THESIS

NOT SO SWEET: POTENTIAL ECONOMIC IMPLICATIONS OF RESTRICTING U.S. SUGAR IMPORTS FROM MEXICO

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ABSTRACT

NOT SO SWEET: POTENTIAL ECONOMIC IMPLICATIONS OF RESTRICTING U.S. SUGAR IMPORTS FROM MEXICO

In December 2014, the U.S. and Mexican governments signed a bilateral agreement constraining Mexico's ability to export sugar to the U.S. because of dumping allegations by U.S. producers. This restriction came after six years of unlimited, tariff-free access to the U.S. market for Mexican sugar producers through the North American Free Trade Agreement. This analysis employs a twenty-eight country partial equilibrium model to estimate the price and welfare impacts of this bilateral trade agreement. Estimates suggest that the agreement successfully increases U.S. price by curbing imports from Mexico. These results translate to an average annual increase in producer surplus of approximately $620 million and decrease in consumer surplus of $1.48 billion across the five-year period simulated.

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LIST OF ACRONYMS

ASC	American Sugar Coalition
CCC	Commodity Credit Corporation
CGE	Computable General Equilibrium
CONADESUCA	National Committee for the Sustainable Development of Sugarcane
ERS	Economic Research Service
EV	Equivalent Variation
F.o.b.	Free on Board
FAO	Food and Agricultural Organization
GAIN	Global Agricultural Information Network
GATT	General Agreement on Tariffs and Trade
GM	Genetically Modified
HFCS	High Fructose Corn Syrup
MCP	Mixed Complementarity Problem
NAFTA	North American Free Trade Agreement
OECD	Organization for Economic Co-operation and Development
OLS	Ordinary Least Squares
ROW	Rest of the World
RTA	Regional Trade Agreement
TRQ	Tariff Rate Quota
USDA	U.S. Department of Agriculture
USDOC	U.S. Department of Commerce
USITC	U.S. International Trade Commission
USTR	U.S. Trade Representatives
WTO	World Trade Organization

Introduction

The simulation of liberalization scenarios is a popular research topic among trade economists, and perhaps no market has a more interesting web of distortionary policies than the global sugar industry. The U.S. sugar program relies on price floors and trade barriers to protect domestic producers, but the market has been trending slowly towards a more free market in recent years, as 2008 saw Mexico gain unlimited, tariff-free access to U.S. markets. As the trade barriers were weakened and imports from Mexico grew, prices fell substantially. Falling prices caused U.S. sugar program expenditures to increase significantly in 2012 through 2013. In 2014, complaints were filed stating that Mexico dumped subsidized sugar onto the U.S. market, and an agreement was signed at the end of the year rolling back Mexico's access to the U.S. sugar market. This research employs a partial equilibrium trade model to estimate the price and welfare effects of the U.S.-Mexico sugar agreement restricting U.S. imports of Mexican sugar. While research that assesses changes in sugar trade policy is abundant and widespread, this work is an important contribution to the literature because analyses generally do not focus on agreements as imminent or focused as this trade deal.

This study begins with a discussion of the unique background of the global sugar industry, focusing on the production and trade policies of the U.S. and Mexico. Background is given for both the physical traits of sugar and the policies that govern its production and trade, which are uncommon for most commodity markets. Extensive literature is available, and this previous research is examined to build the basis for analyzing this trade agreement. The partial equilibrium model of the sugar market and data is then outlined in detail, followed by results, policy implications, and potential future research. Key findings indicate that Mexico's limited access to the U.S. market does increase U.S. price and protects against significant sugar program expenditures. These conclusions translate to a substantial decrease in U.S. consumer surplus and increase in U.S. producer surplus, as well as a moderate decrease in Mexican producer surplus.

Background

Physical Sugar Background

White sugar that humans consume in food and drinks is processed from either sugarcane or sugar beets. The final product is identical no matter the origin crop, but sugarcane is slightly more efficient in conversion to raw sugar than sugar beets. Sugarcane is grown in tropical regions, and processed into raw sugar at plants near to the harvest. The process begins by the sugarcane being cut into small pieces and crushed to extract the juice inside. The juice is boiled into a thick syrup substance with large sugar crystals forming within the syrup. The entire substance is spun in a centrifuge to separate the sugar crystals from the syrup, which is now molasses. The dried raw sugar crystals can be transported more easily for further processing at refineries around the world (Canadian Sugar Institute a, n.d.). Sugar beets are grown in climates that are more temperate and can be transported further distances before processing because of their durable physical nature. Beets are usually stored for around six months before being processed. Juice is extracted from the beets by being soaked in in hot water and filtered. Beets are then further processed into raw sugar in the same way sugarcane is, boiled into syrup and crystals then spun in a centrifuge to separate the two.

Raw sugar crystals come to refineries with large amounts of molasses residue. The crystals are soaked in a hot syrup that connects to the molasses and then spun to separate the molasses and the crystals. The purified crystals are dissolved in water, strained to remove large fragments, and clarified to remove any of the remaining brown color from the raw sugar. What remains is a white syrup made up of only sugar and water. The syrup concentrates to again form crystals that are spun in centrifuges, this time separating the white sugar from the syrup. The sugar is now ready to be stored, consumed, or further converted to specialized products such as fine or powdered sugar (Canadian Sugar Institute b, n.d.).

Currently, there are no genetically modified (GM) sugarcane seeds commercially available, so supplying sugar exclusively from sugarcane ensures no GM products are used. In the U.S., GM sugar beets comprised about 95 percent of the sugar beet crop in 2010, up from 60 percent in 2006 (USDA ERS, 2016). Recently, consumer preferences have been shifting towards non-GM produced crops as an alternative to GM products, citing perceived health concerns. Hershey Company, one of the largest chocolate manufacturers in the U.S., began to transition all of their use to sugar sourced from sugarcane because of worries over GM crops (Charles, 2016). This is the first instance of differentiation of sugarcane and beets, but prices from sugar from the two sources do not currently reflect this discrepancy.

World Sugar Policy Background

Global sugar markets are among the most distorted of any agricultural commodity. Mitchell (2004) found that 60 percent of sugar trade and 80 percent of production takes place at prices above that of the global market equilibrium. Countries protect domestic markets through two general policy schemes: domestic support and trade barriers. Domestic support can come from subsidies, production controls, or price floors. Many nations use a unique blend of these domestic policies to protect sugar producers. The Uruguay Round of the General Agreement on Tariffs and Trade (GATT) in 1995 led to a multilateral trade agreement including 123 countries and eventually to the creation of the World Trade Organization (WTO). Since then, the vast majority of barriers to sugar trade have come in the form of tariff rate quotas (TRQs). TRQs encompass tariffs that are required to be relatively small until a quota is fulfilled (in-quota-tariff rate) and then the importing country is able to increase the tariff to much higher levels (out-of-quota-tariff rate). Often, the out-of-quota-tariff rate is prohibitively high, and the TRQ acts as if it were a hard quota (McMinimy, 2016). This is in opposition to the intent of the Uruguay Round Agreement, as it banned agricultural trade quotas and implemented TRQs as a transitionary measure (WTO, n.d.). The following section characterizes domestic and trade policies of the U.S. and Mexico because of their significance in this analysis. Many other countries employ distortionary measures to domestic and trade markets, and all twenty-eight modeled countries' policies are outlined in Appendix I.

United States Sugar Policy

The U.S. protects the domestic sugar industry through price floors, production controls, and TRQs. U.S. prices are consistently around double that of the representative world price. Figure 1 shows the annual average price for raw sugar in the U.S. and world markets from 1980-2016 (USDA ERS, 2016). World and U.S. sugar prices saw great increases from 2010-2012 due to a number of market factors. Commodity prices as a whole were on the rise over this period, but most agricultural commodities besides sugar saw price increases beginning in 2007. This caused much of the land previously devoted to sugar crops to transfer production to other crops in 2008 and 2009. Decreased global acreage had a substantial effect on increasing sugar prices in 2010 and beyond, but the one of the largest drivers of increased sugar price was the demand for biofuels around 2010. Ethanol is sourced from both corn and sugar, meaning it competes with the sweetener market through both the corn and sugar markets. Both policy and market forces helped drive the increased demand for corn and sugar through increased ethanol production, contributing greatly to the inflation of corn and sugar prices from 2010 to 2012 (McConnell, Dohlman, and Haley, 2010). The U.S. sugar program provides guaranteed prices for both sugar crop producers and processors, generally at no cost to the federal budget, by restricting the quantity of sugar on the market, both domestically produced and imported. The Commodity Credit Corporation (CCC) is a federal company within the U.S. Department of Agriculture (USDA) created to protect farm income and prices (USDA Farm Service Agency, 2016). The Food and Agriculture Act of 1977 granted the USDA the authority to issue loans and purchase sugar (Anderson, 2009), and these actions are currently carried out by the CCC. The CCC annually forecasts the expected price for sugar in the U.S. and sets loan rates below that price. The size of the loan is determined by each producer's expected yield, and different loan rates are specified for different growing regions. If the price U.S. sugar producers receive is above the rate from the CCC loan, then the grower will sell the harvested sugar and pay back the loan. However, should the domestic price fall below the loan rate, the grower will simply turn over their harvest to the CCC. All excess sugar acquired by the CCC is sold to ethanol plants to be converted to fuel as the Agricultural Act of 2014 prohibits human consumption of sugar that has been forfeited to the CCC (McConnell, 2016). Loan forfeitures are costly to the government as the prices paid by ethanol plants is generally far lower than the costs of sugar production in the U.S. In order to control domestic supply amid inflated prices, the CCC restricts production through market allotments. The CCC sets a maximum volume of sugar that each producer is allowed to sell on the market in order to qualify for the loan program. Allotments are freely redistributed from producers that do not fill their quotas to producers with more successful harvests, but there is a hard cap on total domestic sugar allowed on the U.S. market. Quotas are reassigned based on geographic proximity in an attempt to provide the target quantity for processors, but quotas are never redistributed from sugarcane to beet or vice versa. Sugarcane and sugar beets are allocated with 45.65 percent and 64.35 percent of the overall quota, respectively (McConnell, 2016).

The U.S. government heavily restricts competition from foreign suppliers to further protect prices and expenditures. Under the Uruguay Round Agreements on Agriculture, the U.S. must import 1.139 million metric tons of raw or refined sugar each year. The required level of sugar imports is met by supply from 40 countries trading under the TRQ system and several other countries with separate trade agreements (McConnell, 2016). The Office of the U.S. Trade Representative (USTR) currently sets each individual country's quotas in compliance with the Uruguay Round of GATT, and there is an additional allocated quantity that is available on a first-come, first-served basis (Nyberg, 1999). Total TRQ allotments and fulfillments are illustrated in Figure 2. The current in-quota tariff rate is 0.625 cents per pound of raw sugar and 15.36 cents per pound for out-of-quota raw sugar (McConnell, 2016).

Raw sugar is also imported through three Re-Export Programs designed to benefit U.S. refiners without adding any additional supply to the U.S. market. The Refined Sugar Re-Export Program allows U.S. refiners to import raw sugar outside of a country's TRQ, given that the processor exports as much domestic refined sugar to the world market. The Sugar-Containing Products Re-Export Program permits refiners to buy sugar at world prices for refining and resale back on to the world market. The Sugar for the Production of Polyhydric Alcohol Program also allows for unlimited imports for sugar that will not be used for human consumption. Sugar imported within these programs is not counted towards the exporting country's TRQ limit and has averaged about ten percent of imports since their introduction in 2008 (McConnell, 2016).

The Agriculture and Food Act of 1981 took steps to encourage the sugar program to operate at no cost to the federal budget, and in 2012, congress reiterated this instruction (McMinimy, 2016). However, in the Fiscal Year 2013, $259 million was devoted to sugar crop producers because growers in several regions defaulted on their CCC loans (Jurenas, 2012). A large part of the deflating sugar price was the influx of Mexican sugar on the market from the full liberalization under the North American Free Trade Agreement (NAFTA). In 1994, NAFTA was signed, and many North American markets became liberalized. However, agricultural sectors were agreed upon separately, and sugar began a slow process towards full integration. This process came to completion in 2008 when Mexico gained unfettered, duty-free access to U.S. markets. Figure 3 shows U.S. imports of Mexican sugar quantities rising over time, substantially after 2008, but decreasing substantially in 2014 and 2015 due to the drop in price of sugar in the U.S. The decrease in U.S. sugar price in 2013 was potentially caused by the market's overreaction to the biofuel trend observed in 2010 and previously. However, Mexico's unlimited access to the U.S. market continued to put downward pressure on U.S. prices when the market did correct itself. The sharp decrease in prices came to the dismay of both congress and U.S. producers. An additional point of contention is the Mexican government's practice of subsidizing sugar production, much of which was exposed by this sudden increase in Mexican production followed by an increase in exports to the U.S. and subsequent decrease in U.S. price.

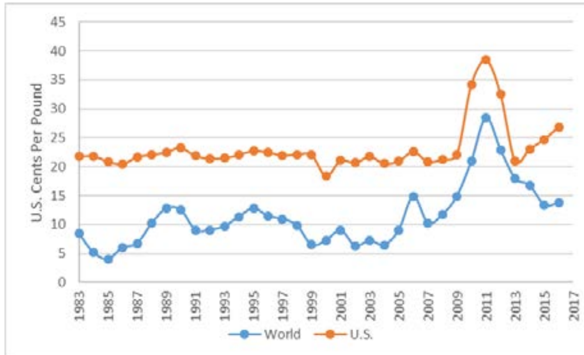

Figure 1. U.S. and World Raw Sugar Prices 1980-2016
Source: USDA ERS, 2016

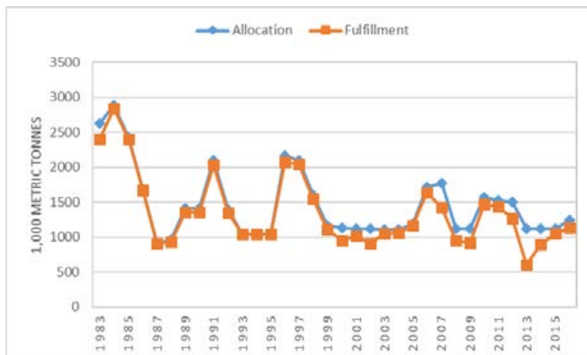

Figure 2. U.S. TRQ Allocations and Imports
Source: USDA ERS, 2016

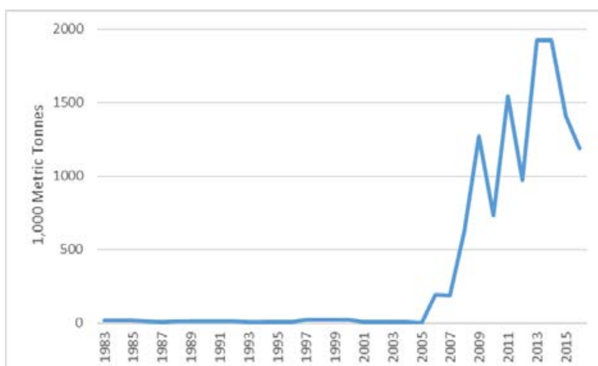

Figure 3. U.S. Imports of Sugar from Mexico
Source: USDA ERS, 2016

Mexico Sugar Policy

Many of the sugar processing plants in Mexico were previously state owned. The final two sugar mills owned by the Mexican government were put up for sale in June 2016, and these mills are still on the market (Flores, 2016b). The National Committee for the Sustainable Development of Sugarcane (CONADESUCA) is a Mexican government entity that supports the "promotion, competitiveness, and innovation" of the Mexican sugarcane industry. The CONADESUCA sets annual reference prices that mills pay to refineries for semi-refined sugar, known as standard sugar in Mexico. This value is used to calculate the price refineries pay to sugarcane producers, as sugarcane growers, by law, receive 57 percent of the reference standard sugar price (Flores and Harrison, 2016). By owning the mills and setting the producer price, the Mexican government was able to subsidize sugar production and pay growers prices well above the market value. Subsidizing practices coupled with unrestrained access lead to a trade dispute with the U.S. that culminated in 2014.

