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Impact of NAFTA on U.S. and Mexican Sugar Markets

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When NAFTA became fully implemented for sugar in 2008, Mexico became the leading sugar exporter into the United States, accounting for nearly 70% of U.S. imports in 2013. A partial equilibrium trade model was developed to estimate the welfare implications of NAFTA for U.S. and Mexican sugar markets from 2008 to 2013. While the net effect of NAFTA on U.S. welfare and Mexican sugar producers was positive, U.S. sugar producers suffered significant losses. The net Mexican welfare effect of NAFTA was significantly positive in 2011, negative in 2008, and slightly positive in 2009–2010 and 2012–2013.

Key words: Mexico, NAFTA, producer surplus, sugar, trade policy, welfare economics

Introduction

On January 1, 1994, the North American Free Trade Agreement (NAFTA) went into effect for the United States, Mexico, and Canada, creating the world's largest free-trade area (U.S. Trade Representative, 2013). However, due to a "Side Agreement on Sugar" between Mexico and the United States (Jurenas, 2006; American Sugarbeet Growers Association, 2014), unrestricted free trade of sugar between the United States and Mexico did not begin until January 1, 2008. Prior to FY2008, Mexico exported a relatively small amount of sugar to the United States. From fiscal years (FY) 2008–2013, Mexican sugar exports to the United States averaged approximately 1.2 million metric tons raw value (MTRV), approximately 12% of total U.S. consumption. By FY2013, Mexican exports of sugar to the United States had reached 1.93 million MTRV, approximately 18% of total U.S. consumption (U.S. Department of Agriculture, Economic Research Service, 2013c). U.S. sugar prices were not initially depressed by increased Mexican exports of sugar in 2008 because of below-average sugar production in the United States and Mexico, which was caused by poor weather conditions (U.S. Department of Agriculture, Economic Research Service, 2013b; Roney, 2012; Knutson, Westhoff, and Sherwell, 2010). However, sugar prices started to decline in 2012, and the U.S. sugar price approached the U.S. loan rate by the end of 2013. Figure 1 provides Mexican sugar exports to the United States for FY2001–FY2013 as well as average U.S. and world sugar prices and U.S. raw sugarcane loan rates for the same time period.

The evolution of an official U.S. sugar policy began with the Jones-Costigan Act of 1934 (Alvarez and Polopolus, 1998). Unlike many other commodities, the 2014 Farm Bill extended all sugar programs contained in the 2008 Farm Bill (American Sugar Alliance, 2014a). As outlined in the 2008 Farm Bill, U.S. sugar policy has three main components: (1) flexible domestic marketing allotments (regulating how much domestic production is allowed to be marketed in a given year), (2)

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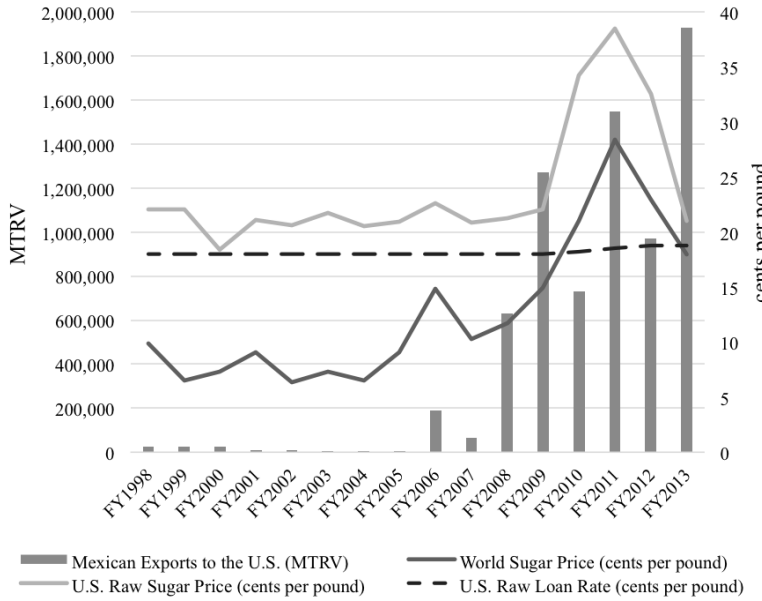

Figure 1. Mexican Sugar Exports to the United States (MTRV), U.S. Sugar Prices, U.S. Raw Loan Rate and World Sugar Prices: FY2001–FY2013

Notes: U.S. prices are Contract No. 14/16, duty fee paid New York; world prices are ICE Contract 11 nearby futures price.

a government loan rate, and (3) tariff-rate quotas (TRQs) imposed on all countries except Mexico and Canada (U.S. Department of Agriculture, Economic Research Service, 2013b).

The secretary of agriculture announces TRQs prior to the start of the fiscal year. Under the Uruguay Round Agreement on Agriculture, the United States must import a minimum quantity of 1.14 million MTRV under the TRQ (U. S. Department of Agriculture, Foreign Agricultural Service, 2012).[1] TRQs are issued to forty countries, and their allocation is controlled by the Office of the U.S. Trade Representative (U.S. Department of Agriculture, Economic Research Service, 2013b). If a country wants to export sugar into the United States beyond the TRQ, it faces an over-quota tariff of $0.1536/pound for raw sugar. The over-quota tariff is almost always prohibitive. Since NAFTA was implemented, only negligible amounts of over-quota entries of sugar have entered the United States (U. S. Department of Agriculture, Foreign Agricultural Service, 2014).

If the domestic sugar market is under-supplied on April 1 of the fiscal year, the secretary of agriculture may increase the TRQ (U.S. Department of Agriculture, Economic Research Service, 2013a). The USDA uses its *World Agricultural Supply and Demand Estimates* (*WASDE*) monthly report, which includes forecasts of U.S. sugar consumption and production and Mexican exports of sugar to the United States, to determine whether to increase the TRQ (U.S. Department of Agriculture, Economic Research Service, 2013a). The USDA's U.S. and Mexican sugar forecasts are a crucial component of proper implementation of U.S. sugar policy, especially considering that the goal of this policy is to maintain the price of sugar above the government loan rate, which is $0.1875/pound for raw sugarcane (U.S. Department of Agriculture, Economic Research Service, 2013a).

