TARIFF RATE QUOTAS UNDER UNCERTAINTY

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Abstract

Estimates of the economic effects of trade policies should reflect uncertainty about market conditions. This is especially important when evaluating the economic effects of tariff rate quotas (TRQs). It is uncertain whether a specific TRQ will fill and there will be effects on domestic production and employment, or will not fill and there will be no economic effects of the policy. In this paper, I develop an industry-specific simulation model that can be used to prospectively estimate the economic effects of a TRQ. The model calibrates uncertainty using recent historical industry data and incorporates this information into the estimates of expected economic effects. I apply the model to a hypothetical TRQ on U.S. imports of soap and other detergents in 2018. I simulate the effects on consumers and domestic producers of alternative versions of the TRQ, with and without uncertainty about market conditions in the industry.

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1 Introduction

A tariff rate quota (TRQ) is a two-tiered tariff schedule.[1] There are three possible outcomes for imports under a TRQ. If imports to not reach the quota amount and the TRQ does not fill, then imports enter at a low in-quota tariff rate and possibly duty-free. If imports exceed or overfill the quota, then imports face an out-of-quota tariff rate. Finally, if imports just fill the TRQ, then there are quota rents and import prices rise.

TRQs are prevalent in agricultural trade, U.S. safeguard remedies, and negotiated bilateral settlements following the U.S. national security (Section 232) investigations of steel and aluminum imports. The economic literature on TRQs presents many calibrated simulation models of specific agricultural products.

In general, estimates of the economic effects of trade policies should incorporate uncertainty about future market conditions, and this is especially important when evaluating the economic effects of TRQs. It is uncertain whether a specific TRQ will fill and there will be effects on domestic production and employment, or will not fill and there will be no economic effects of the policy. To address this issue, I develop an industry-specific simulation model for prospective analysis of the economic effects of a TRQ given uncertainty about future market conditions. It is challenging to quantify uncertainty, but I propose a practical method for calibrating the model to recent historical fluctuations in observable industry data.

To illustrate the modeling framework, I estimate the economic effects of a hypothetical TRQ on U.S. imports of soap and other detergents in 2018, based on information prior to 2018. I estimate percent changes in the import prices faced by consumers and the sales of domestic producers resulting from several different versions of the TRQ, with and without uncertainty about future market conditions. The model cannot precisely estimate the magnitudes of the effects of the TRQ, or whether there will be *any* effects. Instead, it estimates

[1] Skully (2001) provides a useful introduction to the economics of TRQ administration.

probability distributions of these effects.

The rest of the paper is organized in six parts. Section 2 briefly reviews the literature on the economic effects of TRQs. Section 3 presents the modeling framework. Section 4 applies the model to U.S. imports of soap and other detergents in 2018. Section 5 extends the model to analyze the effects of multi-year TRQs. Section 6 modifies the model to include ex ante entry decisions. Section 7 concludes.

2 Economic Literature on TRQs

There is a large economic literature on the economic effects of TRQs that mostly focuses on the implementation of the Uruguay Round Agreement on Agriculture. This literature includes a combination of purely theoretical models and calibrated simulations based on product-specific partial equilibrium models or economy-wide general equilibrium models. Most of the papers I review analyze trade in specific agricultural products, like poultry, beef, and dairy. The studies often assume on imperfect competition in product markets. Only one of the studies considers the implications of uncertainty.

2.1 Applied Empirical Models in the Literature

Grant, Hertel and Rutherford (2009) applies a simulation model to TRQs on U.S. imports of specialty cheese at the level of individual tariff lines. Their model includes Armington preferences and a constant elasticity of transformation in dairy production. They examine how the method for allocating import licenses alters the economic effects of the TRQ.

Chen, Chang and McCarl (2009) applies a partial equilibrium model to simulate the effects of TRQs on imports of rice. Their model contrasts the effects of tariffs, quotas, and TRQs under alternative assumptions about market structure.

Pouliot and Larue (2012) uses a simulation model of prices and the allocation of import licenses to analyze the effects of TRQs on Canadian imports of poultry. Their model of the supply chain includes poultry producers, processers, retailers, and consumers. Their simulations demonstrate that increasing TRQ market access could actually trigger increases in domestic prices.