Antidumping and Countervailing Suspension Agreements

In March 2014, the American Sugar Coalition (ASC), an alliance of sugar cane and beet producers dedicated to preserving and protecting the U.S. sugar industry, filed antidumping and countervailing petitions with the U.S. International Trade Commission (USITC) in response to the Mexican government's subsidization of sugar production. Since these subsidies appeared to distort prices, the USITC levied temporary tariffs on Mexican sugar imports and launched investigations into the Mexican government's sugar subsidizing practices and subsequent dumping onto the U.S. market. The U.S. Department of Commerce (USDOC) and USITC joint investigation determined that Mexican sugar subsidies ranged from 2.99 percent to 17.01 percent, significantly injuring U.S. producers (USDOC, 2015). An agreement was reached in December 2014 between the USDOC, the Mexican government, and producers from both countries. This agreement suspended the investigation and paid back the temporary tariff revenue in exchange for six stipulations. 1) a quantitative restriction on imports based on U.S. needs[1,2], 2) subjection of imported sugar to price floors above the CCC loan rate[3], 3) a maximum of 53 percent of exports are refined[4,5,6] in any marketing year, 4) a seasonal limit on all sugar imports, 5) adoption of a production allocation system in order to reduce the quantity of sugar supplied domestically, and 6) establishment of an export licensing mechanism so that only licensed Mexican exporters may sell sugar in the U.S. (U.S. International Trade Administration, 2014). The Mexican government asserted that they complied with all of the stipulations within the agreement, but U.S. producers argued the seasonal restrictions and polarity requirements did not restrict Mexico's access enough. Both governments and domestic industries began talks to resolve these issues in September 2016 (Flores, 2016a). A pact was signed in June 2017 revising the refined sugar requirements (Lawder and Prentice, 2017), but this second agreement had no impact on the sugar modeled in this study.

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[1] U.S. Needs are calculated as: [(Expected consumption*1.135) – Beginning stocks - Expected production – TRQ imports – Other program imports]. (1)

[2] Other program imports include only the Re-Export Programs, as they are the only programs that include raw sugar imports.

[3] Price floors for Mexican sugar are currently $0.26 per pound for refined sugar and $0.2225 for all other sugars.

[4] Refined sugar is defined as a polarity greater than or equal to 99.5 percent (McConnell, 2016).

[5] Polarity gauges the purity of refined sugar by measuring the color of the sugar, with 100 percent conveying completely refined sugar (Nyberg, 2006).

[6] A June 2017 revision of this agreement changed the maximum refined export limit to 30 percent (Lawder and Prentice, 2017).

Literature Review

Extensive research has investigated the distortion of the global sugar market by employing equilibrium models to project the effect of policy changes. Equilibrium models seek to explain the supply and demand forces of a market to find predicted price, production, and consumption levels. These investigations regularly follows similar outlines: simulation of the future sugar market with policies unchanged, simulation of a world with some amount of liberalization, and compare the results. Often the liberalization scenarios that are simulated are large, multilateral, and unrealistic (e.g. the removal of all trade barriers in the global sugar industry). This wealth of literature provides guidance for policy analyses moving forward.

This review highlights key theoretical issues surrounding projection modeling before moving into an overview of both general and partial equilibrium models. Theoretical concerns generally regard the explanatory variables that are used to project future values of commodity production. Both general equilibrium and partial equilibrium models are popular among trade economists. There is no one approach that is ultimately superior over the other, but research questions usually lend themselves more appropriately to one specific type of equilibrium model. A partial equilibrium model is used for this study because this is an analysis of a bilateral trade agreement with limited effects on other sectors of the economy.

Projection Modeling

Partial equilibrium models, including FAPRI[7] models, are used to predict the future of a commodity's specific market. Many scholars believe that prediction models such as these are scientifically inferior to explanatory models because they lack capability of accurately

[7] FAPRI stands for Food and Agricultural Policy Research Institute, a dual-university research program at Iowa State University and the University of Missouri-Columbia.

identifying the magnitude of causal relationships. FAPRI models, for example, only use a few independent variables to predict production and use of commodities. This will be expanded upon in the Model Description section, but the model used for Elobeid and Beghin (2006) only includes two explanatory variables for the yield of a given crop: lagged yield and a trend variable. There are more factors that influence yield including weather, seed technology, land quality, and other phenomenon that are not considered in this analysis. Furthermore, issues of both endogeneity and autocorrelation could arise when using lagged dependent variables as explanatory variables.

Shmueli (2010) addresses some of the issues with predictive modeling and makes the case for its credibility in applied science. The aricle outlines the difference between explanatory and predictive models, both in their construction and functionality. As a statistician, her motivation for this article was to make a case for the validity of predictive modeling among her academic colleagues. Independent variable χ determines the value of dependent variable Υ, via the function F where *f* is operationalization of F into a statistical model. As Shmueli notes, "F is usually not sufficiently detailed enough to lead to a single *f*" therefore, a set of *f* models are considered in an explanatory situation. In a predictive context, only one *f* is examined. The goal of explanatory analyses is to identify the cause and magnitude of χ on Υ, or to match F and *f* as close as is possible in order to test the causal hypothesis. On the other hand, the goal of predictive models is to generate accurate predictions of Υ, even if a function besides $\hat{f}$ and data other than χ must be used. This is often the case with predictive models.

The two types of models' intentions diverge in four major ways: causation-association, theory-data, retrospective-prospective, and bias variance. Where explanatory models predict *f* as a causal function, *f* captures the association between the dependent and independent variables in predictive modeling. *f* is designed to support an underlying theory and used in testing a causal hypothesis in explanatory modeling, projection models formulate *f* through data and the interpretability of the relationship may be preferable but isn't necessary. Explanatory modeling is retrospective because *f* is used to test an existing hypothesis with historical data, and projective modeling is prospective in that *f* is constructed to forecast new values. Perhaps the most fundamental disparity between the two approaches is the bias-variance aspects. Explanatory models attempt to minimize the bias of the estimated relationship to represent theory as accurately as possible. However, predictive models focus on minimizing the combination of bias and variance of the estimations, sometimes ceding theoretical accuracy for more precise predictions. Shmueli (2010) concludes with an example of how a model lacking a strong theoretical basis can sometimes predict more accurately than a model from a more theoretical approach. This is a similar conclusion to the Milton Friedman's famous Essay in Positive Economics where he ascertains that a hypothesis should be judged on its simplicity in its ability to predict and its fruitfulness the predictions' scope and precision (Friedman, 1953).

Achen (2001) outlines some of the issues that could arise with the inclusion of lagged dependent variables as regressors. Lagged dependent variables often obtain a statistically significant coefficient with a large magnitude, while many other seemingly important coefficients fall into unlikely small and insignificant values, occasionally even taking on the wrong sign. These issues do not necessarily make lagged dependent variables unusable. Variables becoming more significant and influential with the absence of a lagged dependent variable could be a function of omitted variable bias, the included variables obtaining, or representing, the significance the neglected variable actually has. While lagged dependent variables are helpful to increase the prediction power of the model, it is important to acknowledge that these concerns may emerge.

General Equilibrium Trade Models

One of the most basic components of all equilibrium modeling is the Walrasian market clearing condition. Developed by Leon Walras in 1877, this condition asserts that an equilibrium price is obtained when excess supply meets excess demand. The original algorithm assumes two rational agents in any market: consumers driven by their preferences and endowments while producers by their technology. The drivers of behaviors allow the agents to be modeled. Both agents' behavior are theoretically defined within the behavioral equations. The behavior of the agents are simulated so that a single price leaves the market completely cleared (Cheng and Wellman, 1998). The Walrasian market clearing condition is the basis of all equilibrium models, allowing them to converge on a single value for price. This condition lead to the creation of general equilibrium models that are used today. Compared to partial equilibrium models, general equilibrium models have a shorter history with regard to U.S. sugar policy analysis, but they can be beneficial when seeking to characterize a larger scope of the sugar market in the broader context of the overall economy.

General equilibrium modeling describes the interactions between all of the individual markets within an economy. Computable General Equilibrium (CGE) models have become a popular tool for trade economists to simulate policy changes. These models are especially valuable when analyzing commodities with significant downstream effects. Like most agricultural products, sugar can have large downstream impacts on supply and demand of other products. However, general equilibrium models are not used as frequently in the sugar industry as in other agricultural markets. One of the main reasons is that international sugar policy changes often come in the form of bilateral trade agreements, such as the sugar agreement within NAFTA. When sugar is analyzed using a general equilibrium approach, the changes being modeled are usually large or multilateral.

Boyd, Doroodian, and Power (1996) was one of the first studies to analyze the U.S. sugar program using a general equilibrium approach. The CGE model was used to assess the price effects and inefficiencies that the program induced. By modeling fifteen production sectors and fourteen consumption sectors, the researchers were able to attain a robust estimate of the sugar industry's impacts on other markets. Perhaps the most helpful aspect of the article, however, was the extensive modeling detail for the use of the general equilibrium approach specifically for the sugar market, as it diverged from most of the partial equilibrium literature on sugar trade at the time. While CGE models allow the tracing of the complete effect of policies throughout the economy, partial equilibrium models are only able to capture the effects on the specific market being analyzed.

Boyd, Doroodian, and Power (1996) assert that their study was only the second general equilibrium analysis of the U.S. sugar program at the time, and there are several reasons for this. Sugar production plays a relatively small role when it comes to the production sector of the entire U.S. economy. Sugar consumption is more widespread, but sugar is generally used as a small input for food products with many ingredients. Therefore, the impacts on consumption are widespread but somewhat diffuse. In addition, with such a high level of government intervention, prices can be very sensitive to the slightest omission of market details, and general equilibrium models are more prone to missing smaller, more detailed, aspects of a commodity market. These are the intuitive reasons that many researchers have clung to partial equilibrium analyses when assessing the U.S. sugar program. Boyd, Doroodian, and Power (1996) set out to obtain a broader view of the program’s impacts, and they took as many precautions as possible not to lose the specificity of a partial equilibrium analysis when modeling the sugar market in a CGE framework.

In the Boyd, Doroodian, and Power (1996) study, the supply side is made up of fifteen input-output equations, each representing one section of the U.S. production sector. Not all supply equations include sugar-containing products as inputs, such as mining and other non-food products, but all sectors could conceivably be in competition with sugar crop production for land as well as labor and capital resources. The demand side is similar, with fourteen utility functions representing consumption categories. Utility functions are bound by a budget constraint, but it is unclear how this budget constraint is formulated. Foreign supply and demand are additional sectors included within the model to represent imports and exports. These accounts representing trade are balanced so that they have no effect on domestic supply or demand. This assumption of an even net trade account across all sectors is a limit of the model used, especially as the sugar program is phased out.

The results show that the elimination of the U.S. sugar program would have a positive net economic impact on the U.S. economy. Of the fifteen production sectors, only three were negatively impacted by the abolition of the program. These sectors were petroleum refining, finance, and program crops. However, program crops, which includes sugar production, was the only category with significant economic losses. Crude oil and natural gas were shown to have no effect. Most consumption categories show positive effects from this change because of the reduction in prices. Interestingly, consumers with income between $10,000 and $19,999 are the only group that sees a negative impact, a loss that is attributed to the decline of property values of low income farmers, while the two highest groups of earners receive the largest benefit. Boyd, Doroodian, and Power (1996) exemplifies the benefits of broadening the scope for a study, but there are many specific policy mechanism that cannot be built into the analysis because of this broad scope.

Van der Mensbrugghe, Beghin, and Mitchell (2003) programmed TRQs into a CGE Linkage model by using a mixed-complementarity problem (MCP) approach. MCPs are a simplification of nonlinear complementarity problems that are used to model inequalities within mathematical programming. This approach diverges from many previous studies that simply linearized inequalities to model TRQ systems and makes it simpler to measure the rent collected from TRQs. Domestic price is solved endogenously within the MCP, with the possibility for imports to exceed the quota limit. In this case, the quota holder is able to acquire the premium that is the difference between the lower in-quota rate and the higher out-of-quota rate. This is only feasible if the price in the importing country less the premium is still higher than the world price.

Van der Mensbrugghe, Beghin, and Mitchell (2003) focused on the specific policies of sugar markets in the United States, the European Union, and Japan as these three markets consistently see prices more than double that of the world price. Aside from countries for which the E.U. has regional trade agreements (RTA), their TRQ system is effectively a hard quota system because out-of-quota tariff rate is set prohibitively high. U.S. policy includes lower out-of-quota rates than the E.U., but countries still rarely import outside of their TRQ. Japan uses a quasi-TRQ scheme that allows them to report zero tariffs to the WTO, but they are still able to collect large surcharges on imports and redistribute that revenue to subsidize domestic production by obligating all imported sugar pass through a government trading enterprise. Japan's sugar import program is effectively a TRQ scheme and is treated as such by Beghin, and

Mitchell (2003). Three liberalization scenarios for these highly distorted sugar markets were simulated in Van der Mensbrugghe, Beghin, and Mitchell (2003): a 33 percent increase in quota levels, a 33 percent decrease in out-of-quota tariffs, and both scenarios at the same time.

The authors calculate welfare impacts using equivalent variation (EV)[8]. Utility in Van der Mensbrugghe, Beghin, and Mitchell (2003) is based on the amount of sugar consumed through sugar products. Consumers would pay approximately $889 million in total to see a 33 percent increase in quota levels and a 33 percent decrease in out of quota tariffs that cause sugar prices to decrease, which is modeled as the combination scenario.

These general equilibrium studies exemplify the type of policy changes where the modeling framework must capture large and widespread changes. Since this analysis is targeting a single, bilateral trade agreement, a partial equilibrium trade model is used. Giving up economy wide effects of a policy is a worthwhile tradeoff for analyzing greater sectoral detail for the sugar market. Because the market is subject to many different policy mechanisms, more detail and data are necessary within the sugar sector to accurately portray the market. Partial equilibrium studies have a significantly larger presence in the sugar trade literature, making it relatively simple to gather information regarding how to develop a modeling framework for this research.

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[8] EV is a measure of welfare change that represents the minimum payment a consumer would require to offset the negative impact from an increase in price or the left of the Hicksian demand curve. EV is associated with the consumer's Hicksian demand curve, which is found by minimizing expenditure for a bundle of goods, holding utility constant. Hicksian demand functions are difficult to represent because utility functions are unobservable. However, it is useful when analyzing past consumption of a single commodity, as consumption can be held constant to represent utility derived from that commodity while prices change through policy changes.