Prior to full NAFTA implementation in 2008, Mexican exports of sugar to the United States were also limited through the TRQ. Legislation in the 2002 Farm Bill allowed Mexico to export a maximum of 250,000 MTRV of sugar into the United States annually under the TRQ (Jurenas, 2009; American Sugarbeet Growers Association, 2014). Under NAFTA, Mexico became eligible to export

[1] TRQ is defined as the raw sugarcane TRQ.

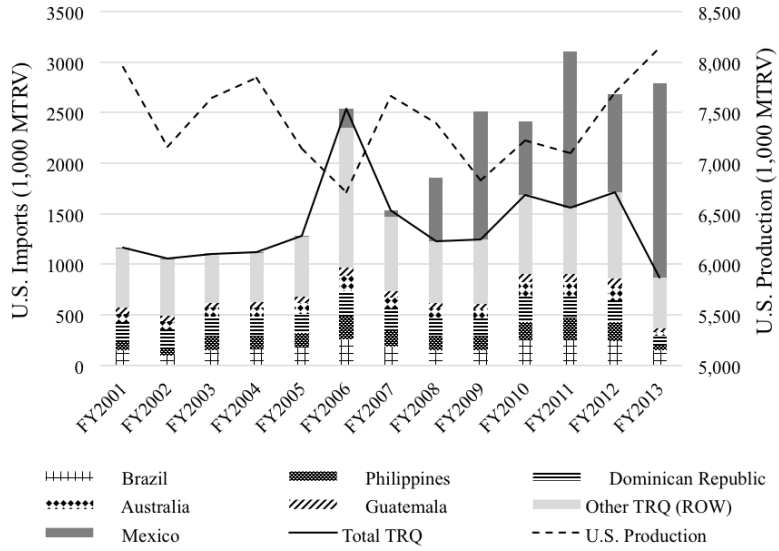

Figure 2. Top Exporters of Sugar into the United States and U.S. Production (1,000 MTRV), FY2001–FY2013

an unrestricted, tariff-free amount of sugar into the United States (U.S. Department of Agriculture, Economic Research Service, 2013b).

Figure 2 provides a detailed breakdown of U.S. sugar imports by country of origin for FY2001–FY2013 as well as total U.S. domestic production of sugar. The total combined TRQ for all forty countries whose sugar exports to the United States are restricted by the TRQ are also provided in figure 2 (shown below the TRQ line). Of the forty countries with restricted TRQs, Brazil, the Philippines, the Dominican Republic, Australia, and Guatemala were the top five exporters of sugar to the United States from FY2001 to FY2013. These countries plus Mexico accounted for 82% of all U.S. raw sugar imports in FY2013 (Mexico accounted for nearly 70% of total U.S. imports in that year). As shown in figure 2, annual U.S. sugar imports post-NAFTA implementation have been steadily higher than pre-implementation annual U.S. sugar imports (with the exception of FY2006). In FY2006 the USDA significantly increased the TRQ to allow additional imports of sugar into the United States as a result of the significant drop in U.S. domestic production caused by Hurricanes Katrina, Wilma and Rita (Haley, Jerardo, and Kelch, 2005).

Overall, since full NAFTA implementation, the amount of sugar imported under the TRQ has fluctuated. In FY2008 and FY2009, imports allowed under the TRQ were set at levels slightly higher than minimum. In FY2010–FY2012, the TRQ was increased multiple times after the April 1 trigger date. And in FY2013, several TRQ countries did not fill their originally allotted TRQ (U.S. Department of Agriculture, Economic Research Service, 2013c).

The decision to increase the TRQ can be controversial and political (Jurenas, 2010; Sweetener Users Association, 2011), relying heavily on USDA forecasts of U.S. production and consumption and Mexican exports of sugar to the United States. It was not until the 2008 Farm Bill that the USDA became required by law to publish a forecast of U.S. imports of Mexican sugar in its monthly *WASDE* (Lewis and Manfredo, 2012). Consequently, Lewis and Manfredo (2012) analyzed the performance of the USDA's U.S. sugar production and consumption forecasts from FY1993 through FY2011 and the USDA's Mexican sugar exports forecast in FY2010 (the first year it was published) and FY2011. Lewis and Manfredo (2012) determined that the USDA had done a respectable job of forecasting U.S. sugar production and consumption and Mexican exports of sugar to the United

States. They also found that the accuracy of the USDA forecasts has stayed consistent over time, despite the full implementation of NAFTA.

This paper analyzes NAFTA's impact on sugar producers and consumers in Mexico and the United States using a partial equilibrium sugar trade model (developed in this paper) for the United States, Mexico, and the forty other countries in the rest of the world (ROW) that export sugar to the United States under the TRQ.

Literature Review

Voluntary Export Restraints and the U.S. Sugar TRQ

Certain theoretical welfare implications resulting from voluntary export restraints (VERs) are applicable to the counterfactual analysis performed in this paper. There exists an extensive literature on the welfare implications of VERs for both the importing and exporting country (e.g., Harris, 1985; Krishna, 1989). As Harris (1985) states,

> Economists working in the tradition of perfect competition tend to think of VERs as being similar to a quota, except that the quota rents are captured by the foreign exporters in the form of higher profits. This presumes of course that entry into the exporting industry is somehow limited. If this is the case, then welfare of the foreign country can improve due to the imposition of VERs because of the transfer of the quota rents to the foreign country. (p. 800)

Allen, Dodge, and Schmitz (1983) explain that voluntary exports restraints are "voluntary" because

> the exporting country has the choice between curtailing its exports or having them reduced by the importing country through protectionist measures such as tariffs. Faced with this choice, an exporting country often voluntarily chooses to limit exports to the exporting country. This result holds because the exporting country can capture tariff equivalent revenues. (p. 291)

In the case of VERs on substitute goods within the framework of perfect competition, the importing country suffers welfare losses because producers are protected at the expense of consumers. Furthermore, as long as the export supply curve is upward-sloping and exporters receive the higher price caused by the import restriction (which holds true in the case of U.S. sugar policy), VERs can, in some cases, lead to welfare gains to producers in the exporting country. For example, Allen, Dodge, and Schmitz (1983) found that as a result of the 1964 U.S. Meat Import Law, producers who exported beef to the United States realized welfare gains of $8.25 million per year from VERs. In another example, Picketts, Schmitz, and Schmitz (1991) found that Canadian potash producers gained $108.4 million after they voluntarily agreed to restrict potash exports to the United States as a result of a 1987 countervailing duty case filed by the United States.