Junker and Heckelei (2012) uses a simulation model with highly disaggregated products to estimate the effects of TRQs on EU imports of beef. Their model of the beef supply chain includes producers, slaughterhouses, freezers, and consumers. They find that the allocation of quota rents is a critical determinant of the welfare effects of the TRQs.

Beckman and Arita (2016) uses an econometric gravity model to estimate the trade costs associated with sanitary and phytosanitary measures and a GTAP CGE model to study how these measures interact with agricultural TRQs.

2.2 Theoretical Models in the Literature

Hranaiova and de Gorter (2005) presents a theoretical model with rent seeking and bargaining over prices. Their two-stage political economy game is motivated by recent TRQs on trade in agriculture, but it is not calibrated to trade data. Their model includes uncertain payoffs.

Scoppola (2010) presents a theoretical model of oligopoly with capacity constraints. Her two-stage model demonstrates how TRQs create an additional, more flexible constraint on supply. Her analysis of the strategic interaction of firms shows that TRQs can lead to changes in market structure.

Finally, Hallren and Riker (2017) compares partial equilibrium models of TRQs under monopolistic competition and perfect competition. They demonstrate that the extensive margin in the monopolistic competition model reacts to changes in in-quota tariff rates even when a TRQ overfills and imports face the higher out-of-quota rate on the margin.

3 Modeling Framework

The industry-specific model in this paper focuses on sales in a single national market. It assumes that domestic consumers have constant elasticity of substitution (CES) demand for domestic varieties and imports.[2] Equation (1) is the demand for each domestic variety, q_d.

$$q_d = \frac{y\ (p_d)^{-\theta}}{n\ (p_d)^{1-\theta}\ +\ (p_m\ (1\ +\ \tau))^{1-\theta}} \tag{1}$$

y is aggregate expenditure on the products of the industry, p_d is the price of domestic products, θ is the elasticity of substitution, n is the number of domestic firms, p_m is the import price before tariffs, and τ is the total ad valorem tariff rate on imports. Equation (2) is the corresponding demand for imports, q_m.

$$q_m = \frac{y\ (p_m\ (1\ +\ \tau))^{-\theta}}{n\ (p_d)^{1-\theta}\ +\ (p_m\ (1\ +\ \tau))^{1-\theta}} \tag{2}$$

Domestic producers are monopolistic competitors with symmetrically differentiated varieties, as in Krugman (1980). They have constant marginal costs per kilogram c and fixed costs per firm f. They set their price at a constant mark-up over their marginal costs.[3]

$$p_d = \left(\frac{\theta}{\theta\ -\ 1}\right)\ c \tag{3}$$

Domestic firms enter the market until their variable profits are equal to their fixed costs and their profits are zero.

$$\pi_d = \left(\frac{1}{\theta}\right)\ \frac{y\ (p_d)^{1\ -\ \theta}}{n\ (p_d)^{1-\theta}\ +\ (p_m\ (1\ +\ \tau))^{1-\theta}} = f \tag{4}$$

[2] While the following partial equilibrium model is very simple, the approach to incorporating uncertainty could be reapplied to a more elaborate structural model of an industry.

[3] Marginal costs are constant and exogenous in the model, so domestic prices are also constant.

This entry condition implicitly defines the equilibrium number of domestic firms n.

Imports are available at exogenous price p_m, with total ad valorem tariff rate τ, so the delivered price of imports is $p_m\ (1\ +\ \tau)$. Absent a TRQ, the baseline tariff rate on imports is τ_0, and the delivered price of the imports is $p_m\ (1\ +\ \tau_0)$.[4]

The TRQ has a quota volume Q, an in-quota rate of zero, and an out-of-quota rate equal to τ_{out}. There are three possible outcomes for the quantity of imports with the TRQ in place. If $q_m < Q$, then the TRQ underfills, and the delivered price of imports is $p_m\ (1\ +\ \tau_0)$. If $q_m > Q$, then the quota is exceeded, the TRQ overfills, and the delivered price of imports is $p_m\ (1\ +\ \tau_0\ +\ \tau_{out})$. If $q_m = Q$, then the TRQ just fills and the delivered price of imports is $p_m\ (1\ +\ \tau_0\ +\ \alpha)$, where α is the ad valorem equivalent of the quota rent. α ranges from a minimum of zero to a maximum of the out-of-quota tarif rate τ_{out}, depending on the level of import demand. There is a unique value of α that sets $q_m = Q$ and clears the market for imports. The model is not concerned about the allocation of import licenses: it assumes that the TRQ fills on a first come, first served basis.[5]