Partial Equilibrium Trade Models

Partial equilibrium models often analyze one specific market within an economy. This simplicity lends itself well to accurately modeling bilateral trade deals such as the agreement modeled here, but it does come with a number of disadvantages. This section will overview some of the advantages and disadvantages of partial equilibrium models and how the disadvantages could be overcome. Then, several partial equilibrium analyses are summarized to focus on how researchers overcome modeling issues and how these studies work in practice.

Partial equilibrium analyses require a minimal amount of data compared to CGE models because of the relatively small number of variables influencing the targeted market compared to the economy as a whole. For example, only twelve equations are used to represent the entire U.S. sugar market in this study, including trade equations. However, the minimal data requirement makes models especially sensitive to poorly estimated elasticities (World Bank, 2010). It is often difficult to obtain a large sample size of disaggregated data, leading to diminishing explanatory power within the partial equilibrium model. Fortunately, there is a wealth of published literature that has been validated and can be used to glean elasticity estimates so that parameter estimation does not need to be conducted for each study. This is a concern that must be taken into consideration when estimating model parameters, and it makes the act of conducting a sensitivity analysis vital.

Partial equilibrium models are also advantageous when dealing with largely disaggregated data. Bilateral trade agreements are generally conducted at a disaggregated level. The U.S.-Mexico agreement does not distinguish sugar provided from sugarcane or sugar beets, but it does specify the type of sugar (raw versus refined) and does not include other sweeteners such as high fructose corn syrup (HFCS). While partial equilibrium models may be able to bilateral trade deals in more, there are significant downstream effects that may go unnoticed when only considering a single market (World Bank, 2010). There are important interactions between products in both supply and demand. Some amount of these linkages, such as substitute prices, can be implemented into these models, but the interactions of market factors and their movements across sectors are largely overlooked. The inclusion of these interactions are a major advantage of general equilibrium models.

Samuelson (1952) artificially formulated a one-commodity partial equilibrium problem into a maximization problem he referred to as the net social payoff function. The social payoff being maximized was the sum of all payoffs in a region minus transportation costs. His problem was formulated linearly, having one commodity and being traded in a perfectly competitive market. Takayama and Judge (1964) set out to depict the world more accurately, and converted the linear supply and demand functions into quadratic problems and described a computable algorithm able to solve the problem. While the quadratic formulation of the supply and demand curves illustrates the world more authentically, they were still operating under the assumption of perfect competition. Especially in the world sugar market, this assumption almost never holds because of the high level of market distortion present (Mitchell, 2004).

Bawden (1964) described how to integrate some common mechanisms, both domestic and international, employed by governments that diverge from the free trade assumption. He used hypothetical data to prove the efficacy of his trade model, which included eight price-distorting policies that can be difficult to model. Import duties are modeled in three forms: fixed, variable, and ad valorem. Fixed duties can simply be added to the transportation costs of each unit traded. Variable duties are employed when there is a target price. Therefore, the price can be treated as exogenous, the market price found, and the levy equals the target price less equilibrium price. Ad valorem tariffs are implemented by making the proportional duty a function of price. Export subsidies can be subtracted from transportation costs of exports. Percentage import quotas are a function of domestic production. Domestically supported prices can be treated as fixed, and then supply and demand equations revised before determining the optimal solution. For both acreage allotments and fixed import quotas, the free trade equilibrium quantities produced and traded are found to determine whether the allocations are binding. If the quota is in fact binding, it is considered exogenous and price is solved for. The hypothetical data used in Bawden (1964) showed a large cross crop effect from trade barriers designed to protect the price of the targeted crop. Some variation of all these distortionary measures have been present in the world sugar market at some point in the recent past.

Koo (2002) estimated the price and welfare effects of the liberalization of the U.S. and E.U. sugar programs using a partial equilibrium model. The reforms include a complete dismantling of each respective U.S. and E.U. programs and trade barriers. The modeling framework employed by Koo (2002) includes a similar structure and consumer surplus is used to calculate welfare changes, just as is done in this study, and a system of behavioral equations are used to find an equilibrium price that satisfies the Walrasian market clearing conditions. Equations represent area harvested, yield, consumption, and carry-over stocks. Just as in the FAPRI International Sugar model, area harvest is a function of lagged area harvested to capture the dynamics of decision-making. Part of this dynamic is the inertia in the production system being evaluated. While changes in labor, technology, and capital can happen rapidly, these factors generally go through periods of relative stability before and after great changes occur. The inclusion of a lagged dependent variable helps to capture the effects that are generally carried over from one period to the next. This inclusion of a lagged dependent variable raises questions about potential endogeneity issues within the estimations. Equation parameters were estimated econometrically, but because of data problems and inaccurate predictions, the final model is a hybrid and a synthetic model. Synthetic parameters were based on advice from market experts and personal judgement. This flexibility in parameter origin highlights the points addressed in Shmueli (2010), which asserts that the coefficient values in parameter models should not be judged on their explanatory power, but on their predictive capabilities. The fact that Koo (2002) was able to use ad hoc coefficient values and largely ignored some of the issues involved with the estimation emphasizes that the means of which coefficients are estimated may be less important that the projections they produce. These measures may be acceptable as long as the predictive powers are sufficient, though the legitimacy of the values may be subject to a higher scrutiny. A sensitivity analysis is may have addressed some concerns regarding this approach, but no such validation measure was mentioned in this article.

Three scenarios were simulated five years into the future in Koo (2002): elimination of the U.S. sugar program and trade barriers, elimination of E.U. sugar subsidies and trade barriers, and both liberalization scenarios at once. Policies of other countries were not explicitly modeled or altered. Liberalizing the U.S. and E.U. markets increased world prices by 33 and 22 percent, respectively, by opening formerly protected demand to the rest of the world. The combination scenario yielded an astonishing 68 percent increase in world price. This significant increase is driven by both the U.S. and E.U. decreasing production because of lower cost imports. Both U.S. liberalization cases decreased the price of U.S. sugar. Sugarcane and beet production in the U.S. decrease by 7 and 3 percent in the complete liberalization scenario, compared to 16 and 11 percent in the U.S. only liberalization case, respectively. These results were simulated more than fifteen years ago, but many countries' sugar programs have remained largely unchanged since that time. Koo (2002) emphasizes the point that the world price is sensitive to the demand of rich countries that is currently heavily protected.

The final scenario increased U.S. consumer surplus by more than $1.2 billion[9], while decreasing producer surplus approximately $680 million. The welfare loss of U.S. sugar producers was felt almost evenly between sugarcane and beet producers. In total, the complete liberalization of U.S. and E.U. sugar programs and trade barriers increased U.S. economic welfare by $254 million. Consumer and producer surplus is a method of welfare estimation that is beneficial when projecting future welfare impacts of an input commodity such as raw sugar, and the same technique is used in this analysis.

The FAPRI International Sugar Model, a partial equilibrium trade model, has been employed in several published analyses. It generally seeks to estimate the price and welfare impacts of large, widespread policy changes. The remainder of this section includes a review of the literature that incorporates the same general model as this study, followed by a detailed description of the model, parameters, and data as applied to this research.

Beghin et al. (2003) utilized the FAPRI International Sugar Model to estimate the welfare impacts of the U.S. sugar program as a whole, as well as the effects of the elimination of the program on world price. The framework includes a partial equilibrium model, designed to capture cross market effects of sugar policy like a general equilibrium model would, while maintaining model manageability. This model used data from 1980-1998. An interesting piece of this analysis is the specific and extensive modeling of HFCS as a sweetener substitute. Since U.S. sugar prices are artificially high because of the domestic program’s distortionary effects, HFCS is an even stronger substitute in the U.S. than elsewhere in the world. Therefore,

[9] All prices in Koo (2002) are measured in 1998 U.S. dollars.

eliminating the program is expected to have large impacts on domestic corn producers. The demand sector modeled includes all aspects of processing and use up to the final consumer. Sweetener usage mix for sweetener-using manufactures was modeled so that the usage of each sweetener would change along with price.

The LINQUAD demand system, a linear income and quadratic price functional form of the incomplete demand system, is used Beghin et al. (2003) to represent consumer expenditure. This approach is helpful because it generates linear demand functions in both income and prices. EV is used in Beghin et al. (2003) to represent consumer welfare changes, and traditional producer surplus, the area below equilibrium price and above the supply curve, is used measure producer welfare changes. The impacts of the market liberalization are calculated using two separate, polar assumptions and are compared. The first assumption is the full internalization of cost savings by sugar-using manufacturers. The second is the full pass through of cost savings to consumers of sweetener products. These authors note that the first case is often the argument used by sugar lobbies in opposition to policy reform.

In the first case, the food industry simply increases its markup and captures the vast majority of the benefits from lower sugar costs. While it does decrease the retail price of sugar, this effect is small and only affects sugar prices. The second scenario sees consumers benefiting from lower sugar prices and lower food prices because of a decrease in sugar prices as well as a decrease in food processing costs as a whole. This is a more likely outcome than the first scenario because as input costs fall, production expands and lowers the output price. The results showed that the sugar program is expected to benefit sugarcane and beet producers by approximately $1 billion in producer surplus gains and imposed a cost to consumers - refiners, food manufactures, and customers – of approximately $1.5 billion in EV losses. Deadweight loss of the program was measured at $535 million. Sugar beet producers and processors captured about 70 percent of the program benefits. World prices increased 13.2 percent with the liberalization of the domestic U.S. market. HFCS producers did not receive any benefit from the sugar program because of the specialization of sweetener markets. This analysis highlights that the benefits from market liberalization are extremely sensitive to the assumption of if and how cost reductions are passed on to consumers.

Beghin et al. (2003) significantly extends the framework of the FAPRI International Sugar Model, as it measures the policy effects on manufacturers, processors, and consumers of both sugar and corn. A LINQUAD demand system is more sophisticated that the demand generally represented within the model in order to measure the policies' effects outside of the market for raw sugar. Because these cross-sector and downstream effects are being modeled, EV was used to measure welfare changes of the policies. Since end prices for end products were represented, EV is a more accurate technique of assessing the effects of end price on consumers. Consumer surplus would capture the impact on sugar processors as well as regular candy consumers. Beghin et al. (2003) shows how the FAPRI International Sugar Model can be utilized to investigate policy impacts on more than a singular market.

Beghin and Elobeid (2013) used the FAPRI International Sugar Model to analyze the welfare, trade, price, and employment impacts of the entire U.S. sugar program. Once again, this is a simulation of the complete dismantling of the U.S. sugar program. This includes the elimination of trade barriers, price floors, and domestic production allotments. This reform scenario is contingent on a few important assumptions. The model assumes that sugar processors will significantly alter their agreements with crop producers in a short period. In order to persuade domestic producers to produce a similar quantity of sugar crops without the program, processors and refiners are likely to offer growers a larger share of the refined sugar price than offered previously. Specifically, this model assumes that sugarcane and beet producers' share of the final sugar price will increase by 30 and 45 percent, respectively; otherwise, domestic production of both would fall drastically. In addition, the inventory responses are reduced in order to reflect more realistic behavior in a free trade scenario. When prices are consistently lower, processors are not necessarily as concerned about buying and storing crops during the periods when prices are lower than usual.

These policy alterations are simulated from 2013 to 2020 using several enhancements to the FAPRI baseline model. The first major augmentation to the baseline is the differentiation of raw and refined sugar. This is necessary with the addition of the refining/processing aspect to the model. The authors also incorporate links in consumption within the U.S., which were previously not a part of the international sugar model. Because major changes are being simulated for raw and refined sugar prices, some amount of change in consumption is expected. In order to capture this change in demand, behavioral equations for HFCS, ethanol, corn, soybeans, and biodiesel are modeled. The Brazilian agricultural and international ethanol models were also included because of their respective large impacts on global demand systems for sweeteners and fuel. Food processor behavior, consumer demand, and employment are all also explicitly modeled to estimate the effects of the sugar program on the U.S. economy.

With the elimination of the U.S. sugar program, the U.S. and world sugar prices swiftly converge through arbitrage. U.S. sugar prices fall by 24 to 40 percent, depending on the type of sugar and year of projection, and world prices increase 2 to 4 percent. Consumption and imports increase 15 percent and imports 80, respectively. Domestic sugar crop production initially decreases approximately 10 percent, but then recovers to near the baseline level by year seven of projection. This is an especially interesting finding as a common consensus is that domestic production is only at its current level because of support from the sugar program. In fact, Elobeid and Beghin (2006) showed that worldwide market liberalization would decrease U.S. production by more than 6 percent. However, this 2006 analysis did not include the assumption of increased shares of end-product revenue for crop producers. The inclusion of this assumption is important and well founded. When allotment quotas bind crop producers, their selling power is low in that respect. However, their selling power is also artificially inflated because of the lack of competition through those same quotas and trade barriers. Obviously, there is some amount of increase in profit shares that will be felt by crop producers because of the abolition of the allotment system, and the results are sensitive to the assumed value of return shares to crop producers. These results are also more moderate than were estimated in Koo (2002), a similar simulation. Some of this can also be explained by the assumptions made within Beghin and Elobeid (2013), but this model is also more sophisticated that Koo (2002). By capturing the cross industry impacts of sugar policy changes, the results are shown to be significantly lower in magnitude.

Food manufacturers see a 1 to 3 percent decrease in costs of food inputs because of the lower price of domestic sugar. Final consumers see the largest benefit of the abolishment of the sugar program through lower costs of sweetener products. Even though the price decrease for the modeled food products were generally very small (about 1 percent for most products), this translated to a $9[10] to $11 annual benefit per consumer. Aggregated, this means an annual $2.9 to $3.5-billion-dollar welfare gain to consumers across the eight-year simulated period. Once again, EV is used to measure consumer welfare gains because sugar is modeled as an end

10 Beghin and Elobeid (2013) results are measured in 2010 U.S. Dollars.

product that is consumed. Employment grows along with the extension of the food production enterprises. Between 17,000 and 20,000 new jobs are projected to be created each year within the food manufacturing industry. This includes small losses of jobs within the sugar crop production and sugar processing sectors.

Beghin and Elobeid (2013) conclude that the complete elimination of the U.S. sugar program would decrease domestic price and create a larger dependence on sugar imports, while at the same time increasing consumer welfare and creating jobs. With major additions to the FAPRI modeling system, these researchers were able to uncover novel effects of the sugar program not previously explored. Beghin and Elobeid (2013) provide an intriguing extension of the same modeling system and technique to be utilized to answer their research question. The more complete modeling of sugar is beneficial, but it requires a capacity that this study's model currently is not capable of, including interactions with other aspects of the FAPRI modeling system.

Abler et al. (2008) used a modified version of the FAPRI International Sugar Model linked with a multimarket U.S. crop model to estimate a significant change in the sugar program, not its dismantling. This research was motivated by the authors' hypothesis that the current U.S. sugar program could become very costly with the full implementation of NAFTA, a hypothesis that was proven true in 2012/2013. The two scenarios that were simulated were a baseline scenario, the U.S. sugar program unchanged, and a reform scenario, the U.S. sugar program being replaced with a direct payment program similar to that of wheat and cotton. Both scenarios incorporate the agreed upon NAFTA (unlimited sugar imports from Mexico) and Doha (TRQ expansion) policy changes.

The U.S. crop sector model is a robust representation of agricultural commodities that includes program instruments, trade policies, and specific bilateral provisions for those trade policies. It also incorporates cross product effects in both supply and demand by allowing producers to alter land use and consumers to alter consumption behavior in response to prices. By dismantling the production allotment system, U.S. sugar producers gain a large amount of flexibility regarding planting decisions.