In the case of U.S. sugar trade with Mexico, the very act of restricting U.S. sugar imports from Mexico to TRQ levels that existed prior to 2008 in our counterfactual scenario yields similar theoretical results as a Mexican VER. Over our examined time frame (FY2008–FY2013), the TRQ imposed on sugar exporters by the United States takes the form of a zero in-quota tariff and an over-quota tariff that is almost always prohibitive. Furthermore, the U.S. TRQ is based on a historical allocation; thus, foreign exporters do not have to pay for a quota license and are therefore able to capture the quota rent (Skully, 2001). Hence, in years when the over-quota tariff is prohibitive, U.S. sugar import restrictions take the form of what Anderson and Neary (1992) term "pure" VERs, where all quota rents are awarded to producers in the exporting country.[2] Our results illustrate that

[2] In the case of Mexico, the sugar mills that export sugar into the United States receive the quota rent. There are fifty-one Mexican sugar mills, nine of which are owned by the Mexican government (U.S. Congress, 2015). Thus, the quota rent is divided between the Mexican government and the privately owned sugar mills.

it would have been possible for Mexico to realize welfare gains if free trade in sugar between the United States and Mexico, from FY2008 through FY2013, had instead been replaced with a binding TRQ that behaved, at least theoretically, like a "pure" VER.

Previous Literature on U.S. Trade Policy in Sugar

Previous research has analyzed numerous aspects of the U.S. sugar market and U.S. sugar policy, ranging from the cost of U.S. sugar policy to the impact of various changes to current U.S. sugar policy (e.g., Babcock and Schmitz, 1986; Leu, Schmitz, and Knutson, 1987; Koo, 2002; Schmitz et al., 2002; Beghin et al., 2003; Petrolia and Kennedy, 2003; Elobeid and Beghin, 2006; Beghin and Elobeid, 2015). Previous research has also analyzed the *ex ante* impact of NAFTA on the U.S. sugar market (e.g., Sano, House, and Spreen, 2004; Abler et al., 2008; Kennedy and Schmitz, 2009; Knutson, Westhoff, and Sherwell, 2010).

Sano, House, and Spreen (2004) created a model that forecasted four possible scenarios of the volume of U.S. sugar imports for FY2002–FY2015. They concluded that "the Mexican sugar industry benefited little in the past ten years of the NAFTA regime and may not expect much in the future either" (pg. 18).

Abler et al. (2008) used the Center for Agricultural and Rural Development international sugar model to project that the average U.S. raw price of sugar for FY2008–FY2015 would be lower than the U.S. sugar loan rate in many scenarios as a result of full NAFTA implementation. This would have made it very unlikely for U.S. sugar policy to be able to continue operating at no cost to taxpayers. Therefore, based on fears that unrestricted, tariff-free sugar exported from Mexico into the United States would cause existing U.S. sugar policy to no longer operate at "no net cost" to taxpayers, Abler et al. (2008) proposed and examined a new U.S. sugar policy based on standard commodity programs found in the 2002 Farm Bill, such as direct payments, which they projected for the average of FY2008–FY2015. They concluded that "the replacement of the current sugar program by a standard commodity program would increase the costs of the program for the U.S. taxpayers but would lower costs for the U.S. sugar users" (pg. 100).

Kennedy and Schmitz (2009) examined the impact of U.S. production control policies in response to increased exports of sugar entering into the United States due to NAFTA. Using data from FY2005, they first examined how increased U.S. sugar import quotas would impact U.S. consumer and producer welfare and how they would impact U.S. welfare if U.S. producers used supply management practices. They reached the conclusion that U.S. sugar production control policies can lessen the impact of increased sugar imports into the United States to a certain extent, but U.S. supply management would eventually fail to compensate for increased sugar import quotas.

To analyze the potential impact of NAFTA on the U.S. and Mexican sweetener industries, Knutson, Westhoff, and Sherwell (2010) utilized the Food and Agriculture Policy Research Institute (FAPRI) U.S. and Mexican sweetener baseline models to project sugar and high-fructose corn syrup (HFCS) supply and demand conditions in the United States and Mexico for FY2010–FY2019. Their projections indicated that NAFTA would not negatively impact the U.S. sugar industry as anticipated and that "dire predictions of U.S. producer interests would not materialize" (Knutson, Westhoff, and Sherwell, 2010, pg. 1).

While Sano, House, and Spreen (2004), Abler et al. (2008), Kennedy and Schmitz (2009), and Knutson, Westhoff, and Sherwell (2010) examined the potential impact of full NAFTA implementation *ex ante*, they did not include an *ex post* analysis, because full implementation of NAFTA for sugar had not yet occurred. We contribute to the existing literature on the impact of NAFTA on the trade of sugar between the United States and Mexico by being the first, to our knowledge, to empirically estimate the *ex post* impact of full NAFTA implementation on U.S. and Mexican producers and consumers by using actual data for FY2008–FY2013, during which NAFTA was fully implemented.

Methodology

We determine the *ex post* impact of full NAFTA implementation of U.S. trade in sugar on U.S. and Mexican producers and consumers by making extensive use of the concept of economic surplus (e.g., producer surplus, consumer surplus, and total welfare), which is frequently used in applied welfare economics to analyze the impact of policy changes involving international trade (e.g., Just, Hueth, and Schmitz, 2004; Schmitz, Schmitz, and Dumas, 1997; Schmitz, 2002). We capture the major aspects of current U.S. and Mexican sugar trade policy using a stylized partial-equilibrium trade model, which incorporates Mexico's unrestricted access to the U.S. sugar market starting in 2008 when NAFTA became fully implemented and takes into account the TRQs issued by the U.S. government to forty sugar exporting countries (ROW). The ROW TRQs were completely filled in FY2008–FY2012 but not in FY2013; thus, our model incorporates both scenarios. Once developed, the model is calibrated for each individual year, FY2008–FY2013, in order to estimate realized economic welfare in the United States and Mexico. The parameters of the model are then used to capture the welfare implications of a counterfactual scenario in which Mexico is initially restricted to 250,000 MTRV (Mexico's pre-2008 TRQ allocation) of sugar exports to the United States.