4 Application to U.S. Imports of Soap

I apply the model to data from the U.S. soap and other detergent manufacturing industry (NAICS code 325611). I consider five different quota levels (300 million kilograms, 325 million, 350 million, 375 million, and 400 million) and two different out-of-quota rates (10% and 20%), for a total of ten different policy scenarios.

I first estimate the economic effects of the TRQ assuming that there is no uncertainty about market conditions. Then I incorporate uncertainty about aggregate expenditure y and import price p_m that is calibrated to recent historical market conditions in the industry.

[4]The baseline tariff rate is the ordinary duty rate that applies to industry imports independent of the TRQ.

[5]On the other hand, the literature reviewed in Section 2 provides many examples of how the allocation of import licenses can determine the distribution of quota rents.

4.1 Data Inputs

Table 1 reports annual data for the U.S. industry in 2015, 2016, and 2017.

Table 1: Data for the Soap and Other Detergent Industry

Measure	2015	2016	2017	Source
Customs value of imports ($ million)	1,003.15	996.78	1,058.77	USITC
Quantity of imports (million KG)	359.32	350.12	374.99	USITC
Calculated duties ($ million)	8.14	9.10	10.25	USITC
Tariff rate (%)	0.81	0.91	0.97	USITC
AUV of imports ($ per KG)	2.79	2.85	2.82	USITC
Landed duty-paid value ($ million)	1,052.84	1,047.70	1,113.55	USITC
FAS value of exports ($ million)	1,511.86	1,423.25	1,445.83	USITC
Total value of shipments ($ million)	22,777.09	23,365.71	24,944.86	Census
Cost of materials ($ million)	7,682.71	7,354.14	8,749.38	Census
Payments to production workers ($ million)	803.82	809.69	913.76	Census
Total employment (number of workers)	21,953	21,845	26,022	Census
Apparent consumption ($ million)	22,318.07	22,990.16	24,612.57	Calculated

The 2015 and 2016 data for the domestic industry are from the Census Bureau's 2013-2016 Annual Survey of Manufacturers Statistics for Industry Groups and Industries tables, which are publicly available at `https://www.census.gov/data/tables/time-series/econ/asm/2013-2016-asm.html`. The 2017 data for the domestic industry are from the Census Bureau's Economic Census 2017 NAICS Sector 31-33 Manufacturing tables, available at `https://www.census.gov/data/tables/2017/econ/economic-census/naics-sector-31-33.html`. The international trade data for all three years are from the U.S. International Trade Commission's Trade Dataweb, available at `https://dataweb.usitc.gov/`. Apparent consumption is defined as the total value of shipments of domestic producers minus the value of their exports plus the landed duty-paid value of industry imports.

The calibrated value of θ, the elasticity of substitution between domestic varieties and imports, is equal to $\frac{p_d}{p_d - c}$, according to equation (3). I proxy this with the ratio of the total value of the domestic shipments of the domestic industry to the total value of these shipments minus the domestic producers' total cost of materials and their total payments to production workers. The estimated value of θ, based on 2017 industry data in Table 1, is 1.63233. There were 616 domestic firms in the industry in 2017, and the industry's baseline tariff rate τ_0 was 0.97%.

4.2 Estimated Effects without Uncertainty

The first step in the simulation is to calculate the equilibrium number of domestic firms n in the baseline equilibrium with no TRQ, given delivered import price $p_m\ (1\ +\ \tau_0)$. Equation (5) is the reduced-form expression for the number of domestic firms implied by equation (4).

$$n = \frac{\frac{y\ (p_d)^{1\ -\ \theta}}{\theta}\ -\ f\ ((p_m\ (1\ +\ \tau_0))^{1-\theta}}{f\ (p_d)^{1\ -\ \theta}} \tag{5}$$

The second step is to calculate the corresponding baseline quantities of domestic products and imports using equations (1) and (2).