A major driver of Abler et al. (2008) is the "no-cost" stipulation of the U.S. sugar program. Simulation results for the baseline show that loan forfeitures could cost up to $175 million per year under the current sugar program. Forfeitures are driven by an 11 percent decrease in U.S. price through the influx of imports from Mexico. Although this was the upper bound of their estimation for loan forfeiture costs, it is interesting to note that sugar loan forfeitures actually cost the U.S. government $239 million in 2012/2013. Through the production allotment system, total sugar production is relatively unchanged in the baseline scenario. This would be expensive for the government at least until a new farm bill could be implemented to alter production allotments.

Industry experts were consulted to determine exactly how the direct payment would be determined. This method includes paying producers based on historical yields, with a target price established to calculate the direct payment value. The target price would guarantee producers a price similar to the price floor currently provided through the loan system. However, the target price would not force the government to obtain sugar stocks if the price falls too low, as would be the case under the current policy. The researcher hypothesized that it is cheaper to pay the difference between the actual price and the target price than to buy sugar for more than its market value. Prices showed similar changes in the reform scenario as the baseline, but government expenditure increased to $463 million per year. Costs to the government, however, do not tell the entire story of these two policies.

Comparing the reform scenario to the baseline scenario showed positive welfare gains resulting from implementing a direct payment program in place of the loan program currently used. Annual combined crop producer surplus was increased more than $350 million, while processors of sugar and HFCS felt negative impacts of around $250 million. Sweetener consumer surplus received nearly a $500 million benefit. These results are driven by the fact that sugar producers are guaranteed a price without any sugar being forfeited to the government. Essentially, taxpayers are footing the bill to support the sugar industry instead of sugar consumers. The difference is that by funding sugar protection in a stabile way, it is done more efficiently. The net economic welfare gains for this policy is $163 million. Just as is done in this study, Abler et al. (2008) simulate an agreed upon policy for the U.S. sugar market to assess its effects, and they provide another example of how the FAPRI International Sugar Model can be broadened to incorporate unique ideas of policy reform.

Elobeid and Beghin (2006) used the same FAPRI International Sugar Model as is used in this analysis to model large, multilateral changes in the world sugar industry. Since the same baseline model is used to simulate a policy change, the specifications of the modeling approach will be addressed in the next section. Their research question, assumptions, and findings are described here.

Elobeid and Beghin (2006) simulated three separate policy reforms in the sugar market, which are imposed on every country around the globe. Modeled policy amendments are the elimination of trade barriers, production support, and consumption subsidies. Consumption subsidies represent the smallest alteration in policy as only a handful of countries offer support to sugar consumers. In situations such as in the U.S., where the abolition of trade barriers would increase government spending drastically (through inevitable loan defaults because of lower prices), it is assumed that the government will continue to honor those agreements, regardless of political feasibility.

In the first reform scenario, removal of trade barriers increases the world sugar price by about 27 percent. This is because the majority of sugar markets are operating above the world price, and many rich countries heavily protect domestic producers, largely shielding the rest of the world from their demand. Impacts on world production and consumption are relatively small, but there are large changes on production location. Highly protected markets such as the U.S. and E.U. see little change in production, even though they have relatively higher costs of production, because of domestic production supports that have not been eliminated in the model (yet).

The second scenario simulates the impact of domestic production reform in addition to trade liberalization. In this case, production in places like the U.S. and the E.U. is far more elastic without allotment quotas, and therefore, production in those countries drops considerably. Within a decade, world sugar beet production decreases by about 23 percent, largely due to the inefficient extraction of raw sugar relative to sugarcane, which increased 7 percent over the same period. Sugar beets also have a higher opportunity cost of production as they are grown in temperate climates suitable for many other crops. For highly protected markets, the price of sugar dropped and therefore consumption increased, and the opposite holds true for countries with lower levels of distortion. Overall, consumption decreases by about 4 percent.

In the final scenario, only Cuba, Egypt, and Morocco’s consumption subsidizing policies were changed. It is an uncommon policy to subsidize sugar consumption, and it is generally used to support the domestic industry while incentivizing higher calorie intake in these relatively poor countries. This reform scheme had insignificant impacts on countries outside of the three that were directly altered.

The final step of Elobeid and Beghin (2006) was to conduct a sensitivity analysis by doubling and halving the price response elasticities in the supply, demand, and stock equations for all countries. Doubling elasticities creates large changes in supply, demand, and trade. Subsequently, the increase in world price through the three scenarios was significantly more modest. As such, halving the elasticities increase world price to an even larger degree than originally estimated. In both scenarios, the qualitative results and direction of changes are the same as in the original analysis, with one exception. When elasticities are halved for the second reform scenario, the U.S. production price response is so small that it completely offsets the drastic increase in world price. Overall, the sensitivity analysis validated the results of the model as expected.

This research lends itself to a partial equilibrium modeling framework. The vast majority of parameters used in this study were obtained from the model used by Elobeid and Beghin (2006). Remaining parameters were estimated using the same specifications, with results and sensitivity analyses discussed in the Methods section. Sugar production, particularly in the U.S., has limited downstream and cross sector effects relative to other agricultural commodities. Government intervention is intended to stabilize the market, meaning the suppression of market forces that promote these cross sector effects in production. Sugar is also highly price inelastic in consumption, sometimes characterized as an addictive substance, leading to weaker linkages to other markets in consumption. These factors lead to many analyses utilizing partial equilibrium trade models to simulate policy changes in the sugar industry. This includes simulations of large, multilateral changes across the globe, which would generally be conducted using general equilibrium models for other commodities.

The literature available for modeling the U.S. and world sugar markets is beneficial in moving forward with analyzing the price and welfare effects of the bilateral agreement restricting Mexico's access to the U.S. sugar market. A general equilibrium approach is useful and provides robust results on how a policy affects the economy as a whole. However, the research question at hand is more appropriately answered using a partial equilibrium model because of the specificity of the trade agreement. The partial equilibrium modeling approach, specifically utilizing the FAPRI International Sugar Model, has been used to investigate similar research questions in the past. This study employs the FAPRI International Sugar Model with newly estimated elasticities and updated data to estimate the price and welfare impacts of the 2014 agreement restricting Mexico's access to the U.S. sugar market.

Model Description

The FAPRI International Sugar Model is utilized in this study to simulate specific policy changes in the U.S., Mexican, and E.U. markets, as well as their interaction with the world market. The partial-equilibrium model is designed as system of dynamic, non-spatial, econometric-based sub-models to generate supply and demand values as well as estimates of prices and other implications of policy changes. Domestic agriculture and trade policies are explicitly specified in the model to establish a baseline that represents market with no policy change. Once a baseline is produced, changes to policy can be modeled to simulate potential effects of policy modifications.

This model defines only raw sugar trade, and sugarcane and sugar beet production are tied to raw sugar through the extraction rate. As sugar is a true homogeneous product, it is not necessary to differentiate the quality of the product on the market nor its crop or geographical origin. This specific model is nearly identical to the model used in Elobeid and Beghin (2006), with the only divergence in the model and dataset being the combination of the European Union and Eastern Europe models. This divergence was necessary because recent data combines all countries of the European Union. Twenty-eight countries/regions, including a rest-of-the-world aggregate (ROW), are represented in order to depict the world sugar market as accurately as possible from 1980-2021. The following countries/regions are represented explicitly in the model: Algeria, Argentina, Australia, Brazil, Canada, China, Colombia, Cuba, Egypt, European Union, India, Indonesia, Iran, Japan, South Korea, Malaysia, Mexico, Morocco, Pakistan, Peru, Philippines, Russia and Ukraine[11], South Africa, Thailand, Turkey, United States, Venezuela, and a ROW aggregate. These countries are included because they make up the FAPRI database

[11] Former Soviet Union data is used to model Russia and Ukraine until 1999. These countries are coupled in the model, just as in Elobeid and Beghin (2006) because of their close trade relations.

and modeling framework, and they combine to represent a majority of the world sugar market. The modeled countries comprise approximately 90 percent of world sugar production, 81 percent of world sugar consumption, and 92 percent of world sugar trade, and ROW represents the remainder of each category.

The model operates as twenty-eight sub-models representing each country interacting with the world model to determine a world price. The sub-models include behavioral equations to simulate production of sugar crops. These behavioral supply equations are defined as:

Area Harvested of sugarcane or beet crop in time *t*:

$$AH_t = \beta_0 + \beta_1 * AH_{t-1} + \beta_2 * CropPrice_{t-1} + \beta_3 * SubstitutePrice_{t-1} + \beta_4 * Trend \tag{2}$$

Yield of sugarcane or beet crop in time *t*:

$$Yield_t = \beta_0 + \beta_1 * Yield_{t-1} + \beta_2 * Trend \tag{3}$$

Production of sugarcane or beet crop in time *t*:

$$Production_t = AH_t * Yield_t \tag{4}$$

where AH designates acreage, CropPrice is the price sugarcane or sugar beet producers face, SubstitutePrice represents the market price of substitute crops, and subscript t expresses the time period. Different crops can be substituted for sugarcane versus sugar beets, and the same substitute crops are used in this model as in Elobeid and Beghin (2006). Each equation is calibrated using historical data to establish the baseline. The difference between the computed value and the actual value is the calibration. The calibration is then added to the computed value to match the historical data. Calibrations are held constant when simulating future values. β's are constants that were econometrically estimated by FAPRI in Elobeid and Beghin (2006) for each country sub-model, with the exception of the U.S. model. The extraction rates describe how much raw sugar is derived from sugar crops and is used as the link between crop and sugar production. It is determined as:

$$Extraction\ Rate_t = \frac{RawSugarProduction_t}{SugarCropProduction_t} \tag{5}$$

Several countries produce both sugarcane and beets, and the total production of the two crops are used in this calculation. Extraction rates are calculated when historical data is still available and are then held constant in order to convert projected crop production to raw sugar available for trade on the world market. When available, producer or farm gate prices are used for sugar crops for the supply equations. However, not all countries have this data accessible, so price transmission equations are used to convert raw sugar prices to sugar crop prices. Transmission equations are defined as:

$$Producer\ Price_t = \frac{1}{2} * RealPrice_{t-1} + \frac{1}{2} * ReaPrice_t \tag{6}$$

$$Real\ Price_t = \frac{DomesticRawPrice_t}{GDP\ deflator} \tag{7}$$

$$Domestic\ Price_t = WorldPrice_t * Exchange\ Rate * (1 + Tariff\ Rate) \tag{8}$$

where WorldPrice is the Caribbean raw sugar price, generally regarded as a representative world price (Elobeid and Beghin, 2006). The basic structure of this model is to only incorporate ad valorem tariffs within TRQs as price distorting trade policies. Tariffs are simply made a function of the price of sugar in the importing country and can be modeled to change after a TRQ is fulfilled. In order to impose other policies into the model, such as quantitative supply or trade restrictions, the framework of this model is slightly altered by constraining production or trade to the policy's levels.

Parameter estimates reflect the price data used. Therefore, the same variation of data was used in this model as in Elobeid and Beghin (2006) even when a country's producer or farm gate price is now available and wasn't for the original model. Data availability will be expanded on in the data section.

Behavioral demand equations are constructed in a very similar fashion:

Consumption in time *t*:

$$PerCapitaConsumption_t = \beta_0 + \beta_1 * RealConsumerPrice_t + \beta_2 * RealGDP_t \quad (9)$$

Ending Stocks in time *t*:

$$Ending\ Stocks_t = \beta_0 + \beta_1 * EndingStocks_{t-1} + \beta_2 * Consumption_t + \beta_3 * RealConsumerPrice_t \quad (10)$$

Income and price responses for consumption and price responses for supply were estimated in Elobeid and Beghin (2006). 1980-2001 data was used for estimating these price and income effects. The dataset may seem somewhat outdated for estimations used to predict activity in the future, but the global sugar industry has remained relatively unchanged over the relevant timeframe. The high level of government intervention in all sugar production and biological characteristics of sugarcane combine to make sugar highly inelastic in supply. Sugar consumption is also highly inelastic in demand as it is a major ingredient in a variety of foods. This inelastic nature in supply and demand is similar today as it was at the time of the parameter estimation (Elobeid and Beghin, 2015). It is likely that sugar has become more elastic in consumption as HFCS has become a stronger substitute sweetener; though, some of this effect was being observed in the dataset used to estimate parameters and is therefore reflected in those estimations. Figure 4 shows that after peaking in the early 2000s, U.S. consumption of HFCS has actually returned to early 1990's levels. This graphic also compares HFCS and refined sugar consumption over this time period to show that refined sugar consumption was lower than HFCS before 2009, and has subsequently become the leading sweetener product in the U.S. (USDA ERS, 2016).

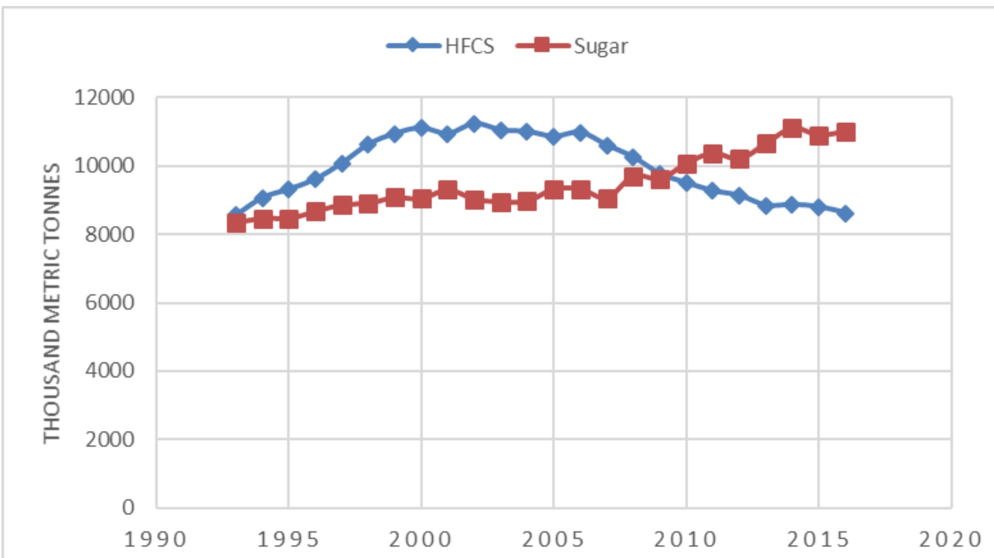

Figure 4. U.S. HFCS versus Refined Sugar Consumption 1993-2016
Source: USDA ERS, 2016

A major component of sugar demand is the substitutability of competing crops. Many crops compete with sugar production on the supply side. However, only a handful of countries have strong enough substituting crops to have a large impact on production choice[12], and even fewer countries allow producers the flexibility to change away from sugar production to a

12 Only soybeans in Brazil, wheat in Canada and the E.U., rice in Malaysia, and corn and soybeans in the U.S. are explicitly modeled into supply equations as substitutes.

meaningful degree (Elobeid and Beghin 2006). The cross-price effects in production are based on FAPRI elasticity of substitution estimates. Sugar crops also have multiple uses. Countries with high levels of sugarcane output, such as Brazil, oftentimes convert the sugarcane to alcohol to use as a fuel source (Ethanol, n.d.). Unfortunately, this model is not able to incorporate the substitution links in consumption dynamically. Instead, a constant ratio is used based on historical data. This technique is used to predict sugarcane used for ethanol in Brazil as well as sugar's share of sweetener use in the U.S. and Mexico.