Theoretical Model

A model of sugar trade is provided in figure 3. The United States imports sugar from the forty ROW TRQ countries and from Mexico. Mexico is a net exporter of sugar and, since full implementation of NAFTA in 2008, has exported all but a negligible amount of its sugar exports to the United States (U.S. Department of Agriculture, Economic Research Service, 2013c). Most of the ROW countries (such as Brazil) have associated production and shipping costs that are typically lower than Mexico's, while some have associated costs that are higher than Mexico's in some years (dependent on global market conditions).[3] While exports by the ROW to the United States are restricted by import quotas under the TRQ, the within-quota tariff is essentially zero, which implies that the ROW countries usually receive a price for U.S. sugar exports that is much higher than the world price. The ROW is allowed to export sugar to the United States beyond the quota, but the over-quota tariff is effectively prohibitive. No significant amount of sugar was exported to the United States beyond its TRQ from FY2008 through FY2013.

The United States is a large-country importer of sugar, while Mexico and the ROW are large-country exporters. In the left panel of figure 3, the U.S. supply and demand curves are S_u and D_u, respectively. The U.S. excess demand curve is ED_u (in the middle panel of the diagram), which equals the horizontal difference between D_u and S_u. In the right panel of figure 3, the Mexican demand curve is D_m and the Mexican supply curve is S_m. The Mexican excess supply curve is equal to the horizontal difference between S_m and D_m (not shown in figure 3). In order to construct the excess supply curve facing the United States (which includes sugar from both Mexico and the ROW), two distinct cases must be considered. Case I represents years in which the TRQ was originally completely filled by all forty TRQ countries (figure 3) and is applicable to FY2008–FY2012. Case II represents years in which the TRQ was not originally completely filled by the ROW. The middle panel of the three-panel trade diagram associated with this alternative case is shown in figure 5 and is applicable to FY2013.

Case I: The ROW TRQ was Originally Filled (FY2008–FY2012)

In Case I, the realized excess supply curve facing the United States, ES_1, consists of three distinct segments, as shown in the middle panel of figure 3. At price P_3, the United States begins importing

[3] Brazil is considered the world's least-cost producer of sugarcane, with production costs often below the world price (Haley, 2013).

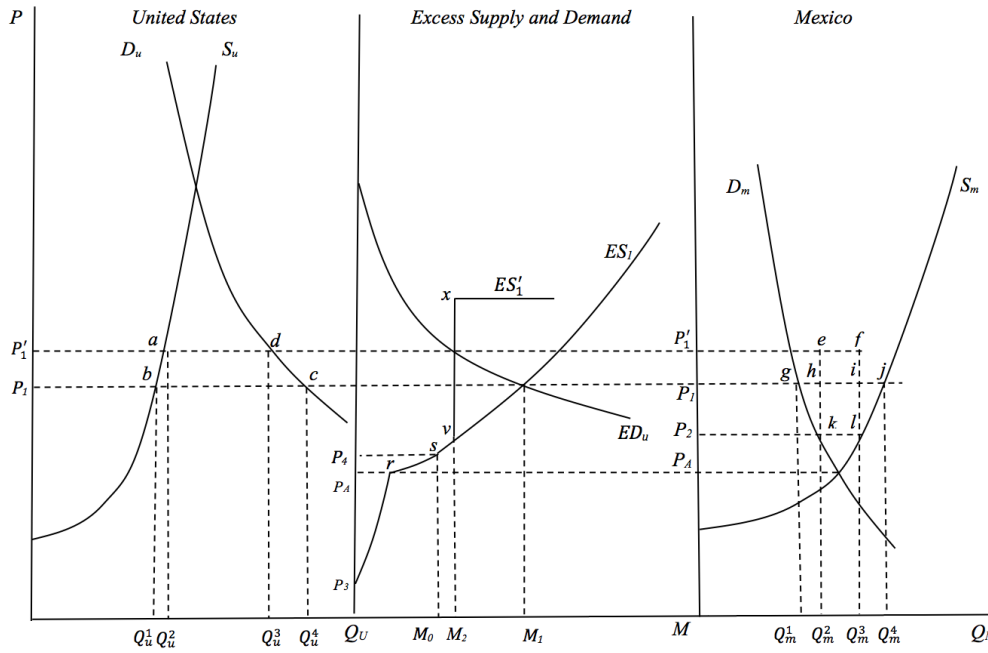

Figure 3. Case I: Sugar Markets in the United States and Mexico When the TRQ Is Originally Filled

sugar from the ROW countries with the largest excess supply. As the price increases above P_3, the United States imports from the ROW exclusively up to price P_A at point r (which corresponds to the price of sugar in Mexican that would exist in autarky). The slope of this first segment is the same as the slope of the residual excess supply curve of the ROW with respect to the United States. At price P_A, the United States imports sugar from both Mexico and the ROW simultaneously along the second segment up until price P_4 at point s, which is where the ROW TRQ is completely filled by the ROW. At a price above P_4, the United States imports sugar exclusively from Mexico along the third segment. Mexico continues to export sugar to the United States under NAFTA along ES_1, where the slope of the excess supply curve facing the United States is equal to the slope of the Mexican total excess supply curve.

Under Case I, the equilibrium volume of U.S. sugar imports from Mexico and the ROW combined is M_1 and the equilibrium Mexican and U.S. domestic price is P_1, which occurs at the intersection of ED_u and ES_1 in the middle panel of figure 3. The United States consumes Q_u^4 and produces Q_u^1 in the left panel. Mexico consumes Q_m^1, produces Q_m^4, and exports $(Q_m^4 - Q_m^1)$ in the right panel of figure 3.

The above framework was formulated to capture the behavior of the United States, Mexico, and the TRQ countries under realized global market conditions that existed as a result of full NAFTA implementation commensurate with Case I. Now we consider a counterfactual scenario in which NAFTA was never fully implemented. Prior to full implementation of NAFTA, Mexico was restricted by a TRQ of 250,000 MTRV. Under the counterfactual scenario commensurate with Case I, the excess supply curve facing the United States must be separated into four segments. The counterfactual excess supply curve facing the U.S, ES_1', is identical to ES_1 up until point v, where both Mexico and the ROW completely fill their TRQs (represented by M2 in the middle panel of figure 3). The United States will not import sugar under the initial TRQ beyond M_2, so the excess supply curve facing the United States continues vertically above point v. At point x, the excess supply curve facing the United States becomes perfectly elastic, as the United States expands the

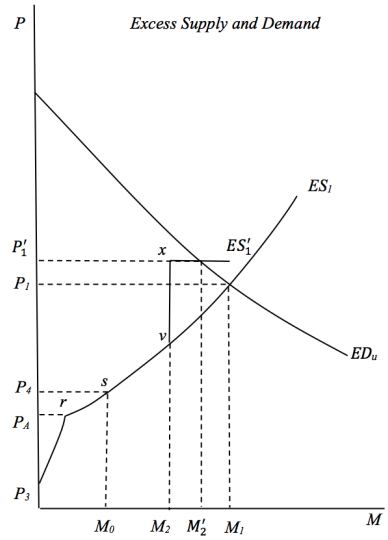

Figure 4. TRQ Is Originally Filled and Counterfactual U.S. Imports Expand beyond the TRQ

TRQs for Mexico and the ROW whenever the U.S. price is about to exceed the world sugar price plus the U.S. over-quota tariff plus transportation costs.

