The Effect of Tariff in a Two Country Model

ECON 567, Spring 2014

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1. Introduction

In this project, we simulate the effects of tariff with a two-country model. The setups in this project come from Chapter 19 of "Introduction to Numerical Simulation for Trade Theory & Policy" by John Gilbert and Edward Tower. For the analysis of the models in the project, we use computable general equilibrium model using General Algebraic Modeling System (GAMS).

We set up two countries with similar sizes. We start with the free trade scenario without any market intervention. The parameters are calibrated so that it gives symmetric results in the free trade case. Next, we introduce various tariffs under same settings. First we investigate the effect of countervailing duties. Export subsidy is imposed on one country, and then the other country reacts accordingly with import tax. Next, we solve for the optimal level of tariff for the home country. Finally, with the previous findings, we simulate the tariff war. That is, each country is responding with the optimal tariff conditional on the other country's tariff level. We try to find the ultimate equilibrium of the retaliatory tariff war.

2. Model

2.1 General Assumptions

- There are two countries: Home country and foreign country.
- There exist two goods: good 1 and good 2.
- People in each country have same preference on goods. They share the same utility function.
- Utility function in each country has Cobb-Douglas form.
- International trade market clears. All goods exported in one country is imported by the other.
- Production function has constant elasticity of substitution (CES) form.
- The world price of good 1 is the numéraire and is normalized to one.
- Home country exports good 1, and imports good 2.
- The objective is to maximize utility.
- There is no intervention other than tariff.

2.2 Variables and Parameters

Variables	Definition	Parameters	Definition
U(D)	Utility indices	ALPHA(D)	Shift parameters in utility
T(I,D)	Trade taxes	BETA(I,D)	Share parameters in utility
P(I,D)	Prices	PO(I,D)	Initial domestic prices
C(I,D)	Consumption levels	PWO(I)	Initial world prices
Q(I,D)	Output levels	XO(I,D)	Initial trade
R(J,D)	Factor prices	CO(I,D)	Initial utility levels
F(J,I,D)	Factor use levels	GAMMA(I,D)	Initial consumption levels
PW(I)	World prices	DELTA(J,I,D)	Shift parameters in production
X(I,D)	Trade levels	RHO(I,D)	Share parameters in production
GDP(D)	GDP	FBAR(J,D)	Elasticity parameters in production
		RO(J,D)	Factor Endowments
		GDPO(D)	Initial GDP

2.3 Equations

(1) Utility : U(D)=ALPHA(D)*PROD(I, C(I,D)**BETA(I,D))

- The utility function has a Cobb-Douglas form, with a shift parameter alpha and share parameter beta.

(2) Demand : C(I,D)=BETA(I,D)*GDP(D)/P(I,D)

- The consumption level is determined by share parameters in utility and the budget constraint.

(3) Material balance : X(I,D)=Q(I,D)-C(I,D)

- Any goods produced that are not consumed are exported. That is, the production quantity equals the domestic consumption and net export.

(4) International market clearing : SUM(D, X(I,D))=0

- Any goods exported from one country are imported by the other country.

(5) Arbitrage : P(I,D)=(1+T(I,D))*PW(I)

- Domestic price of one country is equal to the world price times tariff effect.

(6) Production : Q(I,D)=GAMMA(I,D)*SUM(J,DELTA(J,I,D)
*F(J,I,D)**RHO(I,D))**(1/RHO(I,D))

- The production function has constant elasticity of substitution(CES) form with shift parameter gamma, share parameter delta, and the elasticity parameter rho.

(7) Resource constraint : FBAR(J,D)=SUM(I, F(J,I,D))

- The total factor demand has to equal the initial factor endowments

(8) Factor demand : R(J,D)=E=P(I,D)*Q(I,D)*SUM(JJ, DELTA(JJ,I,D)
*F(JJ,I,D)**RHO(I,D))**(-1)*DELTA(J,I,D)*F(J,I,D)**(RHO(I,D)-1)

- This is the result from the long-run profit maximization of the economy. This equation can be derived through differentiation of Lagrangian.