Country sub-models are used to predict raw sugar production, consumption, and ending stocks. Stocks are held over in storage for a variety of reasons, including: price stability, profit maximization, and domestic supply security, so a large amount of crops and products are stockpiled each year instead of being sold onto the market. The following values are used to determine the quantity traded for each country, where net trade is calculated as:

$$\begin{aligned} Net\ Trade = {} & Production_t + Ending\ Stocks_{t-1} - Consumption_t \\ & - Ending\ Stocks_t \end{aligned} \tag{11}$$

The sign of the solution from the net trade equation determines whether a country is a net importer or exporter. Walras' Law is the principle that asserts a commodity is in equilibrium when excess demand matches excess supply. By imposing a Walrasian market clearing condition, prices can be solved for endogenously.

Coefficient estimation was conducted using ordinary least squares (OLS) and linear specifications in order to save degrees of freedom. These specifications are imperative because of the relatively small time series used for estimation. The parameters of the U.S. sub-model is the intellectual property of FAPRI and unavailable for this study. Therefore, supply and demand parameters were estimated using the same OLS and linearized specifications, and the data range for the U.S. sub-model is 1980-2013. The parameter estimation results are outlined in the Data and Parameter section and are used for all policy reform scenarios. The same framework is used in the U.S. sub-model, but some expansions must be included to model the U.S.-Mexico agreement.

Supply restrictions, such as the allotment system in place in the U.S. and E.U., are fixed in the short term when data is available and those policies in place. However, this information is not available more than a year into the future, so this model attempts to predict domestic production under the current policy. Designated domestic production levels are generally a function of domestic needs. For example, annual U.S. domestic production allotments must be at least 85 percent of expected domestic need for that year (McConnell 2016). Since this model is projecting total domestic needs and an extraction rate has been found for converting projected crop production into raw sugar production, it is relatively simple to implement a restriction that domestic production must meet that requirement. The projected crop level must be at least 85 percent, in this case, of the consumption of raw sugar, divided by the extraction rate. Mechanisms for price floors are built into specific country sub-models if the domestic price happens to fall below the exogenous price floor.

In order to explicitly model the U.S. market, a few additional equations were required specifically for this sub-model. The USTR currently sets the overall TRQ level based on expected production and consumption, with a minimum required by WTO agreements[13].

[13] Current minimum for U.S. TRQ imports is 1.1172 million metric tons

Therefore, allocations are determined by:

$$TRQ\ Allocation = \beta_0 + \beta_1 Production_{t-1} + \beta_2 * Consumption_{t-1} \tag{12}$$

and TRQ fulfillments are represented by:

$$TRQ\ Fulfillments = \beta_0 + \beta_1 U.S.Price + \beta_2 * WorldPrice \leq TRQ\ Allocation \tag{13}$$

Usually TRQ allocations are much larger than the minimum because the U.S. is such a large consumer of sugar. Fulfillments are estimated as a percentage of the allocation as opposed to the actual imported value.

Prior to 2008, Mexican sugar was subject to TRQ's in the U.S., but the in-quota-tariff-rate was zero. U.S. tariff-free imports from Mexico are modeled following Elobeid and Beghin (2006), and is specified as:

$$Imports\ from\ Mexico = \beta_0 + \beta_1 \frac{Mexican\ StandardPrice}{U.S.Price} \leq Mexio's\ Limit \tag{14}$$

As mentioned previously, this prediction model violates some of the theory that are strictly adhered to in explanatory models, such as the strict exogeneity assumption for OLS estimations with respect to lagged dependent variables serving as explanatory variables. The use of these regressors is not without warrant. Lagged area harvested is has a strong causal relationship with area harvested because of government mediation in production decisions. There are many factors that could influence yield besides lagged yield, but it is not feasible to add a weather or soil quality variable into such a broad trade model. This makes lagged dependent variables more suitable for this model. Lagged consumption was not included for parameter estimation, following the framework of Elobeid and Beghin (2006). While lagged consumption would allow for the capture of inertia in the U.S. demand system, its inclusion does not produce substantially different results, as described in Appendix II. Furthermore, the main goal of these behavioral equations is not to measure the effect that each independent variable has on the dependent variable but to accurately predict what the values of the dependent variable will be in the next period. The magnitude of these effects (particularly price response coefficients) are important when the independent variables are changing due to policy implementations. Elobeid and Beghin (2006) account for issue through sensitivity analyses by halving and doubling the price responses, an approach that is replicated in this study. The same qualitative results should be produced under the circumstances of doubled and halved price response coefficients as the baseline. There are techniques to account for some of the issues within the estimations.

Since a lagged dependent variable is being used, one observation is already being dropped. The two-stage least squares approach is effective in accounting for the endogeneity of a lagged dependent variable. However, the twice-lagged level used in this approach causes another observation to drop (Baum, 2013), and losing another observation is too costly with such a short time series used. The Arellano-Bond estimator is used with dynamic panel data. Its main purpose is to account for the violation of the strict exogeneity assumption of OLS that comes with utilizing lagged dependent variables as regressor variables. This estimator is best suited for panel data with a small time series and large panel (Greene, 2010). This would be an effective way to estimate parameters as the time series used here is short, but each country's parameters are estimated individually. This makes the data strictly time series, not panel. Unfortunately, the short time series and non-panel data leaves simple OLS as the most effective estimation approach. While the issues with OLS and lagged dependent variables are valid, the main purpose of this study is to predict the future accurately, and this is the most advantageous method to use with the available data.

Sensitivity analysis is conducted to test the model results. Since this study uses the same model as Elobeid and Beghin (2006), the same sensitivity analyses techniques, along with an additional approach, are utilized here. The price responses for production, consumption, and inventory are all doubled and halved for each country. If the model is operating correctly, the outcome of each scenario will have similar qualitative results, though a different magnitude of results. A further approach is added to this analysis, simulating the hypothetical conversion of sugar beet production from GM to non-GM. In this hypothetical scenario, 2015 would be the last year that GM sugar beet seeds are used in production, and yield data from 2005 is used in place of 2016 data to represent reverting to non-GM production. This is done to reset the calibration of the model before projections are made. The policy mechanism is introduced on top of this non-GM restraint, and again, the same qualitative results are expected. This requires relaxing some assumptions for the U.S. sugar program itself. With sugar beets' yield decreased substantially, the acreage allotment would have to expand to maintain the ratio of sugarcane and sugar beets produced as required by law. This is relaxed to observe the market's reaction to a shock in yield that is not unrealistic given current consumer trends towards a preference for non-GM sourced sugar.

As previously noted, this study measures welfare changes in consumer and producer surplus. Consumer surplus is measured by the area below the demand curve and above equilibrium price, while producer surplus is the area above the supply curve and below equilibrium price. Many recent studies use EV to measure consumer welfare because refined sugar is modeled to represent the prices end consumers are faced with, which is not the case here. Consumer surplus measures are inherently large, especially in the case of sugar with relatively inelastic demand, but the most important aspects of these calculations are the changes in welfare from one policy scenario to the next, not necessarily the magnitude of total welfare itself.

Data and Parameter Estimation

The data included in this model and database has been completely updated from the Elobeid and Beghin (2006) version, using largely the same data sources. The vast majority of these data come from intergovernmental organizations, with some obtained from national government databases. Sugarcane and beet crop data for acreage, yield, and production was obtained from the Food and Agricultural Organization (FAO) of the United Nations (FAO, 2017). This data is available until 2013. Historical centrifugal sugar production, consumption, and carry-over stock data were collected from the Production, Supply, and Distribution's query view of the USDA (USDA PS&D, 2017). The International Monetary Fund has macro data such as nominal GDP, GDP deflators, and population available that are employed to project consumption. GDP deflators were based in various years, so they were all update to represent 2015 as the base year. Exchange rates were accessed through the World Bank (World Bank, 2017).

Sugar prices for the U.S., world, and Mexico are published on the USDA's Economic Research Service (ERS) website (USDA ERS, 2017). The Caribbean Free on Board (f.o.b.) price for raw sugar is used for the world price, just as in Elobeid and Beghin (2006), as it is representative of the prices obtained for raw sugar around the world. Although many of the countries modeled are not members of the Organization for Economic Co-operation and Development (OECD), this institution published a great deal of price data for non-member countries. The OECD-FAO Agricultural Outlook is a publication of agricultural commodity projections (OECD, 2016). The published statistics include farm and producer prices for crops, which were gathered and utilized for this model. Often, there is a considerable difference between the price of raw sugar and the price received for sugar crops by farmers, and this difference is accounted for in the model. As noted previously, observed producer prices are used for some countries[14] but not others due to data availability at the time of the parameter estimation for Elobeid and Beghin (2006), and domestic prices for countries without published price data are calculated by Equation 8.

USDA Global Agricultural Information Network (GAIN) reports are a great source for data and policy information. The Mexican reference price is determined by CONADESUCA, and published in Mexico's annual GAIN reports. Each year Brazil's GAIN report publishes the percentage of sugar that is used for human consumption against fuel production for the past fiscal year and a projection for the current fiscal year (Barros, 2016).

Parameters for the behavioral equations were largely provided by Elobeid and Beghin (2006), with the exception of the U.S. model. U.S. parameters were estimated with an updated dataset, ending with 2011 data. More recent TRQ fulfillment data is available, so estimation data of these parameters ends in 2014. Summary statistics for key estimation variables are outlined in Table 1, and complete results for parameter estimates and discussion is included in Appendix II. U.S. parameter values generally align with the parameters of other countries, with a few exceptions. Sugarcane production is shown to have a negative relationship with lagged price of sugarcane. However, the magnitude of this relationship is small. Sugar consumption is negatively related to real GDP and positively related to the price of sugar. These three results are in opposition to economic intuition, but the model predicts with more precision and accuracy with the inclusion of these parameters as estimated. The full results are expanded on in Appendix I. As previously noted, there are some issues with the inclusion of lagged dependent variables in

[14] Observed farm gate prices were used for Australia, Canada, China, European Union, India, Japan, Thailand, and the U.S.

explanatory modeling. In this study, it is beneficial to include the lagged dependent variable, but regressions and predictions are both conducted with and without the lagged dependent variable in order to compare the results of the two.

Table 1. Summary Statistics for Key Variables

Variable	Obs.	Mean	Standard deviation	Minimum	Maximum
Sugar beet acreage (1000 HA)	32	516.74	54.04	406.51	618.08
Sugar beet Yield (MT/HA)	32	51.05	6.92	41.75	65.58
Sugarcane acreage (1000 HA)	32	356.79	35.12	296.5	417.76
Sugarcane Yield (MT/HA)	32	78.91	4.85	69.9	89.98
U.S. Raw Sugar Price (cent/lbs.)	32	22.64	3.87	18.4	38.46
Per Capita Consumption (MT/1000 people)	32	32.28	2.68	29.66	42.46
Ending Stocks (1000 MT)	32	1433.78	213.03	1110	2013
TRQ Allocation (1000 MT)	34	1459.97	502.89	910.89	2880.45
TRQ Fulfillment (1000 MT)	34	1356.16	516.30	601.75	2839.86
TRQ Fulfillment (percentage)	34	92.27	9.08	53.86	99.71

Source: FAO, 2017 and USDA PS&D, 2017

Results

U.S.-Mexico Agreement Simulation

The initial step in analyzing the U.S.-Mexican trade pact is to simulate the sugar market as if there had never been an agreement. This scenario will be referred to as S1, where Mexico is allowed to export unlimited duty-free sugar to the U.S. with no restrictions or price floors as NAFTA had originally been implemented. In S2, Mexican sugar exports to the U.S. are subject to both a quantitative, needs-based restriction and price floors[15]. Both scenarios use data until 2016 aside from farm gate crop prices, which is only available through 2014. Again, Equation 1 represents the needs-based limited is calculated within the model according to the formula:

$$\begin{aligned} &Needs\ from\ Mexio \\ &\quad = (Expected\ Use * 1.135) - Beginning\ Stocks - Production \\ &\quad - TRQ\ Imports - Other\ Program\ Imports^{16} \end{aligned} \tag{1}$$

with Other program imports being held constant at just below 400,000 metric tons, the average over the last decade. It may not be problematic to assume constant imports from other programs as imports from these programs are not used for domestic human consumption. In this scenario, projections are made for how much sugar Mexico would export to the U.S. in an unfettered market, just as in S1. If the predicted trade level is higher than the limit, Mexico only exports the limit to the U.S. The same is approach is taken with price. If U.S. expected price were to fall below the price floor, the price would simply become the price floor. Since the entire market is changing, especially prices, the first year of projections is the only year that S1 U.S. imports from Mexico are the same as the amount Mexico wishes to export to the U.S. in S2.

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15 Price floor is 22.25 cents per pound for raw sugar (USITC, 2014).
16 Other program imports include the Re-Export Programs, as they are the only programs that include raw sugar imports.

Figure 5 is a representative illustration of the difference in supply of sugar in the U.S. between S1 and S2 for 2017, the first year of projection. Both supply curves from S1 and S2 feature a kink were supply goes from being relatively inelastic to nearly perfectly inelastic. This represents an import limit being reached in both scenarios. The S1 kink is caused by TRQ imports reaching the set allotment, and S2's curve kinks when Mexican imports reach their limit. It is important to note that the kink happens after the equilibrium price in S1 and before the equilibrium price in S2, causing the market price of S2 to be higher. Table 2 and Figure 6 display the price effects of implementing this restriction on U.S. sugar imports from Mexico. Under the stable market projection simulated here, S1 does see prices increase gradually. These price increases align with the historical movements of nominal prices of raw sugar, although in less volatile fashion. Restricting Mexico's access does increase the price of sugar considerably, approximately an 11 percent average increase above baseline levels across the simulation, and especially in year two, which sees nearly a 20 percent rise in price compared to the baseline. The degree of these price increases does level off to approximately 6.5 percent by the final year of simulation (2021), showing the market adjusting to the new reality of limited trade with Mexico.

The expected price increases have substantial effects on the producer price of sugarcane and beets as well as the retail price of refined sugar. Table 3 shows that sugarcane growers enjoy approximately a two to six percent increase in crop price, and sugar beet farmers see about a one and a half to seven percent increase in price from the reform, displayed in Table 4. The refined sugar price increase ranges from four to eleven and a half percent over the five-year timeframe (Table 5). All three S2 prices peaked in 2018, just as with raw sugar. The prices sugarcane and beet producers face due to the trade agreement are noteworthy; however, the price increases do not lead to expanded production in either crop because of the meager price response parameters described in Appendix II.