The equilibrium U.S. domestic price under the counterfactual scenario is P_1', which occurs where ED_u intersects ES_1' in the middle panel of figure 3. The equilibrium quantity of sugar imported by the United States is M_2 (250,000 MTRV of which originates from Mexico, while the remainder originates from the ROW TRQ). The United States produces Q_u^2 and consumes Q_u^3 in the left panel. The domestic price of sugar in Mexico is P_2, which is found by setting $S_m - D_m$ in the right panel equal to 250,000 MTRV. Mexico consumes Q_m^2 and produces Q_m^3 and exports $Q_m^3 - Q_m^2$ to the United States at price P_1'.

The change in welfare is found by comparing the counterfactual scenario with the realized scenario. If NAFTA had not been fully implemented, the increase in the U.S. domestic price from P_1 to P_1' would have caused U.S. producer surplus to increase by $P_1'P_1ba$, but U.S. consumer surplus would have decreased by $P_1'P_1cd$, which would result in a net loss in U.S. welfare of $abcd$. Mexican consumer surplus would have increased by P_1P_2kg in the right panel. Mexican producers would have lost P_1P_2lj because of the lower domestic price but would have gained $eklf$ because of the higher price received for exports to the United States. Hence, if NAFTA had not been fully implemented, the change in Mexican producer surplus would have been $ehif - (P_1P_2kh + ilj)$. Thus, under certain market conditions, it is possible that removing NAFTA and restricting Mexico to its previous quota allocation could actually improve Mexican producer welfare (a result that is analogous to the case of VERs). It remains an empirical question as to whether this net change in Mexican producer surplus is positive or negative. Finally, the impact on the Mexican economy is found by adding the change in producer surplus to the change in consumer surplus so that the change in total welfare is equal to $ehif - (gkh + ilj)$. Therefore, it remains an empirical question as to which years (if any) the Mexican economy was worse off as a result of full NAFTA implementation.

Figure 3 depicts years in which the excess demand curve intersects the vertical portion of the counterfactual excess supply curve. However, there are years in which the excess demand curve intersects the horizontal portion of the counterfactual excess supply curve. This situation is depicted in figure 4, which is the same as the middle panel of figure 3, except that the excess supply curve in figure 4, ES_1', intersects the excess demand curve, ED_u, along its perfectly elastic segment. In figure 4, the combined TRQ for Mexico and the ROW is expanded from M_2 to M_2'.

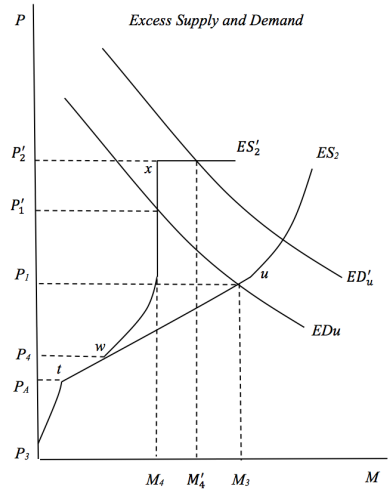

Figure 5. Case II: Sugar Markets in the United States and Mexico When the ROW TRQ Is Not Originally Filled

Case II: The ROW TRQ was not Originally Filled (FY2013)

The only difference between Case I and Case II is the excess supply curve facing the United States. Therefore, figure 5 depicts only the middle panel associated with Case II. The realized excess supply curve facing the United States, ES_2, consists of three distinct segments (figure 5). At price P_3, the United States begins importing sugar from the ROW, exclusively, up to price P_A at point t (which corresponds to the price of sugar in Mexico that would exist in autarky). At price P_A, the United States begins importing sugar from both Mexico and the ROW simultaneously along the second segment until the equilibrium price is reached at P_1. At point u, the TRQ would theoretically be completely filled by the ROW. At a price above point u, the United States would continue to import more sugar exclusively from Mexico along the third segment. In Case II, under excess demand curve ED_u, the equilibrium volume of U.S. sugar imports from Mexico and the ROW combined is M_3 and the equilibrium Mexican and U.S. domestic price is P_1.

Under the counterfactual scenario associated with Case II, the excess supply curve facing the United States would be identical to ES_2 up until price P_4 at point w, where Mexico completely fills its TRQ. At a price above P_4, the United States will import sugar exclusively from the ROW until M_4, where the ROW TRQ is filled. The United States will not import sugar under the within-quota tariff beyond M_4, so the new excess supply curve facing the United States continues vertically along M_4. At point x, the excess supply curve facing the United States becomes perfectly elastic, as the United States expands the TRQ for Mexico and the ROW whenever the U.S. price is about to exceed the world sugar price plus the U.S. over-quota tariff plus transportation costs. If the excess demand curve is ED_u, the equilibrium U.S. domestic price is P_1', U.S. imports equal M_4, and the welfare implications are theoretically similar to Case I. Alternatively, if the excess demand curve is ED_u', then the equilibrium price would instead be P_2' and the combined TRQ for Mexico and the ROW would expand from M_4 to M_4'.

