estimates presented above are used to estimate the trade and welfare impacts of removing all import restrictions on U.S. potatoes. For this analysis, we assume Mexico is a relatively small importer compared with the scale of the U.S. market.[5] We also assume that the initial price and quantity are from the most recent marketing year, 2008. After presenting the initial results, we relax this assumption to introduce potential price effects in addition to the pure trade and welfare results.

All trade and welfare effects depend on the price gap between Mexican consumer prices and import prices, or τ in the economic model described above. Using the average prices reported for 2008 as a benchmark, we find that consumer prices are 15.1% higher than import prices. Once the market is opened, trade will flow to reestablish an equilibrium between these two prices—controlling for the difference in preferences for Mexican and U.S. potatoes. Table 5 shows the potential annual trade impacts that result under three elasticity assumptions. Given that the elasticity estimates presented above are just that—estimates—the true values are unknown so we present welfare results using a range of elasticities that encompasses a range of plausible values on the demand and supply sides ($\varepsilon_D = -0.25$ to -1.00 and $\varepsilon_S = 0.25$–1.00). Under the baseline elasticity assumption ($\varepsilon_D = -0.599$, $\varepsilon_S = 0.409$) we find that the quantity demanded on the Mexican market would rise from 2.39 million tons per year to 3.62 million tons per year and the quantity supplied would fall from 2.32 million tons to 1.76 million tons per year so imports would rise by 1.78 million tons per year. At 2008 prices, this represents an additional 3.4 billion pesos ($317.7 million) in incremental trade value. Clearly, this is a very significant increase in trade given that total U.S. production in 2005 was approximately 20.7 million tons. Although we are confident in the accuracy of our supply and demand estimates, if the elasticity of demand were -1.0 and the elasticity of supply 1.0, then the rise in trade would be much greater: 3.2 million tons per year, or approximately 15% of total U.S. production. Under a more conservative assumption regarding the elasticities of demand and supply—a demand elasticity of -0.25 and supply elasticity of 0.25—the rise in trade becomes 0.80 million tons per year, which is still roughly 10 times the volume of current U.S./Mexican potato trade. Increased trade, however, will benefit a wider group of stakeholders than U.S. potato exporters.

Because greater trade flows, by definition, imply lower prices for Mexican consumers, consumer surplus will rise upon removing the trade restrictions. Of course, much of this gain will come from Mexican potato producers. We quantify this result by calculating the changes in consumers' surplus (CS) and producers' surplus (PS) that result from opening potato trade with Mexico. Table 5 shows the changes in CS and PS under the three elasticity scenarios described above. In the baseline, or estimated case, CS rises by over 4.0 billion pesos per year ($380.0 million U.S. Dollars [USD]). Mexican growers, on the other hand, stand to lose over 2.8 billion pesos per year ($266.1 million USD). If Mexican policymakers weigh consumers' and producers' interests equally, the net gain of 1.2 billion pesos per year suggests that removing the remaining barriers to potato trade would be in the best interests of the Mexican economy as a whole. Under the high elasticity scenario, the rise in CS is almost 4.6 billion pesos per year ($432.1 million USD) and the lost PS is 2.4 billion pesos ($227.0 million USD) so the gains are even more substantial. With the more conservative elasticity assumption from the consumer perspective, the gain in CS falls to 3.6 billion pesos ($334.9 million USD), but the loss in PS rises to 3.0 billion pesos ($283.9 million USD). Clearly, the less elastic is demand, the smaller the gain in CS, but the less elastic is supply, the larger the loss in PS. Under all scenarios, however, the net gain to the Mexican economy is significant.

[5] In 2005, Mexican imports were 54,594 tons (Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación, Servicio de Información y Estadística Agroalimentaria Pesquera, 2006) while U.S. production was 20.7 million tons. Mexican imports were, therefore, only 0.2% of U.S. production so not likely to have a significant price impact. Further, the U.S. industry is highly competitive, so any increase in demand would be met by an equal increase in production in the long run, maintaining prices at average cost in the long run.