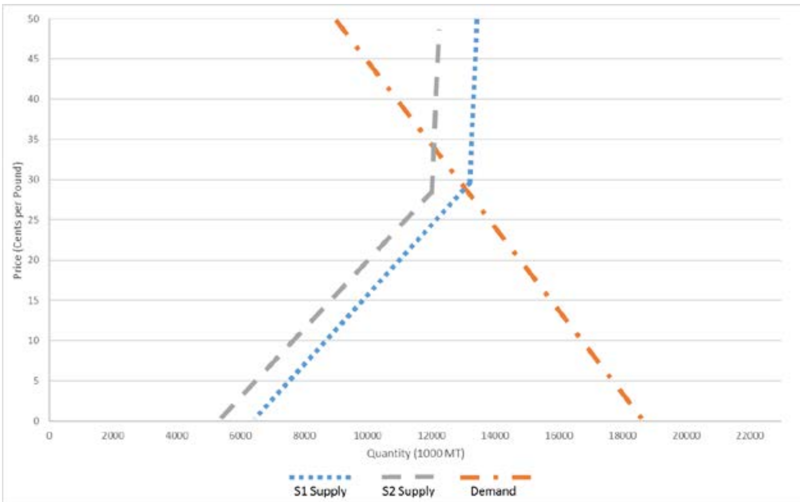

Figure 5. 2017 U.S. Sugar Market Supply and Demand Curves
Source: Author's representation

Table 2. Simulated U.S. Raw Sugar Prices

Year	2017	2018	2019	2020	2021	Average
S1 (cents per pound)	29.35	29.59	30.01	30.44	30.90	30.06
S2 (cents per pound)	31.95	35.35	33.79	33.01	32.94	33.41
Difference S2-S1	2.61	5.76	3.79	2.57	2.04	3.35
%Δ in S1 & S2	8.89%	19.46%	12.63%	8.45%	6.59%	11.20%

Source: Author's simulation

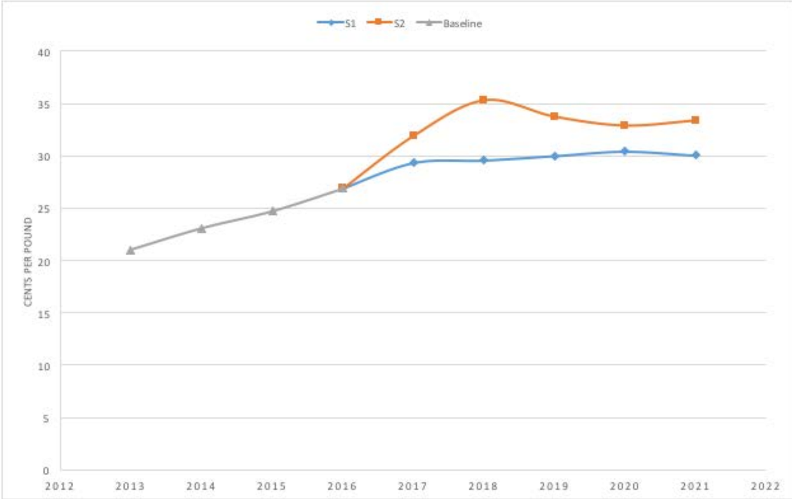

Figure 6. Simulated U.S. Raw Sugar Prices
Source: Author's simulation

Table 3. Simulated U.S. Sugarcane Producer Price

Year	2017	2018	2019	2020	2021	Average
S1 (cents per pound)	1.63	1.63	1.64	1.64	1.65	1.64
S2 (cents per pound)	1.67	1.72	1.70	1.68	1.68	1.69
Difference S2-S1	0.04	0.09	0.06	0.04	0.03	0.05
%Δ in S1 & S2	2.63%	5.77%	3.79%	2.57%	2.03%	3.36%

Source: Author's simulation

Table 4. Simulated U.S. Sugar Beet Producer Price

Year	2017	2018	2019	2020	2021	Average
S1 (cents per pound)	2.54	2.55	2.57	2.58	2.60	2.57
S2 (cents per pound)	2.61	2.72	2.67	2.64	2.64	2.66
Difference S2-S1	0.07	0.17	0.10	0.06	0.04	0.09
%Δ in S1 & S2	2.61%	6.78%	4.03%	2.31%	1.50%	3.45%

Source: Author's simulation

Table 5. Simulated U.S. Refined Sugar Price

Year	2017	2018	2019	2020	2021	Average
S1 (cents per pound)	68.25	68.59	69.15	69.75	70.38	69.22
S2 (cents per pound)	71.83	76.50	74.36	73.28	73.18	73.83
Difference S2-S1	3.58	7.91	5.20	3.53	2.80	4.61
%Δ in S1 & S2	5.25%	11.54%	7.53%	5.07%	3.97%	6.67%

Source: Author's simulation

Tables 6 and 7 show the projected area harvested for sugarcane and sugar beets, respectively. Estimated sugarcane area harvested is expected to be essentially the same between the two scenarios. Estimated sugar beet acreage expands between 30 and 270 hectares, less than one percent, due to the price increases stemming from the policy change. This very slight expansion in production led to a similarly small increase in U.S. production of centrifugal sugar (Table 8). The meager upticks are driven by the lack of flexibility sugar crop producers have in planting decisions, a freedom they forgo in exchange for considerable price protection provided by the U.S. sugar program. In fact, these protectionist policies are not meant to expand production of domestic sugar in any way. They are only designed to protect the profitability of crop producers themselves, and this is the reason for relatively low supply elasticities in the model that prevents production from increasing substantially when prices increase.

Table 6. Simulated. U.S. Sugarcane Area Harvested

Year	2017	2018	2019	2020	2021	Average
S1 (1000 hectares)	375.84	385.06	393.29	400.61	407.11	392.38
S2 (1000 hectares)	375.84	385.06	393.29	400.61	407.11	392.38
Difference S2-S1	0.00	0.00	0.00	0.00	-0.01	0.00
%Δ in S1 & S2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Source: Author's simulation

Table 7. Simulated U.S. Sugar Beet Area Harvested

Year	2017	2018	2019	2020	2021	Average
S1 (1000 hectares)	450.16	444.78	440.11	435.96	433.09	440.82
S2 (1000 hectares)	450.19	445.53	441.39	437.57	433.99	441.73
Difference S2-S1	0.03	0.75	1.28	1.60	0.90	0.91
%Δ in S1 & S2	0.01%	0.17%	0.29%	0.37%	0.21%	0.21%

Source: Author's simulation

Table 8. Simulated U.S. Centrifugal Sugar Production

Year	2017	2018	2019	2020	2021	Average
S1 (1000 MT)	7890.09	7953.91	8015.52	8073.25	8135.21	8013.60
S2 (1000 MT)	7890.09	7960.78	8027.62	8088.64	8143.76	8022.18
Difference S2-S1	0.00	6.88	12.11	15.39	8.55	8.58
%Δ in S1 & S2	0.00%	0.09%	0.15%	0.19%	0.11%	0.11%

Source: Author's simulation

As discussed previously, sugar consumption is insensitive to price changes. Table 9 presents the projection results for U.S. per capita sugar consumption. In year two, sugar consumption is expected to increase by 0.03 percent, the largest increase in the timeframe analyzed. Econometric estimation found sugar consumption to have a significant positive relationship with the price of sugar, although this effect is was very small because sugar can be an addictive substance and is demand inelastic in price. As a result, the policy change is shown to have no practical consequence on sugar consumption within the U.S.

Table 9. Simulated U.S. Sugar Consumption Per Capita

Year	2017	2018	2019	2020	2021	Average
S1 (1000 MT/million)	33.95	33.95	33.95	33.94	33.94	33.95
S2 (1000 MT/million)	33.95	33.96	33.95	33.95	33.95	33.95
Difference S2-S1	0.01	0.01	0.01	0.00	0.00	0.01
%Δ in S1 & S2	0.02%	0.03%	0.02%	0.01%	0.01%	0.02%

Source: Author's simulation

The focus of this trade agreement was limiting Mexico's access to U.S. sugar markets, and estimations show that a binding quota based on U.S. needs does successfully curb Mexican exports to the U.S. (Table 10). Under S1 where Mexican source sugar is unlimited, imports are relatively constant throughout the simulation, peaking in year two. The cap on imports from Mexico is shown to lower expected trade levels more than 20 percent compared to the baseline in each of the first three years, but this difference is also largest in year two, with the two trade scenarios begin to converge. S1 imports from Mexico are more than 20 percent higher than in S2 for the timeframe analyzed, showing that the policy mechanism of this agreement is operating as intended.

Table 10. U.S. Imports from Mexico

Year	2017	2018	2019	2020	2021	Average
S1 (1000 MT)	2093.29	2272.34	2248.81	2241.02	2237.84	2218.66
S2 (1000 MT)	1594.53	1623.20	1782.76	1848.77	1891.39	1748.13
Difference S2-S1	-498.76	-649.14	-466.05	-392.25	-346.45	-470.53
%Δ in S1 & S2	-23.83%	-28.57%	-20.72%	-17.50%	-15.48%	-21.22%

Source: Author's simulation

Mexico's limit, determined by U.S. needs, are calculated for both scenarios but are used only as the upper limit on U.S. imports from Mexico in S2. Table 11 displays these needs and shows them beginning to decrease slightly under the reform scenario, yet they are larger during the last three years of projection. As discussed, production and consumption in the U.S. are relatively stable and unaffected by prices because of government intervention in the market and sugar's inelastic nature in demand. Therefore, the two components driving the variation in U.S. needs are beginning stock levels and imports from TRQ programs.

Table 11. Simulated "U.S. Needs" from Mexico

Year	2017	2018	2019	2020	2021	Average
S1 (1000 MT)	1608.63	1635.96	1724.54	1791.45	1849.14	1721.95
S2 (1000 MT)	1594.53	1623.20	1782.76	1848.77	1891.39	1748.13
Difference S2-S1	-14.10	-12.76	58.21	57.32	42.25	26.19
%Δ in S1 & S2	-0.88%	-0.78%	3.38%	3.20%	2.28%	1.44%

Source: Author's simulation

Carry-over stocks are an important component of this model and are key drivers of many of the results. The amount of sugar on the market at the end of each time period is consistently as large as the amount traded with Mexico, the U.S.'s biggest sugar trade partner. Table 12 displays the results of ending stocks in the U.S. under both scenarios. Carry-over stocks are projected to have an inverse relationship with raw sugar prices. With S2 prices significantly higher than S1 prices, about five to eleven percent less sugar is held over from one period to the next in the projected U.S. market. As prices begin to converge, so too do the ending stock levels.

Table 12. Simulated U.S. Ending Sugar Stocks

Year	2017	2018	2019	2020	2021	Average
S1 (1000 MT)	1512.35	1501.32	1498.38	1496.63	1494.31	1500.60
S2 (1000 MT)	1443.36	1334.01	1361.97	1399.09	1419.35	1391.56
Difference S2-S1	-68.99	-167.31	-136.40	-97.54	-74.96	-109.04
%Δ in S1 & S2	-4.56%	-11.14%	-9.10%	-6.52%	-5.02%	-7.27%

Source: Author's simulation

Expected TRQ allocations (Table 13) are similar between the two scenarios, both well above the 1.1172 million metric ton minimum. However, there is significant variation in projected sugar imported to the U.S. through these programs (Table 14). As raw sugar prices are higher in S2 compared to S1, expected fulfillments are also considerably larger. Quantity imported under these programs is largest in year two of projections, when S2 prices were largest and the difference in S1 and S2 prices was greatest. In S1, a substantial amount of Mexican sugar in the U.S. is keeping TRQ fulfillments low despite the consistently rising price. Another factor causing TRQ fulfillments to be smaller in the unlimited, S1 scenario is the persistent increase in world price, which is displayed in Table 15.

Table 13. Simulated U.S. TRQ Allocations

Year	2017	2018	2019	2020	2021	Average
S1 (1000 MT)	1126.10	1264.03	1246.22	1229.67	1215.24	1216.25
S2 (1000 MT)	1126.10	1264.39	1243.16	1223.41	1206.97	1212.80
Difference S2-S1	0.00	0.36	-3.06	-6.26	-8.27	-3.45
%Δ in S1 & S2	0.00%	0.03%	-0.25%	-0.51%	-0.68%	-0.28%

Source: Author's simulation

Table 14. Simulated U.S. TRQ Fulfillments

Year	2017	2018	2019	2020	2021	Average
S1 (1000 MT)	1106.73	1181.54	1139.76	1115.17	1093.94	1127.43
S2 (1000 MT)	1122.79	1260.68	1239.51	1180.72	1142.13	1189.17
Difference S2-S1	16.06	79.14	99.75	65.55	48.19	61.74
%Δ in S1 & S2	1.45%	6.70%	8.75%	5.88%	4.40%	5.44%

Source: Author's simulation

Table 15. Simulated World Raw Sugar Prices

Year	2017	2018	2019	2020	2021	Average
S1 (cents per pound)	14.7574	17.3799	18.8225	19.6767	20.5087	18.229
S2 (cents per pound)	14.7574	17.3585	18.9387	19.8656	20.5664	18.2973
Difference S2-S1	0	-0.02135	0.11624	0.18896	0.05773	0.06832
%Δ in S1 & S2	0.00%	-0.12%	0.62%	0.96%	0.28%	0.35%

Source: Author's simulation

The U.S.-Mexico sugar agreement has less than a one percent expected impact on world prices. After negligible decrease in world price compared to the baseline, the predictions show minor price increases. This effect is driven by the U.S. market being opened up to the rest of the world besides Mexico. Due to geographic proximity and NAFTA liberalization, Mexico has an advantageous trade position with the U.S. relative to the rest of the world, even countries with large TRQs through RTAs. When Mexico's access is limited, simulated prices rise making it more beneficial for countries on the other side of the world to send sugar to the U.S. and come closer to fulfillment of their entire quota.

Years 1 and 2 of projection show a less negative U.S. sugar trade balance (Table 16). Both scenarios show the U.S. continually relying more on imported sugar, but in year three and beyond, S2 shows a more negative trade balance than S1. This means that restricting imports from Mexico actually increases sugar net trade, mostly coming from higher TRQ imports. The U.S. has historically carried a substantial sugar trade deficit as the world's largest sugar importer.

However, results reflect that, without further policy adjustments, restricting imports from Mexico does not make the U.S. less dependent on foreign sugar.

Table 16. Simulated U.S. Net Trade

Year	2017	2018	2019	2020	2021	Average
S1 (1000 MT)	-3138.51	-3218.04	-3250.33	-3279.35	-3301.99	-3237.64
S2 (1000 MT)	-3071.25	-3116.60	-3271.56	-3304.46	-3317.29	-3216.23
Difference S2-S1	67.26	101.44	-21.23	-25.11	-15.30	21.41
%Δ in S1 & S2	-2.14%	-3.15%	0.65%	0.77%	0.46%	-0.68%

Source: Author's simulation

Policy Implications

The take away from the quantitative results is that restricting Mexico's access does, as the policy intended, increase domestic prices, but disagreements regarding the effectiveness of this agreement remain today. American producers take issue with "loopholes" that allow Mexico to export heavily processed sugar that is practically refined sugar within the raw sugar limit. The results of this analysis suggest that this agreement would do exactly what it is intended to do, given trade is occurring according to the spirit of the agreement. Therefore, this study maintains that, if no parties are taking advantage of technicalities within the agreement, this policy adequately increases the price of raw sugar in the U.S. and protects domestic producers. By the end of the simulated period, the market is beginning to adjust to the new policy regime as prices are beginning to converge. Unless domestic policies are altered, total imports are expected to continue growing, even with imports from Mexico reduced. Current policies do not allow domestic production to expand, as a more market-based strategy would permit, so prices and imports are expected to continue to grow. Similar to other policies within the U.S. sugar program, this agreement benefits those who produce sugar by increasing prices. Next, the producer and consumer welfare effects are addressed.