The third step in the simulation is to calculate the delivered price of imports, number of domestic firms, and the quantities of domestic products and imports for each of three possible TRQ outcomes. When the TRQ does not fill, $\tau = \tau_0$, assuming that the in-quote tariff rate is zero. When it just fills, $\tau = \tau_0\ +\ \alpha$, where α is the ad valorem equivalent of the quota rent. When it overfills, $\tau = \tau_0\ +\ \tau_{out}$. When the TRQ just fills, α and n are jointly determined by the conditions that $q_m = Q$ and the profits of the domestic producers are zero.[6] The model calculates import and domestic quantities and the TRQ fill rate for each of the three TRQ outcomes and then determines which of the three outcomes prevails.

Tables 2 and 3 report the estimated effect on each of the variables for each of the ten policy scenarios. These effects are calculated as the percent changes from the equilibrium value of each variable without the TRQ to its equilibrium value under the TRQ.

[6]There is a unique market-clearing value of α such that import demand is equal to Q given n.

Table 2: Fill Rates and Effects on Import Volume

Quota (million kilograms)	Out-of-Quota Rate (%)	Quota Fill Rate (%)	Import Quantity (% change)
300	10	111.603	-14.286
300	20	100.000	-23.197
325	10	103.018	-14.286
325	20	100.000	-16.797
350	10	100.000	-10.397
350	20	100.000	-10.397
375	10	100.000	-3.996
375	20	100.000	-3.996
400	10	96.653	0.000
400	20	96.653	0.000

Table 3: Effects on Domestic Quantity and Delivered Import Prices

Quota (million kilograms)	Out-of-Quota Rate (%)	Domestic Quantity (% change)	Import Price (% change)
300	10	0.275	9.904
300	20	0.461	17.549
325	10	0.275	9.904
325	20	0.326	11.924
350	10	0.197	6.956
350	20	0.197	6.956
375	10	0.074	2.530
375	20	0.074	2.530
400	10	0.000	0.000
400	20	0.000	0.000

Whether the TRQ fills depends on the size of the quota Q and out-of-quota tariff rate τ_{out}, as well as market conditions that affect import supply and demand. The decline in the quantity of imports reported in Table 2 is greater for a more restrictive TRQ – one with a higher out-of-quota rate, a lower quota, or both. The percent changes in domestic quantity and imports prices reported in Table 3 are also greater for more restrictive TRQs.

Given the production function of the domestic industry, the percent change in total domestic employment in the industry is determined by the percent change in $n\ q_d$. For example, a TRQ of 300 million kilograms with an out-of-quota rate of 10% would increase $n\ q_d$ by 0.275%, and domestic employment would increase by 72 workers (26,022 worker multiplied by 0.00275). A TRQ with the same quota level and an out-of-quota rate of 20% would increase $n\ q_d$ by 0.461% and would increase domestic employment by 120 workers.

4.3 Estimated Effects with Uncertainty

This section extends the model to incorporate uncertainty about import prices (p_m) and aggregate expenditure in the domestic market (y), two market conditions that have direct effects on import supply and demand.

I assume that the natural log of y has the simple random walk time series representation in equation (6).

$$\ln y_t - \ln y_{t-1} = \eta_t \tag{6}$$

t indexes years. I assume that the innovation η_t is normally distributed with mean μ_y and standard deviation σ_y. These moments of η_t are calibrated to recent historical data for the industry in Table 1.[7] The forecasted value of y_{2018} is equal to $e^{\ln y_{2017}\ +\ \eta_{2018}}$. I use the same method to forecast the value of p_m based on the mean and standard deviation of innovations

[7]In other words, I assume that the stochastic distribution in the recent historical data for the industry will continue to apply in the future period.

in p_m in the recent historical data for the industry.