Table 4. Supply Model Estimates: Potatoes, Corn, Rice and Beans

	OLS		2SLS		GMM	
	Estimate	t-Ratio	Estimate	t-Ratio	Estimate	t-Ratio
γ_{10}	0.905*	2.473	−0.216	−1.555	−0.311*	−2.431
γ_{11}	2.405*	3.180	0.032	0.116	0.648*	3.248
γ_{12}	0.116	0.555	0.054	0.589	0.072	0.843
γ_{13}	−2.430*	−3.019	0.23	0.838	0.618*	3.218
γ_{14}	−0.352	−1.608	0.043	0.592	0.273*	2.478
τ_{11}	−0.970*	−3.104	−0.007	−0.062	0.090	0.919
τ_{12}	−0.932	−2.951	0.036	0.322	0.141*	2.441
τ_{13}	−0.631*	−2.700	−0.024	−0.286	0.056	0.822
τ_{14}	−0.183	−1.116	−0.044	−0.776	0.001	0.035
γ_{20}	−0.003	−0.022	0.109	1.876	0.141*	3.220
γ_{21}	−4.934*	−3.565	1.174	1.383	0.461*	2.785
γ_{22}	4.618*	3.946	0.976	1.341	1.245	1.810
γ_{23}	0.578*	2.022	0.299*	2.202	0.088*	2.281
τ_{21}	0.377*	3.472	0.110	1.656	0.008	0.289
τ_{22}	0.328*	2.761	0.019	0.267	−0.082*	−3.001
τ_{23}	0.270*	3.138	0.076	1.545	0.013	0.47
τ_{24}	0.076	1.312	0.039	1.254	0.006	0.244
γ_{30}	41.559*	2.682	16.610	1.162	−0.71	−0.145
γ_{31}	−61.666	−1.508	20.819	0.571	5.818*	7.186
γ_{32}	4.332	0.665	11.049*	2.420	0.921*	2.405
τ_{31}	9.462	1.825	4.685	0.993	−1.822	−0.874
τ_{32}	4.456	0.827	−2.559	−0.516	−8.905*	−4.239
τ_{33}	8.170*	2.218	3.385	0.972	−0.558	−0.296
τ_{34}	5.576*	2.514	5.460*	2.488	3.507*	1.979
γ_{40}	0.781	1.251	1.513*	5.353	1.120*	5.298
γ_{41}	−2.91	−0.398	11.960*	2.519	12.835*	2.734
τ_{41}	0.169	0.340	0.739*	2.280	−0.02	−0.161
τ_{42}	−0.147	−0.310	0.325	1.001	−0.399*	−3.341
τ_{43}	0.432	1.292	0.713*	3.038	0.247*	2.054
τ_{34}	0.047	0.219	0.206	1.420	0.026	0.211
R^2	0.781		0.678		0.926	
D.W.	1.536		2.318		2.285	
G					134.461	
Es					0.409	
Hausman					826.618	

[a] In this table, a single asterisk indicates significance at a 5.0% level. Symmetry and convexity are imposed in estimation. *G* is the GMM objective function value and *Es* is the elasticity of supply at sample means. The critical value of the Hausman statistic is 54.572. Monthly binary variables suppressed to conserve space.

The fact that the trade restrictions persist even though these benefits are potentially achievable suggests that the Mexican industry may have a strong political influence over agricultural policymakers in Mexico.