Welfare Impacts of the U.S.-Mexico Sugar Agreement

As model results show, this agreement increases the expected price by decreasing the expected quantity of Mexican sugar in the U.S, leading to welfare changes within the market. Supply must be disaggregated by source to properly calculate the welfare changes for U.S. and Mexican producers. Behavioral equations for U.S. domestic supply, U.S. supply from Mexico, and demand, are used to estimate the relevant welfare changes from the U.S.-Mexico sugar agreement. Table 17 shows the changes in U.S. and Mexican producer surplus and U.S. consumer surplus given the estimated price and quantity changes. Estimated U.S. producer surplus increased more than $3 billion over the five year simulated period, while U.S. consumer surplus is projected to decrease more than double that by approximately $7.5 billion. Changes in expected prices lead to a total surplus decrease of more than $4 billion over the simulated timeframe. Mexican producers are also expected to have a welfare decrease more than approximately $380 million over the five-year period. The magnitude of this change is considerably smaller than the expected impacts for U.S. agents, as Mexican producers are expected to obtain a higher price in the U.S., but this is expected to be in tandem with a decrease in the quantity traded. To put these changes in perspective, Table 18 displays the percentage changes in welfare for relevant agents affected by this agreement.

Table 17. Welfare Effects of U.S.-Mexico Sugar Agreement (millions of 2015 US Dollars)

	2017	2018	2019	2020	2021	Total
Change U.S. PS S2-S1	$453.6	$1,045.8	$708.6	$490.3	$394.1	$3,092.4
Change U.S. CS S2-S1	-$725.5	-$1,936.2	-$1,721.9	-$1,361.3	-$1,663.6	-$7,408.5
Change MX PS S2-S1	-$224.9	-$18.4	-$17.2	-$51.6	-$69.1	-$381.3
Change Total Surplus S2-S1	-$496.9	-$908.9	-$1,030.4	-$922.6	-$1,338.6	-$4,697.4

Source: Author's calculations

Table 18 Welfare Effects of U.S.-Mexico Sugar Agreement (Percentage)

	2017	2018	2019	2020	2021	Total
U.S. PS %Δ in S1 & S2	8.89%	19.50%	10.71%	7.23%	5.03%	9.89%
U.S. CS %Δ in S1 & S2	-1.03%	-2.70%	-2.34%	-1.84%	-2.23%	-2.03%
U.S. Surplus %Δ in S1 & S2	-0.36%	-1.15%	-1.26%	-1.08	-1.61%	-1.10%
MX PS %Δ in S1 & S2	-16.99%	-1.61%	-1.49%	-4.42%	-5.84%	-6.38%

Source: Author's calculations

Inelastic supply and demand functions yield relatively small welfare changes given a change in price. However, the magnitude of estimated welfare changes here are quite large because the U.S. consumes more sugar per capita than any other country, totaling more than twenty four billion pounds in 2016. Several previous studies have analyzed welfare impacts of various policy changes, so there are of examples to compare with these estimates[17].

For 1998, Koo (2002) estimated an annual $2.7 billion increase in consumer surplus and a $977 million decrease in producer surplus with the abolition to the entire sugar program.

17 All comparison estimates are converted to 2015 U.S. Dollars, as is used in this study. Inflation calculations from http://www.usinflationcalculator.com.

Beghin et al. (2003) predicted the entire sugar program costs consumers between $2 and $2.5 billion annually in EV, while benefiting producers between $1.1 and $1.4 billion annually. Beghin and Elobeid (2013) measured more downstream effects of eliminating the full sugar program by estimating the effects on employment and other markets, estimating a $3 to $3.6 billion annual benefit to consumers, measured as EV. When analyzing end products as opposed to the price of inputs EV is a useful measure for welfare, and EV is inherently smaller than consumer surplus for normal goods because it measures the area below the steeper Hicksian demand curve. However, these measures are expected to be similar in the case of sugar because the Marshallian demand curve is already relatively steep due to the inelastic nature of sugar demand. These three studies also estimated the effects of the complete liberalization of U.S. sugar policy, a far more drastic change than a bilateral trade agreement. However, Mexico has been the U.S. largest sugar-trading partner, and Mexican sugar has comprised more than 10 percent of all sugar consumed in the U.S. since NAFTA's sugar implementation in 2008. Furthermore, U.S. is the largest per capita sugar consumer in the world, consuming more than twenty-four billion pounds in 2016. The magnitude of these welfare changes are smaller than reported in prior studies because the simulated policy is more modest than those studies. Therefore, welfare estimates present here are legitimized by prior welfare calculations, both qualitatively and quantitatively.

Sensitivity Analysis

In reflecting Elobeid and Beghin (2006), the final step in this analysis is to validate the model and results as thoroughly as possible. This research conducts a very similar sensitivity analysis, along with an additional measure. Elobeid and Beghin (2006) simulated a reform scenario with price responses both doubled and halved, and the same sensitivity approach is employed to validate the results of the original simulation.

Doubling the price responses of production, use, and inventory is expected to produce more moderate price changes because agents are more sensitive to prices, but quantities of production, use, and trade should be magnified. Table 19 compares the baseline results to the results with price responses doubled. Both doubled parameters used for S1 and S2 show lower prices than the baseline equivalent, but the percent changes from S1 to S2 are larger with doubled price responses. This is driven by the low price produced in doubled S1, caused by Mexico’s production expansion with more sensitive price responses. Since Mexico has full access to U.S. markets and its production is allowed to broaden more easily in S1, there is a large influx of Mexican sugar on the U.S. market in this case. When the relatively high imports of Mexican sugar is curbed by the trade agreement, prices rise greatly in S2 compared to S1, but these prices are still considerably smaller than the baseline. Figure 7 shows major increases in S1 imports from Mexico because of Mexico’s responsive sugar production. S2 imports from Mexico increase from the last year of data, but they do not yet reach the levels of the highs that were observed in 2013 and 2014.

Table 19. U.S. Raw Sugar Prices (Doubled price responses vs. Baseline)

Year	2017	2018	2019	2020	2021	Average
S1 (Doubled)	23.70	21.91	22.14	22.35	22.54	22.53
S1 (Baseline)	29.35	29.59	30.01	30.44	30.90	30.06
%Δ Baseline to Doubled	-19.22%	-25.95%	-26.22%	-26.58%	-27.05%	-25.04%
S2 (Doubled)	29.43	31.13	30.35	29.95	29.92	30.15
S2 (Baseline)	31.95	35.35	33.79	33.01	32.94	33.41
%Δ Baseline to Doubled	-7.91%	-11.96%	-10.20%	-9.26%	-9.17%	-9.75%

Source: Author's simulation

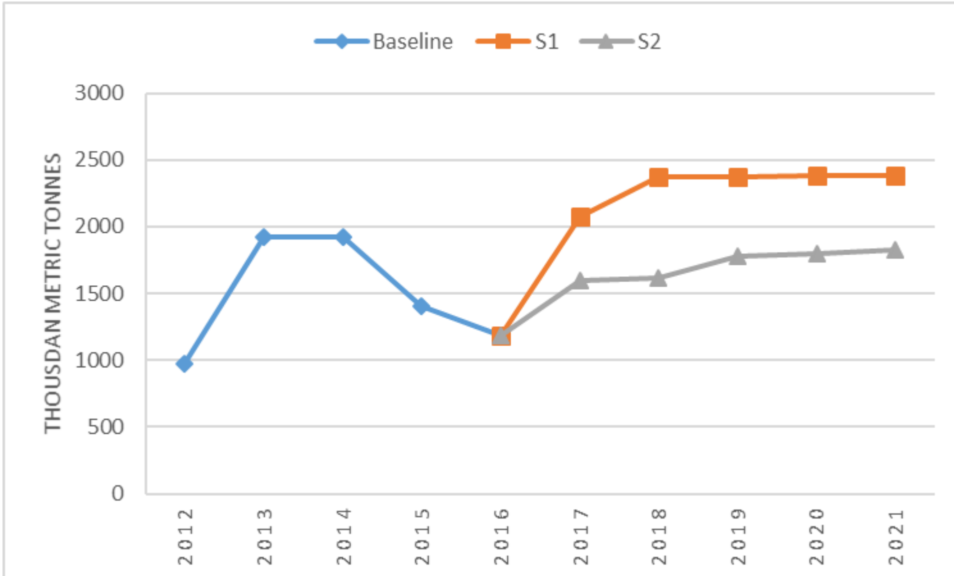

Figure 7. U.S. Imports from Mexico (Doubled price responses)

Source: Author's simulation

Halving price responses parameters is expected to magnify price changes in tandem with dampened changes in production, consumption, and trade, as is confirmed by results shown in Table 20. Both S1 and S2 prices are substantially higher in the halved case compared to the baseline. This is because the U.S. price response for sugar consumption is relatively low with respect to most countries, and halving these values only magnifies these results. Figure 8 shows imports from Mexico under this halved response scenario. Unlimited S1 imports begin higher than S2, but the two scenarios begin to converge and stabilize by 2019 (year three). With such high prices, TRQ imports are large under both scenarios, and U.S. domestic supply is relatively stable. This leaves Mexico to export about the same quantity to the U.S. under both the unlimited and restricted case, and Mexico's production is less responsive to the increase in U.S. price. Although this result's magnitude is small, the direction of impact still aligns with the scenarios that employ baseline parameters.

Table 20. U.S. Raw Sugar Prices (Halved price response vs. Baseline)

Year	2017	2018	2019	2020	2021	Average
S1 (Halved)	49.05	56.66	62.54	66.91	69.97	61.03
S1 (Baseline)	29.35	29.59	30.01	30.44	30.90	30.06
%Δ Baseline Halved	67.15%	91.46%	108.43%	119.83%	126.43%	102.66%
S2 (Halved)	58.91	65.88	72.56	77.55	81.07	71.19
S2 (Baseline)	31.95	35.35	33.79	33.01	32.94	33.41
%Δ Baseline to Halved	84.35%	86.34%	114.71%	134.93%	146.15%	113.30%

Source: Author's simulation

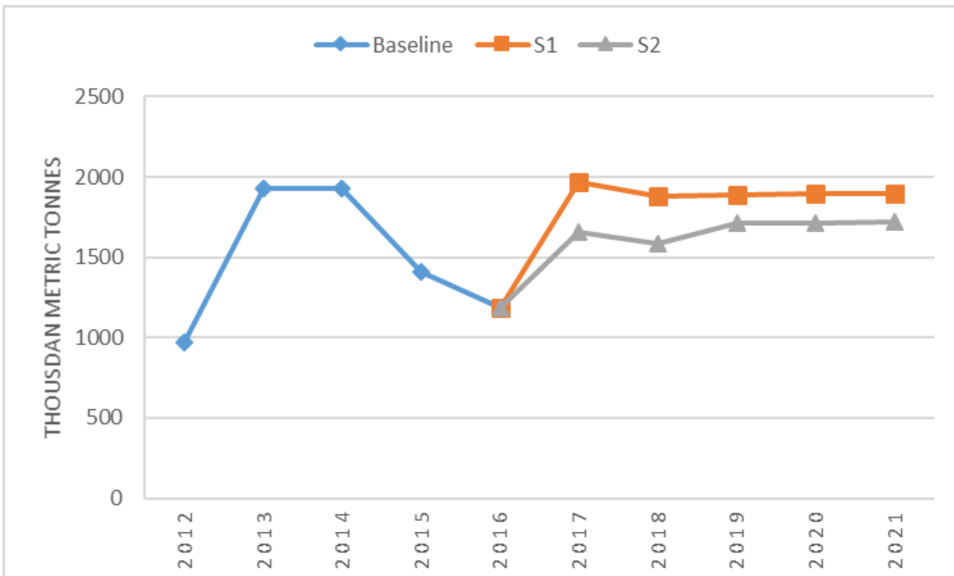

Figure 8. U.S. Imports from Mexico (Halved price responses)
Source: Author's simulation

In conclusion, these sensitivity analysis scenarios help to validate the estimation results for the price and welfare effects of the U.S.-Mexico trade agreement by showing the sensitivity of results to price responsiveness parameters in the model. While the magnitude of changes were sometimes surprising, the directions of changes compared to the results of the baseline scenario, are maintained. The sensitivity analysis was crucial in understanding the complexity and performance of this partial equilibrium trade model.

Conclusions

This research estimates the price and welfare effects of a 2014 trade agreement restricting Mexico's access to U.S. the sugar market by using a partial equilibrium trade model known as the FAPRI International Sugar Model. The agreement is in response to Mexico's dumping of subsidized sugar on to the U.S. market, which was allowed by the unlimited, tariff free access to U.S. prices Mexico gained through the full implementation of NAFTA in 2008. The U.S. government is heavily incentivized to protect domestic prices because of the construction of the U.S. sugar program. The sugar program protects U.S. producers through substantial trade barriers and government guaranteed prices floors, which are costly to implement if domestic prices do fall too low, which happened in 2012/2013, leading to the 2014 U.S.-Mexico sugar agreement. This study indicates that the agreement sufficiently protects U.S. prices, and it contributes considerably to U.S. producer welfare at the expense of U.S. consumers and Mexican producers. Results show that U.S. prices could increase by an average of 11 percent across the five year simulated period. This would inflict an estimated increase in U.S. producer surplus of approximately $3 billion and a decrease in consumer surplus of more than $7 billion, both across that time span. These results would deem the agreement a success when it comes to protecting domestic sugar producers, but perhaps economically inefficient because of the damages to consumers. However, when judged through the scope of the current U.S. sugar program, this agreement is successful in protecting domestic producers and minimizing government expenditures by increasing U.S. prices.

This study analyzed a specific sugar trade agreement between the U.S. and Mexico, overriding sugar's implementation in NAFTA only six years earlier. The results suggest that the agreement is successful in increasing U.S. sugar prices by curbing imports from Mexico.

However, the results also indicate that this agreement imposes significant damage, mostly attributed to decreased welfare for U.S. consumers. This ex-post policy analysis estimates the potential price and welfare effects of the agreement, showing a substantial net welfare loss, but ex-ante analyses could be helpful to potentially find a more efficient way to protect U.S. sugar producers, without such damage inflicted to consumers. There is also the very real possibility that this policy may not be maintained far into the future.

In 2016, the U.S. sugar industry began pressuring the USDOC again about the alleged dumping of Mexican sugar onto the U.S. market, citing a loophole in the agreement that may allow this to occur. The Mexican government disagreed that there was any violation of the agreement and continued to export sugar to the U.S. In March 2017, Mexican export licenses were suspended by the USDOC because of a new interpretation of the U.S.-Mexico sugar agreement's language regarding the seasonality restrictions for trade to the U.S. May 1, 2017 was established as a deadline to resolve this issue only to be extended until June 5, 2017 because the two sides could not reach a solution. U.S. Commerce Secretary Wilbur Ross said that the two sides were at an impasse, which creates some doubt about this agreement's longevity (Rueters, 2017). This analysis is only able to analyze the agreement as if all parties are holding up their end of the agreement, which according to the other side, neither are.