For each of 10,000 random draws of future y and p_m, the model calculates delivered prices of imports, n, q_d, and q_m without the TRQ to establish the expected baseline outcomes. Then the model calculates delivered prices of imports, n, q_d, and q_m with the TRQ in place under the three possible TRQ outcomes and determines which of the TRQ outcomes will prevail by comparing q_m to Q. The estimated effect on each of the variables is again calculated as the percent change from its equilibrium value without the TRQ to its equilibrium value under the TRQ.

Tables 4 and 5 report the estimated 50th percentile quota fill rates and percent changes in import quantities, domestic quantities, and delivered import prices. The table also reports the 10th and 90th percentile values of these variables in parentheses to indicate the range of uncertainty around the median effects. There is a small range around most of the estimated effects for most of the policy scenarios, though the TRQ with the 400 million kilogram quota rarely fills and so the expected effects in that case are very close to zero and are rounded to zero in tables 4 and 5.

Table 4: Fill Rates and Effects on Import Volume

Quota (million kilograms)	Out-of-Quota Rate (%)	Quota Fill Rate (%)	Import Quantity (% change)
300	10	110.578 (110.533, 110.624)	-14.286 (-14.286, -14.286)
300	20	100.000 (100.000, 100.000)	-22.486 (-22.518, -22.454)
325	10	102.072 (102.029, 102.114)	-14.286 (-14.286, -14.286)
325	20	100.000 (100.000, 100.000)	-16.026 (-16.061, -15.992)
350	10	100.000 (100.000, 100.000)	-9.567 (-9.603, -9.529)
350	20	100.000 (100.000, 100.000)	-9.567 (-9.604, -9.529)
375	10	100.000 (100.000, 100.000)	-3.107 (-3.147, -3.067)
375	20	100.000 (100.000, 100.000)	-3.107 (-3.147, -3.067)
400	10	96.756 (96.716, 96.796)	0.000 (0.000, 0.000)
400	20	96.756 (96.716, 96.796)	0.000 (0.000, 0.000)

Table 5: Effects on Domestic Quantity and Delivered Import Prices

Quota (million kilograms)	Out-of-Quota Rate (%)	Domestic Quantity (% change)	Import Price (% change)
300	10	0.260	9.904
		(0.260, 0.260)	(9.904, 9.904)
300	20	0.421	16.887
		(0.421, 0.422)	(16.858, 16.917)
325	10	0.260	9.904
		(0.260, 0.260)	(9.904, 9.904)
325	20	0.293	11.294
		(0.293, 0.294)	(11.266, 11.322)
350	10	0.171	6.354
		(0.171, 0.172)	(6.327, 6.381)
350	20	0.171	6.354
		(0.171, 0.172)	(6.327, 6.381)
375	10	0.055	1.953
		(0.054, 0.055)	(1.927, 1.978)
375	20	0.055	1.953
		(0.054, 0.055)	(1.927, 1.978)
400	10	0.000	0.000
		(0.000, 0.000)	(0.000, 0.000)
400	20	0.000	0.000
		(0.000, 0.000)	(0.000, 0.000)

5 Multi-Year TRQs

Next, I add multiple future years to the model to address two issues: first, uncertainty about market fundamentals compounds as the time horizon lengthens; second, out-of-quota rates in TRQs typically decline over time.

In the simulation reported in Table 6, I consider a TRQ that is constant over three years, with a 325 million kilogram quota and a 20% out-of-quota rate in every year. The table reports the 10th, 50th, and 90th percentile values. It also reports the ratio of the difference between the 90th and 10th percentile values divided by the 50th percentile value as a measure of variance in parentheses. Uncertainty compounds over time, leading to a larger ratio in parentheses in the later years of the three-year constant TRQ.

Table 6: Effects over Time with a Constant 20% Out-of-Quota Rate

	Out-of-Quota Rate (%)	Domestic Quantity (% change)	Import Price (% change)
Year 1	20	0.293, 0.293, 0.294 (0.006)	11.266, 11.294, 11.322 (0.005)
Year 2	15	0.262, 0.264, 0.265 (0.012)	10.611, 10.667, 10.723 (0.010)
Year 3	10	0.234, 0.236, 0.238 (0.019)	9.960, 10.044, 10.127 (0.017)

In the simulation reported in Table 7, on the other hand, I consider a three-year TRQ with the same 325 million kilogram quota but an out-of-quota rate that declines over time, starting at 20% in the first year, declining to 15% in the second year, and then declining again to 10% in the third year. Table 7 again reports the 10th, 50th, and 90th percentile values and the ratio of the difference between the 90th and 10th percentile values divided by the 50th percentile value. In this case, there is not a uniform increase in this variance ratio over the three years, because the effect of compounding uncertainty is partly offset by the annual decline in the out-of-quota tariff rate.