Functional Forms and Welfare Measures

Estimates of producer and consumer surplus are derived using functional forms for supply and demand curves adapted from Schmitz, Schmitz, and Dumas (1997) and Schmitz (2002). The supply

and demand curve in the United States and Mexico are assumed to be of the form

$$P_S(Q) = \alpha + \beta Q_S^{\gamma}; \tag{1}$$

$$P_d(Q) = \delta Q_d^{\theta}; \tag{2}$$

where the demand curve is a constant elasticity curve and the supply curve is a constant elasticity curve, shifted upward by an intercept α, which represents the shutdown price (average variable cost). Under this specification, the price elasticity of demand and price elasticity of supply can be written as

$$\eta = \frac{\partial \ln Q_d}{\partial \ln P_d} = \frac{1}{\theta}; \tag{3}$$

$$\varepsilon = \frac{\partial \ln Q_S}{\partial \ln P_S} = \frac{1}{k\gamma} \tag{4}$$

where $k = (Ps - \alpha)/Ps$ and $0 \leq k \leq 1$. Thus, k is the difference between the producer price and the shutdown price, divided by the producer price. If the shutdown price were 0, k (which depends on both the producer price and the shutdown price) would equal 1 and the supply curve would revert to a constant elasticity form.

Under the above specification, the parameters θ, γ, δ, and β can be recovered given the shutdown price (α), the price received by producers (P_s), the price received by consumers (P_d), the quantity supplied (Q_s), the quantity demanded (Q_d), the price elasticity of supply (ε), and the price elasticity of demand (η) as follows:

$$\theta = \eta^{-1}; \tag{5}$$

$$\gamma = (k\varepsilon)^{-1}; \tag{6}$$

$$\delta = P_d Q_d^{-1/\eta}; \tag{7}$$

$$\beta = kP_S Q_S^{-1/k\varepsilon}; \tag{8}$$

where subscripts u, m, and r refer to the United States, Mexico, and the ROW, respectively. The excess demand curve for the United States is simply the horizontal difference between the U.S. supply and demand curves, S_u and D_u:

$$ED_u = \left(\frac{P}{\delta_u}\right)^{\eta_u} - \left(\frac{P - \alpha_u}{\beta_u}\right)^{k_u \varepsilon_u}. \tag{9}$$

Finally, the excess supply curve facing the United States equals the horizontal sum of the Mexican excess supply curve and the residual excess supply curve of the ROW:

$$ES = \left(\frac{P - \alpha_m}{\beta_m}\right)^{k_m \varepsilon_m} - \left(\frac{P}{\delta_m}\right)^{\eta_m} + \left(\frac{P - \alpha_r}{\beta_r}\right)^{k_r \varepsilon_r} - \left(\frac{P}{\delta_r}\right)^{\eta_r}. \tag{10}$$

In the above system, the formula for producer surplus at price $P^* > \alpha$, for any region, is

$$PS = \int_{\alpha}^{P^*} Q_S(P) dP = \int_{\alpha}^{P^*} \left(\frac{P - \alpha}{\beta}\right)^{\gamma^{-1}} dP. \tag{11}$$

After integrating equation (11), substituting equation (6), and simplifying, producer surplus at price P^* is

$$PS = \left(\frac{\beta^{-k\varepsilon}}{1 + k\varepsilon}\right)(P^* - \alpha)^{1+k\varepsilon}. \tag{12}$$

Table 1. U.S. and Mexican Data, 1,000 MTRV

	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013
United States						
Price	468.92	486.56	754.70	847.93	717.20	462.97
Production	7,396	6,832	7,224	7,104	7,700	8,143
Imports	1,858	2,515	2,414	3,111	2,680	2,791
TRQ	1,228	1,243	1,682	1,562	1,709	868
Mexico	630	1,272	732	1,549	972	1,923
Consumption[a]	9,254	9,347	9,638	10,215	10,380	10,934
Mexico						
Production[b]	6,078	5,419	5,976	5,802	5,856	7,623
Exports[c]	677	1,378	751	1,558	985	2,091
Consumption[d]	5,401	4,041	5,225	4,244	4,871	5,532

Notes: Prices are in $/MTRV and were converted from cents/pound to dollars/MT by the following conversion: 1,000 pounds= 0.4535924 MTRV.
[a]For the model, U.S. Consumption was set equal to U.S. Production + U.S. Imports.
[b]Mexican production is set equal to Mexican domestic production + Mexican imports.
[c]All but a negligible amount of Mexican exports are shipped exclusively to the United States.
[d]For the model, Mexican Consumption was set equal to Mexican Imports + Mexican Production − Mexican Exports.

The formula for the change in consumer surplus from a lower price P_1^* to a higher price P_2^* is

$$\Delta CS = \int_{P_2^*}^{P_1^*} Q_d(P)dP = \int_{P_2^*}^{P_1^*} \left(\frac{P}{\delta}\right)^{\theta^{-1}} dP. \tag{13}$$

After integrating equation (13), substituting equation (5), and simplifying, the change in consumer surplus is

$$\Delta CS = \frac{\delta^{-\eta}}{(1+\eta)}\left(P_1^{\eta+1} - P_2^{\eta+1}\right). \tag{14}$$

Parameterization and Data

Data regarding U.S. and Mexican sugar prices, production, consumption, exports, and imports for FY2008–FY2013 were obtained from the U.S. Department of Agriculture, Economic Research Service (2013b) and are provided in table 1. Since full implementation of NAFTA, U.S. sugar production averaged 7.4 million MTRV and U.S. sugar consumption averaged 10 million MTRV. Thus, U.S. sugar imports averaged approximately 2.6 million MTRV, which was 26% of total U.S. consumption. Mexico's domestic production of sugar averaged 6.1 million MTRV and its domestic consumption averaged 4.9 million MTRV.[4] Therefore, approximately 20% of Mexico's sugar production was exported to the United States, on average, for FY2008–FY2013.

Point estimates of the short-run price elasticity[5] of demand and supply for sugar in both Mexico and the United States were acquired from the FAPRI sugar baseline model (table 2).[6] The price

[4] In the model, Mexican production is set equal to Mexico's domestic production plus its imports. In the counterfactual scenario we assume that Mexican imports remain constant, which is a limitation of our analysis. It is possible in the counterfactual scenario that Mexico would have imported less sugar had NAFTA not been fully implemented.

[5] FAPRI provided us with both short-run and long-run elasticities. Given that we model each year individually, the short-run estimates are appropriate for our empirical analysis. We considered using the FAPRI long-run elasticity estimates as our "high" elasticities. However, a review of previous literature determined that "high" sugar elasticities were actually slightly higher than FAPRI's long-run elasticity estimates. Therefore, we used the "high" elasticities from previous literature to perform our sensitivity analysis rather than FAPRI's long-run sugar elasticities.

[6] The FAPRI elasticities were obtained by allowing other sectors to adjust to changes in sugar prices. Thus, a change in sugar prices also impacts HFCS prices as well.