In such a distorted market, there are always going to be new deals and agreements to research, each with their own impacts and complexities. A more intricate production structure in the model could analyze the U.S.-Mexico trade agreement more accurately by implementing industry mechanisms such as processing and trade of refined or semi-refined sugar. This research and model is currently constructed to begin analysis of other, similar trade agreements. Beginning in 2017, the E.U. will move to a more market based approach to sugar production by abolishing their U.S.-style allotment system. Formerly the largest exporter of beet-sourced sugar, this move could have large implications for the global sugar industry, especially the many nations in RTAs with the E.U. Policy changes are expected in the future, and this modeling framework is well suited to investigate the impacts of agreements and other policy changes with only slight alterations to the modeling framework. As previously noted, consumer preferences are shifting towards non-GM food products, in many cases, and this potential preference shift provides an opportunity for further analysis. Since no sugarcane is currently produced with GM seeds, research investigating the differentiation of sugar sourced from sugarcane versus sugar beets could be a valuable addition to the literature. Furthermore, if non-GM products do in fact sufficiently drive consumer choice of sugar products, research could investigate the market effects of moving from current sugar beet production using both GM and non-GM seeds to a hypothesized production scenario that prohibits GM technology in sugar beets. This may be modeled with the current framework as a negative productivity shock to sugar beet yields as non-GM sugar beet varieties are currently lower yielding than GM varieties. This could provide insight into how the U.S. sugar program may operate given relatively large changes in sugar beet production.

U.S. sugar policy is designed to protect domestic producers through a number of policy mechanisms. This analysis shows that a needs based limit imposed on the U.S.'s largest sugar trade partner, Mexico, is sufficient in providing this protection from foreign suppliers. NAFTA was a rare moment in U.S. sugar policy, as it took a substantial step towards a market based trade strategy. This step was deemed to be too far, as the influx of Mexican sugar undercut U.S. producers and led to large government expenditures. Reverting to more protectionist policies, the 2014 U.S.-Mexico sugar agreement potentially provides noteworthy welfare gains to U.S.

producers, but the losses to U.S. consumers could be much larger. Examining this agreement based on economic efficiency is simple, when countries trade, the market is more efficient. Based on this criterion, the analyzed agreement is not an appropriate policy for the U.S. to employ. However, this agreement is designed to bolster domestic U.S. sugar prices to support domestic producers, and in this regard, the 2014 U.S.-Mexico sugar agreement works exactly as intended.

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Appendix I. Current Sugar Policy Overview by Country

Country	Domestic and Trade Policy
Algeria	5 percent tariff rate on raw cane and beet sugar
Argentina	Imposes 20 percent tax on sugar imports, export tax was eliminated in 2015
Australia	Completely liberalized market in 1997
Brazil	Imposes a 20 percent tariff on imports but has not imported sugar since 1994
Canada	$CAD 30.86 per MT tariff on refined imports and $22.07 to $24.69 per MT on raw sugar, depending on polarization, many countries have duty free access through trade agreements
China	15 percent import in quota tariff and 50 percent on out of tariff
Colombia	Duty free access for Andean countries, countries outside of this are subject to variable import tariffs usually around 15 percent
Cuba	10 percent tariff rate on raw and refined sugar, government controls the sugar industry and subsidizes production through direct payments
Egypt	Added and removed a 20 percent import tax in 2016, exports are now subject to a tariff of EGP 900 ($101.35)
European Union	Out of quota import rates are €339 for raw sugar and €419 for refined sugar, duty-free access for many developing countries, quota system will be abolished September 2017, and export subsidies decreased to zero
India	INR 4.5 subsidy per MT paid directly to farmers, refined and raw import duty is 25 percent, and a 20 percent export tax
Indonesia	Imposes a tariff rate of 20 and 25 percent for cane and beet sugar, respectively, price floors are also imposed
Iran	Imposes a 20 percent import tariff and banned exports in 2012
Japan	Imposes a prohibitive tariff on refined sugar of JPY 268.88/kg, sets minimum price for both sugarcane and sugar beets, subsidies are paid to growers and refiners, a volume target is set for importers and a surcharge is imposed for exceeding that volume, a variable surcharge is imposed on imports depending on supply and demand in that year
Malaysia	Imposes a 5 percent tariff on sugar imports with potential additional

	taxes, prices are controlled by the government
Mexico	Sets reference prices for refined sugar and growers are required by law to be paid 57 percent of the reference price
Morocco	Imposes a variable tariff rate of 25 to 60 percent, generally at 35 percent
Pakistan	Imposes a 40 percent import tariff on raw and refined sugar, sets domestic prices, sets export quotas, and provides export subsidies that are announced each year
Peru	Imposes a $93 per MT duty on imports
Philippines	Imposes import tariffs of 50 and 65 percent for in and out of quota sugar, respectively
Russia and Ukraine	Imposes seasonally varying tariffs rates between EUR 0.015/kg and EUR 0.18/kg
South Africa	Sets a minimum price for imported sugar, imposing a duty equate import prices to reference prices
Thailand	Uses quotas and direct payments domestically, imposes a 65 and 94 percent tariff for in and out of quota sugar, respectively
Turkey	Sets production quotas, imposes a 135 percent import tariff
United States	Sets production quotas and imposes tariff rates of 0.625 and 15.36 per pound of raw sugar for in and out of quota sugar, respectively
Venezuela	Imposes a 15 percent import tariff with additional surcharges imposed with the price band system, duty free access for Andean nations

Appendix II. Parameter Estimation

Regression results to estimate parameters for the U.S. sub-model were necessary to obtain before any policy analysis could be conducted. As previously indicated, all regressions were completed with OLS and linear specifications. Regression results are used as parameters for all policy scenarios, unless noted otherwise, as some results are displayed for comparison purposes.

Table 21 shows the regression results for sugar beet area harvested (SBAH). Parameter estimates for lagged area harvested (LagSBAH), lagged sugar beet price(LagSBPrice), and lagged soybean price (LagSoyPrice) are each statistically significant at the 1 percent level and take on the expected relationship. Corn is also a substitute of sugar beet production, but shows a positive price relationship without significance between lagged corn price (lagCornPrice) and sugar beet acreage. Achen (2001) discussed that a variable's significance could be depressed and take on the wrong sign by the inclusion of a lagged dependent variable as a regressor. The regression results excluding lagged area harvested can also be found in Table 21. Coefficients have a similar magnitude in each regression, and corn price does not gain statistical significance or take on the correct sign. It is likely from the results that corn may not be a substitutable crop for sugar beets as anticipated, although both crops can be grown in some of the same regions. Prediction are more accurate with the inclusion of corn prices despite the unintuitive results of the relationship.

Table 21. U.S. Sugar beet Area Harvested

VARIABLES	(1) SBAH	(2) SBAH
LagSBAH	0.720***	---
	(0.117)	---
LagSBPrice	109.0***	110.2***
	(25.12)	(39.15)
LagSoyPrice	-13.78***	-18.78***
	(3.554)	(5.394)
LagCornPrice	9.711	0.363
	(5.820)	(8.759)
Year	-0.747	0.855
	(0.714)	(1.037)
Constant	1,517	-1,212
	(1,383)	(2,042)
Observations	31	31
R-squared	0.784	0.453

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author's simulation

Table 22 shows that similar results are found for the sugarcane area harvested regression. Other coefficients gain statistical significance when lagged area harvest is not included, also found in Table 22, but lagged sugarcane price does not take on the expected positive relationship. This negative relationship may be explained by two main factors: government interference with market decisions being made, and the time it takes to grow sugarcane to harvest. Since sugarcane needs two to three years before the first harvest, a single lagged price may not have much influence on producer decisions. A more disaggregated and complete dataset would be useful to estimate these parameters using two or three year lags. However, this amount of data is not available, so estimation specifications here still match Elobeid and Beghin (2006). Just as with sugar beets, the predictions are far more accurate with the lagged dependent variable included. Variables are: sugarcane area harvested (SCAH), lagged sugarcane area harvested (LagSCAH), lagged sugarcane price (LagSCPrice), and a trend variable (Year).

Table 22. U.S. Sugarcane Area Harvested

VARIABLES	(1) SCAH	(2) SCAH
LagSCAH	0.909***	---
	(0.103)	---
LagSCPrice	-2.506	-65.69**
	(16.34)	(28.16)
Year	-0.155	2.778***
	(0.416)	(0.511)
Constant	346.8	-5,091***
	(790.5)	(1,008)
Observations	31	32
R-squared	0.866	0.509

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author's simulation

Tables 23 and 24 show sugar beet yields (SBYield) and sugarcane yields (SCYield). It is noteworthy that the sugar beet yield trend variable is statistically significant at the 1 percent level while lagged yield (LagSBYield) is not statistically significant at the 10 percent level. Lagged sugarcane yield (LagSCYield) is the only statistically significant variable within that regression. The biological characteristics of the crops are expected to drive these results. Sugar beets are annual crops and must be harvested at the end of each season, but sugarcane harvest is more flexible. If a field of sugarcane did not grow as expected one season, its harvest can be pushed over into the next. Furthermore, it is advantageous for producers to be selective in their harvest because too successful of a harvest will push producers over their allotment, leading to the liquidation of sugar to lower priced ethanol production. Sugar beet growers do not have the luxury of selecting the most beneficial harvesting season for their crops. Collectively, these factors may be important determinants but are not accounted for in the analysis.

Table 23. U.S. Sugar beet Yield

VARIABLES	(1) SBYield
LagSBYield	0.235
	(0.175)
Year	0.512***
	(0.125)
Constant	-982.1***
	(242.7)
Observations	31
R-squared	0.707

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author's simulation

Table 24. U.S. Sugarcane Yield

VARIABLES	(1) SCYield
LagSCYield	0.435**
	(0.173)
Year	-0.095
	(0.094)
Constant	235.006
	(193.08)
Observations	31
R-squared	0.281

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author's simulation

The refined sugar price's effect on sugar beet (Table 25) and sugarcane prices (Table 26) is highly significant, and raw sugar price's impact on refined sugar price (Table 27) is statistically significant at the 1 percent level. These results are unsurprising as each price represents a commodity in different stages of processing.

Table 25. U.S. Sugar beet farm Price

	(1)
VARIABLES	SBPrice
RefinedPrice	0.0342***
	(0.00487)
Constant	0.572**
	(0.227)
Observations	36
R-squared	0.592

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author's simulation

Table 26. U.S. Sugarcane Farm Price

	(1)
VARIABLES	SCPrice
RefinedPrice	0.0163***
	(0.00303)
Constant	0.778***
	(0.141)
Observations	36
R-squared	0.458

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author's simulation

Table 27. U.S. Refined Sugar Price

VARIABLES	(1) RefinedPrice
RawPrice	1.374***
	(0.253)
Constant	12.00**
	(5.808)
Observations	32
R-squared	0.496

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author's simulation

The demand equations present in the U.S. model are ending stocks and consumption. Table 28 shows the regression results for endings stocks, and a significant relationship with consumption and prices is observed. It is interesting that ending stocks does not have a statistically significant negative relationship with beginnings stocks, but consumption and price may be driving the decisions that U.S. processors make when it comes to carrying inventory over to the next period. As consumption rises, processors may begin to hold on to a higher reserve to meet demand in the next period. These results suggest that processors may not be concerned with carrying over inventory when prices increase, as they might rather capture the benefit of higher prices by selling more of their supply in the current period.

Table 28. U.S. Ending Stocks

VARIABLES	(1) ES
BeginningStocks	0.216
	(0.176)
Consumption	0.121**
	(0.0564)
RawPrice	-26.54**
	(10.58)
Constant	676.2
	(411.6)
Observations	31
R-squared	0.349

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author's simulation

Table 29 summarizes the results for U.S. per capita consumption of sugar. Refined sugar price is found to have a positive relationship with consumption of sugar. This runs counter to demand theory, but the results are statistically significant at the 1 percent level. Sugar is highly inelastic in demand, as it is used in a wide variety of products and can be an addictive substance. These results indicate that as sugar prices increase so too does sugar use could be driven by a number of effects. Sugar consumption is measured by the amount of sugar processed used in a given year, not necessarily the amount actually ingested by people. It could be that as prices increase producers are more willing to sell to processers, and processers accept as much sugar as possible to meet the demand of the U.S. population. Prices of candy and other sugar-sweetened products do not fluctuate like the price of wholesale raw and refined sugar to, so these results are difficult to interpret, but the statistical significance of the relationship, although meager, suggest that the relationship is positive. It is possible that the effect of refined sugar price on sugar consumption is driven by a substantial decrease in consumption between 1980 and 1986 because the variation is very small after that time. However, since the prediction results are satisfactory, the estimated parameters will be employed accordingly. Real GDP has a negative relationship with consumption, but this effect is very small. A trend analysis of consumption can be found in Table 30, and it provides significant results that show per capita consumption decreasing over time. As previously mentioned, lagged consumption could be included to capture the inertia of the U.S. sugar demand system. Results for U.S. consumption parameters when lagged consumption is included are displayed in Table 31. Nevertheless, the predictions are more accurate when using the same formulation as in Elobeid and Beghin, which does not include lagged consumption as a regressor (2006). Despite unexpected signs on some parameter values, the model predicts with reliable accuracy. Estimation results are similar across the three definitions of consumption, but the parameter estimates for U.S. demand are different from the estimates for other countries. While most countries feature inelastic demand and negative relationships between prices and consumption for sugar, the U.S. is the only country in the model that shows a positive relationship between price and consumption per person. The U.S. also features the only negative relationship between consumption and real GDP per capita. However, most countries manifest small responses for both price and GDP, and the U.S. results reflect this trend.

Table 29. U.S. Per Capita consumption of sugar

VARIABLES	(1) PerCapCons
RefinedPrice	0.153***
	(0.0387)
RealGDP	-0.000560***
	(0.000124)
Constant	32.07***
	(1.175)
Observations	36
R-squared	0.387

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author's simulation

Table 30. Trend Analysis U.S. Per Capita consumption of sugar

VARIABLES	(1) PerCapC
Year	-0.152***
	(0.0440)
Constant	336.5***
	(87.80)
Observations	32
R-squared	0.286

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author's simulation

Table 31. U.S. Per Capita consumption of sugar with lagged consumption

VARIABLES	(1) PCCons
RefSugP	0.0427**
	(0.0175)
RealGDP	-0.0251
	(0.0296)
LagPCC	0.650***
	(0.0628)
Constant	10.23***
	(2.636)
Observations	36
R-squared	0.867

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Author's simulation

The TRQ allocation parameters are displayed in Table 32, and fulfillment results are shown in Table 33. The allocation equation predicts how much imported sugar the U.S. government will allow through the sum of the TRQ programs. Both production and consumption take on the expected relationship with TRQ allocations and are highly statistically significant. As supply increases, imports through TRQ's decrease in order to not flood the market. As demand increases, TRQ's expand to fill excess domestic demand. U.S. price and world price are also highly statistically significant and have the anticipated impact on TRQ fulfillments. As U.S. price increases, TRQ's from individual countries will be brought closer to fulfillment. The opposite effect is found when world price increases, as it is no longer as advantageous for countries to send sugar to the U.S.

Table 32. U.S. TRQ Allocation

VARIABLES	(1) Allocation
LagProduction	-0.560***
	(0.117)
LagConsumption	0.209**
	(0.0940)
Constant	3,473***
	(615.2)
Observations	34
R-squared	0.457

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author's simulation

Table 33. U.S. TRQ Fulfillments

VARIABLES	(1) Percent
USPrice	2.264***
	(0.552)
WorldPrice	-2.048***
	(0.430)
Constant	63.49***
	(9.106)
Observations	34
R-squared	0.423

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author's simulation