Table 7: Effects over Time with a Declining Out-of-Quota Rate

	Out-of-Quota Rate (%)	Domestic Quantity (% change)	Import Price (% change)
Year 1	20	0.293, 0.293, 0.294 (0.006)	11.266, 11.294, 11.322 (0.005)
Year 2	15	0.262, 0.264, 0.265 (0.012)	10.611, 10.667, 10.723 (0.010)
Year 3	10	0.233, 0.233, 0.234 (0.004)	9.904, 9.904, 9.904 (0.000)

6 Investments of Domestic Firms under Uncertainty

In the simulations in the earlier sections, economic decisions about pricing and entry were made ex post, after the uncertainty about market conditions in each year was resolved. In this section, in contrast, I modify the modeling framework to include ex ante decisions about whether a domestic firm decides to incur the fixed cost to participate in the market. The firm is deciding whether to invest under uncertainty. There is a large and growing economics literature that demonstrates how uncertainty about trade policy has had significant effects on trade and investment decisions, including Handley and Limão (2015) and Handley and Limão (2017).[8] Unlike these studies that focus on policy uncertainty, my model focuses on uncertainty about market conditions, specifically the future values of y and p_m. I model how this uncertainty alters the economic effects of the TRQ.

Adding uncertainty complicates the calculations, because it requires determining a single

[8]Mueller and Riker (2020) offers a partial equilibrium adaptation of these models.

value for the number of domestic firms (n) that will be common across the three possible TRQ outcomes and across all 10,000 draws of y and p_m, rather than a value of n that is specific to each, like in the simulations reported in Sections 4 and 5. For this model extension with ex ante deicisions about n, I return to the simpler single-year TRQ in Section 4. The ex ante decision to incur the fixed costs is locked in for the year, regardless of innovations in y and p_m. In equilibrium, the ex ante number of firms equates the expected value of variable profits (across all 10,000 random draws of y and p_m and the TRQ outcome that results from each of these draws) to the fixed cost per firm f.

Table 8 reports a simulation of a TRQ with a quota of 325 million kilograms for two alternative out-of-quota rates, 10% and 20%. The top panel is the expected effects on domestic quantity with ex ante decisions about firm entry. To facilitate side-by-side comparison, the bottom panel replicates the outcomes from Table 5, which ex post entry decisions. Ex ante decisions about fixed cost investment result in a slightly smaller impact of the same TRQ on domestic quantity and employment for the same stochastic distribution of market conditions. There is not a measurable difference in the effect on delivered import prices.

Table 8: Effects on Domestic Quantity and Delivered Import Prices

Quota (million kilograms)	Out-of-Quota Rate (%)	Domestic Quantity (% change)	Import Price (% change)
Ex ante			
325	10	0.249	9.904
		(0.249, 0.250)	(9.904, 9.904)
325	20	0.282	11.294
		(0.281, 0.282)	(11.266, 11.322)
Ex post			
325	10	0.260	9.904
		(0.260, 0.260)	(9.904, 9.904)
325	20	0.293	11.294
		(0.293, 0.294)	(11.266, 11.322)

7 Conclusions

Overall, the simulations demonstrate that it is practical to incorporate uncertainty about market conditions into estimates of the economic effects of TRQs, though in the case of the hypothetical TRQ on U.S. soap imports in 2018 adding calibrated uncertainty still results in a tight range of expected effects. It is straightforward to extend the model to multiple years or to adjust the timing of entry decisions in the model.

It is important to emphasize that the model provides a positive analysis of the effects of TRQs, not a normative analysis of the policy scenarios. The model does not try to assign welfare weights to the competing interests of consumers and domestic producers, and it does not try to identify the optimal TRQ.

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