Many researchers in this area (Calvin and Krissoff, 1998; Josling, 1997; Roberts and Orden, 1997) regard the potential demand or supply shifts in the host country that may accompany a relaxation of SPS trade regulations as a key source of either welfare gains or losses. In the Mexican potato case, if a shift were to occur, it would be on the supply side, because the quarantine was put in place to protect against agricultural pests that would reduce yields and raise production costs, but not alter eating quality or the inherent safety of either domestic or imported potatoes. Although

Table 5. Welfare and Trade Effects of Opening U.S./Mexico Potato Trade

		Elasticity Assumptions		
		Estimated[a] $E_d = -0.599$ $E_s = 0.409$	Low $E_d = -0.25$ $E_s = 0.25$	Medium $E_d = -1.00$ $E_s = +1.00$
ΔCS	million 2008 pesos	4,033.59	3,554.91	4,586.25
ΔPS	million 2008 pesos	−2,886.22	−3,013.28	−2,410.17
ΔT	,000 tons	1,783.35	797.72	3,204.89
q_d^0	,000 tons	2,393.37	2,393.37	2,393.37
q_s^0	,000 tons	2,319.69	2,319.69	2,319.69
q_d^1	,000 tons	3,615.58	2,902.51	4,438.87
q_s^1	,000 tons	1,759.09	2,031.11	1,160.32

[a] ΔCS is the change in consumer surplus relative to the initial, trade-restricted case, in millions of 2008 pesos. ΔPS is the change in producer surplus in millions of 2008 pesos. ΔT is the change in trade (imports less exports), in thousands of metric tons. q_d^0 and q_s^0 are the initial demand and supply of potatoes in Mexico, in thousands of metric tons, respectively and q_d^1 and q_s^1 are their values after easing the trade restrictions. Note that all values are annual averages.

the Mexican government began to allow U.S. imports from all 50 states in 2003, and promised to relax the 26 km zone restriction within 2 years, this latter change has yet to take place. Furthermore, because our data begins in January of 2004, it is not possible to test for any supply or demand changes that may have resulted from even this threat of opening the border further. Nevertheless, it is instructive to compare the baseline scenario considered in Table 5 with one that envisions either a positive or negative supply response to the removal of all trade barriers. Either is possible, depending on the nature and validity of the SPS trade bans (Josling, 1997).

We recalculate the change in trade and welfare under an assumption that Mexican potato supply shifts backward (falls) at each price by 10% and under an alternative assumption that Mexican supply rises by 10%. The change in trade and welfare that result are found in Table 6. Because Mexican potatoes are significantly differentiated from U.S. imports, both consumers and producers of Mexican potatoes will be impacted by any change in supply of domestically produced potatoes. Producers face higher or lower costs depending on the nature of the shift. In the case of a backward shift in supply, costs may rise due to increased monitoring efforts, spraying, fumigating, or other processes required to ensure the imported disease does not destroy their crop or their ability to grow. With a negative supply shock of 10%, PS falls by approximately 2.6 billion pesos ($246.9 million USD), or 266.4 million pesos less than the no-shock scenario with the opening of trade under base elasticity assumptions. The loss in producer surplus is smaller under the negative supply-shock scenario because producer prices rise as a result, and the net benefit to opening trade is still positive.

On the other hand, supply may instead shift outward due to induced efficiencies on the part of Mexican growers as they try to reduce costs to compete with U.S. imports. Assuming the magnitude of this improvement is again 10%, the results in Table 6 show that the change in PS due to the border opening is approximately 2.9 billion pesos ($269.1 million USD), or 30.3 million pesos less than under the no-shock scenario. Although prices fall as a result of the shock to supply, the added production partially outweighs the price effect. Policymakers should add this potential benefit to the gain in CS above when comparing the costs and benefits of further relaxing the border restrictions.

More scientific research into the basis of either side's claims would add another dimension to this welfare analysis. Orden and Romano (1996) recognize that the potential shift in supply described here is not a "deterministic" or certain event. Rather, the evaluation should be conducted as a risk assessment exercise, with probabilities attached to each outcome. In the avocado case considered by Orden and Romano (1996), the science that had been conducted into potential infestation of Mexican