Table 2. Supply and Demand Elasticities and Shut-Down Prices for U.S. and Mexican Sugar, MTRV

	FAPRI Elasticity	High Elasticity	Shut-Down Prices
United States			$0.16/pound
Supply	0.25	0.50	
Demand	-0.12	-0.60	
Mexico			$0.18/pound
Supply	0.15	0.50	
Demand	-0.13	-0.60	

Table 3. Counterfactual Estimates for the United States and Mexico 1,000 MTRV

Variable	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013
FAPRI						
United States						
Price	$541	$734	$868	$920	$900	$805
Production	7,619	7,341	7,467	7,247	8,108	8,857
Imports	1,478	1,556	2,011	2,868	1,994	1,378
TRQ	1,228	1,296	1,751	2,189	1,709	1,117
Mexico	250	260	260	679	285	261
Consumption	9,097	8,897	9,478	10,115	10,102	10,235
Mexico						
Price	$406	$397	$577	$516	$495	$400
Production	5,801	4,520	5,690	5,215	5,410	6,070
Exports	250	261	260	679	285	261
Consumption	5,551	4,259	5,430	4,536	5,125	5,809
High Elasticity						
United States						
Price	$489	$549	$795	$974	$772	$534
Production	7,544	7,201	7,410	7,589	7,977	8,645
Imports	1,478	1,493	1,932	1,812	1,959	1,367
TRQ	1,228	1,243	1,682	1,562	1,709	1,117
Mexico	250	250	250	250	250	250
Consumption	9,023	8,694	9,342	9,402	9,936	10,017
Mexico						
Price	$444	$420	$699	$678	$637	$403
Production	5,881	4,781	5,741	5,114	5,493	6,443
Exports	250	250	250	250	250	250
Consumption	5,631	4,530	5,491	4,864	5,243	6,193

Notes: Prices are in $/MTRV.

elasticity of demand for the United States and Mexico are very similar in magnitude and indicate that consumers are relatively not that sensitive to changes in the price of sugar. On the other hand, U.S. sugar producers are nearly twice as price sensitive compared to Mexican producers. A set of "high" elasticities was also used to perform a sensitivity analysis of our results. The "high" elasticity estimates were taken from Kennedy and Schmitz (2009), who used a range of elasticities adapted from previous literature (Lopez, 1989, 1990; Tyers and Anderson, 1992; Gardiner, Liu, and Roningen, 1989; Uri and Boyd, 1994).[7] The average variable cost of sugar production in the United States and Mexico was obtained from industry experts. U.S. and Mexican sugar industry shutdown prices were calculated by taking the average of those estimates. As a result, the shutdown prices used to obtain empirical estimates from the model were \$0.16 for the United States and \$0.18 for Mexico (table 2).

Data from tables 1 and 2 were inserted into equations (5)–(8) to recover the parameters necessary to estimate the U.S. and Mexican supply curve (equation 1) and demand curve (equation 2) as well as the U.S. excess demand curve (equation 9) and the excess supply curve facing the United States (equation 10). In order to empirically estimate the equilibrium prices and quantities under the counterfactual scenario, the Solver function in Microsoft Excel was applied in each year to the U.S. excess demand curve and the excess supply curve facing the United States, subject to the TRQ constraints for Mexico and the ROW. As a result, regardless of the year chosen and the parameters associated with the residual excess supply curve of the ROW, the TRQ for the ROW and the TRQ for Mexico were always filled under the counterfactual scenario in each year.[8] Additionally, the cost of shipping sugar from the ROW to the United States was assumed to be \$0.03/pound, following Beghin and Elobeid (2015). Changes in consumer surplus and producer surplus between the realized and counterfactual scenario in each year were estimated using equations (12) and (14).

The counterfactual estimates for the United States and Mexico associated with a TRQ constraint on the maximum volume of Mexican exports allowed into the United States are provided in table 3. When comparing the counterfactual price of sugar in the United States and Mexico (table 3) with the realized U.S. price of sugar (table 1), limiting Mexican exports of sugar into the United States would result in a significantly higher U.S. price of sugar and a significantly lower domestic price of sugar in Mexico. Counterfactual U.S. and Mexican production and consumption estimates were obtained by substituting the counterfactual price of sugar in Mexico and the United States into their respective domestic supply and demand curves.

Empirical Results

The impact of NAFTA on U.S. producers and consumers in FY2008–FY2013 is provided in table 4. If Mexico were restricted by the TRQ (counterfactual scenario), the annual average U.S. producer surplus for FY2008–FY2013 would have ranged from \$2.1 billion to \$3.1 billion compared to \$1.6 billion to \$1.8 billion.[9] Thus, due to full NAFTA implementation, U.S. producer surplus decreased by an average of \$474 million to \$1.3 billion annually from FY2008 through FY2013. U.S. producer surplus was reduced by its greatest amount, \$613 million to \$2.9 billion, in FY2013, which is expected given this was the year Mexico exported nearly 2 million MTRV of sugar to the United States. Initially, NAFTA cost U.S. producers \$150 million to \$538 million in FY2008. However, from FY2011 through FY2013, NAFTA decreased U.S. producer surplus by an average

[7] While previous literature provides ranges for U.S. domestic supply and demand elasticities, to our knowledge, no literature provides a range of Mexican sugar supply and demand elasticities. Therefore, the "high" Mexican elasticities were increased by the same magnitude as the corresponding "high" U.S. elasticities.

[8] In the counterfactual scenario, U.S. domestic marketing allotments were allowed to increase to compensate for lower U.S. sugar imports. Thus, U.S. producers were assumed to have the ability to market the extra sugar they produced.

[9] Throughout this section we report a range of estimates based on the FAPRI elasticities and the "high" elasticities described earlier.

Table 4. Impact of NAFTA on U.S. Producer and Consumer Surplus, FY2008–FY2013 (Millions of Dollars)

	Producer Surplus (PS)			Consumer Surplus (CS)	Δ Total Welfare
FY	Actual	Counterfactual[a]	Δ PS	Δ CS	(ΔCS+ΔPS)
FAPRI					
2008	809	1,347	−538	657	118
2009	855	2,616	−1,760	2,249	489
2010	2,562	3,395	−833	1,083	250
2011	3,070	3,590	−520	737	216
2012	2,490	3,936	−1,445	1,869	424
2013	847	3,781	−2,933	3,607	674
Average	1,772	3,111	−1,338	1,700	362
High Elasticity					
2008	765	915	−150	184	34
2009	804	1,242	−438	562	123
2010	2,293	2,588	−295	382	87
2011	2,723	3,647	−924	1,231	307
2012	2,038	2,664	−426	551	126
2013	802	1,415	−613	762	149
Average	1,571	2,079	−474	612	138

Notes: [a]Counterfactual is the scenario where NAFTA is not implemented and Mexico is constrained to 250,000 MTRV by the TRQ.