Table 6. Welfare Effects of Opening U.S./Mexico Trade, with Mexican Supply Shock

		Supply Shock Assumption		
		No Shock[a]	ΔS = −10%	ΔS = +10%
ΔCS	million 2008 pesos	4,033.59	3,951.85	4,116.03
ΔPS	million 2008 pesos	−2,886.22	−2,619.84	−2,855.99
ΔT	,000 tons	1,783.35	1,836.99	1,729.72
q_d^0	,000 tons	2,393.37	2,393.37	2,393.37
q_s^0	,000 tons	2,319.69	2,319.69	2,319.69
q_d^1	,000 tons	3,615.58	3,493.85	3,738.41
q_s^1	,000 tons	1,759.09	1,583.81	1,935.01

[a] Elasticity values used to generate results in this table are from the estimates reported above. All values are annual averages.

avocados had advanced to such a state that statistical analysis was indeed possible. In the U.S. potato case, however, there is little evidence upon which to base an empirical assessment of the likelihood of any infestation in the U.S. being carried into Mexico. In fact, given that Animal and Plant Health Protection Service and the U.S. industry maintain that any pathogen borne by U.S. potatoes already exists in Mexico, the point is mute. If future research should advance in this direction, however, a risk assessment of potential shifts in Mexican supply due to invasive species would be warranted.

Conclusions and Implications

In this study, we examine the welfare effects on the Mexican economy of SPS trade restrictions on U.S. potato imports. Specifically, we conduct a trade-volume and welfare analysis of relaxing SPS regulations on the import of fresh U.S. potatoes into Mexico beyond the current 26 km exclusion zone. To calculate the likely trade and welfare effects of letting more U.S. potatoes into the larger Mexican urban markets, we estimate econometric models of Mexican potato supply and demand that explicitly recognize the differentiated nature of U.S. and Mexican potatoes. These models provide estimates of the elasticities of supply and demand—parameters that determine how equilibrium trade flows will change if U.S. and Mexican prices are allowed to readjust to a new equilibrium. Consistent with recent literature in the trade analysis field, we use a "price-wedge" modeling framework in which a "tariff equivalent" value of existing trade restrictions is used to impute a likely change in potato prices in Mexico should trade barriers be reduced. This price change is then used to calculate the likely change in Mexican demand, supply, trade, and welfare.

Our results show that Mexican and U.S. potatoes are indeed differentiated products, and that both supply and demand are inelastic. Inelastic demand and supply mean that the price change that is likely to result from opening the Mexican market to trade will cause a relatively small change in both quantity demanded and supplied within Mexico, but given the volume of Mexican potato consumption, the change in trade is significant. Mexican prices are expected to fall by approximately 15% once trade is allowed beyond the exclusion zone. As a result, reestablishing equilibrium between Mexican and world prices would cause trade to rise by nearly 1.8 million metric tons, which would lead to a rise in Mexican consumer surplus of some 4.0 billion pesos per year at a cost of 2.9 billion pesos in grower profit. Even under more conservative assumptions of the elasticities of supply and demand, consumers would benefit by nearly 3.5 billion pesos per year while producers lose 3.0 billion. Clearly, maintaining the 26 km exclusionary zone benefits Mexican potato growers at the expense of Mexican consumers, and potato producers in the rest of the world.

Although we are confident in our results, the modeling approach used in this study requires a number of assumptions. First, we assume that the Mexican data are accurate and has been appropriately adjusted for inflation and currency exchange. Second, although we allow for

Mexican and U.S. potatoes to be regarded as differentiated products by consumers, unlike the conventional price-wedge approach, our analysis still simplifies the market somewhat in ways that may or may not be realistic. For example, different regions within Mexico have distinctly different preferences for potatoes, corn, and other staple products, but our data would not support a regional analysis within Mexico. Furthermore, because there is no data describing truly free trade between the U.S. and Mexico, there is no way to know with certainty whether or not there will be a price impact in the United States. Third, as with any other study based on econometric estimation, we assume that our statistical models are appropriate and that the specification tests used are sufficient to rule out other, potentially better, modeling approaches. Fourth, we assume that the economic effects of allowing free trade in potatoes between the U.S. and Mexico will not elicit a strategic response from Mexican trade authorities in other commodity markets, or in other areas of potato and potato product trade.

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