Table 5. Impact of NAFTA on Mexican Producer and Consumer Surplus, FY2008–FY2013 (Millions of Dollars)

	Producer Surplus (PS)			Consumer Surplus (CS)	Δ Total Welfare
FY	Actual	Counterfactual[a]	Δ PS	Δ CS	(ΔCS+ΔPS)
FAPRI					
2008	428	88	341	−344	−3
2009	473	85	388	−376	12
2010	1,997	1,027	969	−950	19
2011	2,423	675	1,748	−1,455	293
2012	1,758	497	1,159	−1,110	49
2013	494	101	392	−362	30
Average	1,262	412	833	−766	67
High Elasticity					
2008	407	256	139	−139	0
2009	445	133	312	−288	23
2010	1,728	1,426	302	−299	4
2011	2,067	1,135	858	−773	86
2012	1,534	1,080	420	−403	16
2013	470	71	399	−355	44
Average	1,099	683	405	−376	29

Notes: [a]Counterfactual is the scenario where NAFTA is not implemented and Mexico is constrained to 250,000 MTRV by the TRQ.

of $654 million to $1.6 billion annually. U.S. consumer surplus as a result of NAFTA increased by an annual average of $612 million to $1.7 billion annually.[10] Similar to the impact on producer surplus, NAFTA did not initially have a major impact on U.S. consumer surplus. In FY2008, U.S. consumer surplus increased by only $184 million to $657 million annually, while this number grew to $762 million to $3.6 billion in FY2013. Overall, NAFTA did not have a large impact on total U.S. welfare in FY2008, providing a modest increase of between $34 million to $118 million. However, by FY2013, NAFTA increased combined U.S. producer and consumer welfare of sugar by $149 million to $674 million. Overall, since full implementation of NAFTA, overall U.S. welfare has increased by an annual average of $138 million to $362 million.

The impact of NAFTA on Mexican producers and consumers in FY2008–FY2013 is provided in table 5.[11] Under NAFTA, Mexican producers gained an average of $405 million to $833 million annually in FY2008–FY2013. Thus, U.S. producers lost a much greater amount annually compared to how much Mexican producers have gained due to full implementation of NAFTA. In general, nearly all the benefits accruing to Mexican producers were offset by an average loss in Mexican consumer surplus of between $376 million and $766 million over that same time period. Overall, due to NAFTA, average total Mexican consumer and producer welfare improved by only $29 million to $67 million annually. Most notably, full NAFTA implementation actually caused the Mexican economy to experience a net welfare loss of $3 million in FY2008 in the FAPRI elasticity scenario. Therefore, if Mexico were bound by its pre-2008 TRQ, the Mexican economy would have experienced a net welfare gain in FY2008 (FAPRI elasticity scenario). This result is not surprising when considered in the context of the literature on the welfare implications of VERs. Indeed, the foregoing analysis implies that there is a range of exports restraints that could possibly improve Mexican welfare.

Conclusions, Limitations, and Topics for Future Research

Since full implementation of NAFTA for sugar in 2008, both the U.S. and Mexican sugar markets have undergone considerable changes (American Sugar Alliance, 2013; Wexler, 2013), as Mexican exports of sugar into the United States increased from 4% of total U.S. sugar imports in FY2007 to nearly 70% in FY2013 (U.S. Department of Agriculture, Economic Research Service, 2013c). Therefore, we developed a theoretical model of trade between the United States, Mexico, and the TRQ countries that export sugar into the United States to quantify NAFTA's impact on consumer and producer welfare in Mexico and the United States. While previous research has predicted the *ex ante* impact of NAFTA with respect to sugar, we are the first to empirically quantify the *ex post* impact of NAFTA on U.S. and Mexican welfare by estimating the impact of a counterfactual scenario in which Mexico is restricted by its pre-2008 TRQ. We also show that restricting Mexico to its pre-2008 TRQ quantity has the potential to increase total welfare in Mexico, which coincides with the literature on VERs.

Full implementation of NAFTA caused U.S. net welfare to rise by an annual average of $138 million to $362 million and Mexican producer surplus to increase by $405 million to $833 million annually. However, it came at a cost to U.S. sugar producers of $474 million to $1.3 billion annually and cost Mexican consumers $376 million to $766 million annually. We also found that under certain market conditions, net Mexican welfare actually decreased (as in FY2008) due to NAFTA, which is a result consistent with the literature on VERs. However, on average, Mexican total welfare increased by $29 million to $67 million annually from FY2008 through FY2013.

[10] Among U.S. sugar consumers, 60% are classified as food manufacturers (e.g., bakery, cereal, ice cream) and 40% are non-industrial users (e.g., restaurants, grocers, and hotels) (U.S. Department of Agriculture, Economic Research Service, 2013c).

[11] The Mexican government owns 20% of Mexico's sugar production (U.S. Congress, 2015). Thus, Mexican producer surplus (and quota rent) is divided among the Mexican government and domestic sugar producers.

Our analysis is not without limitations. For example, in our counterfactual scenario we are unable to know with full certainty when the USDA would have chosen to increase the TRQ. Therefore, it is possible that our model overestimates the increase in U.S. consumer surplus and Mexican producer surplus and overestimates the decrease in U.S. producer surplus and Mexican consumer surplus as a result of NAFTA. Another limitation is that our analysis does not consider changes in U.S. and Mexican sugar stocks.

Our analysis could be extended and expanded in several ways in order to analyze other policy issues currently under debate related to the U.S. sugar complex. For example, the U.S. sugar industry submitted antidumping and countervailing duty petitions against Mexico in March 2014 that led to an agreement between the United States and Mexico in December 2014, which restricted Mexican sugar entering the United States (American Sugar Alliance, 2014b). It would be interesting to analyze the impact of these new trade barriers by building upon the aforementioned model. Future research efforts could integrate the present analysis with certain game-theoretical aspects found in the literature on VERs in order to analyze the new agreement between the United States and Mexico.

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