(9) Income : GDP(D)=E=SUM(I, P(I,D)*Q(I,D))-SUM(I, PW(I)*T(I,D)*X(I,D))

- Total income equals the production with tax revenues/expenditures.

3. Simulations and Analysis

3.1 Free Trade Condition

In the free trade equilibrium, all prices of both goods in both countries are 1, so the consumption levels of both goods in both nations will be identical to each other at 137.5. H has a larger endowment of capital than F, while F has a larger endowment of labor than H, and since good 1 is capital intensive, while good 2 is labor intensive, H will produce in free trade, 200 of good 1 and 75 of good 2, while F will produce 200 of good 2 and 75 of good 1. Each nation produces more of the good that they have a comparative advantage in. Because the elasticity of demand is identical for both goods in each country, both countries will want to spend half of their income on each good. Because there are no restrictions on trade, we will have that H exports 62.5 of good 1 to F and F exports 62.5 of good 2 to H, a basic HOS model result, since H exports the capital intensive good, while F exports the labor intensive good. Since factor prices are all normalized to 1 at the start, and there is no change of outputs in the free trade equilibrium, we have that factor prices remain at 1 for both labor and capital in both nations. World and domestic prices of goods will stay the same at 1. The GDP for both nations is just the sum of the outputs of both goods, which is 275, and as mentioned earlier, both nations have a utility from consumption of 275.

	Good	Utility	Trade Tax(Subsidy)	Prices	Consumption	Output	Trade	GDP
Home	1	275	0	1	137.5	200	62.5	275
	2		0	1	137.5	75	-62.5	
Foreign	1	275	0	1	137.5	75	-62.5	275
	2		0	1	137.5	200	62.5	

<Free Trade>

3.2 Countervailing Duty

Next, we simulated the countervailing duty. Countervailing duty is an import tariff imposed when trying to counter the effect of export subsidy of another country. Export subsidy is imposed when a country is trying to boost the level of export. The result of 10% export subsidy on home country is as follows:

	Good	Utility	Trade Tax(Subsidy)	Prices	Consumption	Output	Trade	GDP
Home	1	271.3	0.1	1.1	132.5	206.5	74.0	291.4
	2		0	1.05	139.0	68.4	-70.6	
Foreign	1	278.2	0	1	142.4	68.4	-74.0	284.9
	2		0	1.05	135.8	206.4	70.6	

<Home Country 10% Export Subsidy>

Compared with the free trade case, the absolute level of trade has increased. As a result of an export subsidy on home country, export level of good 1 exceeds the import level of good 2. Therefore, the trade balance of the home country is positive. In terms of utility, however, the country subsidizing export is worse off, and the opponent is better off as it gets higher utility. Utility of the home country is lowered to 271.3, and the utility of foreign country is increased to 278.2. Therefore, with regard to the utility maximizing, strategy involving export subsidy will be harmful to a country.

	Good	Utility	Trade Tax(Subsidy)	Prices	Consumption	Output	Trade	GDP
Home	1	269.0	0.1	1.1	134.5	200	65.5	296.0
	2		0	1.1	134.5	75	-59.5	
Foreign	1	281.0	0.1	1.1	140.5	75	-65.5	309.0
	2		0	1.1	140.5	200	59.5	

<Home Country 10% Export Subsidy, Foreign Country 10% Import Tax>

Next, we have the countervailing duties. Foreign country is responding with the same 10% import tariff on good 1. In this case, the world price of good 1 is one, but the domestic prices of good 1 in both countries are the same at 1.1. This is as if the home country is selling goods in a cheaper price to the world, but the foreign country is buying goods in a more expensive price from the world market. Now, the absolute value of the trade balance goes back to the original level of free trade. However, the utility of the foreign country increases and that of home country drops even more than the case of only export subsidy. Therefore, it is more harmful utility-wise to the home country when the foreign country responds with countervailing duties.

3.3 Optimal Tariff on Home Country

We now try to find the optimal level of tariff. First, we assume that the foreign country does not impose tariff and calculate what would be the optimal tariff level for the home country. Then, we will simulate the tariff war between home and foreign country, by assuming each country imposes their optimal level of tariff in turn.

In this model, optimal tariff means the level of tariff that maximizes one country's utility level. For the GAMS implementation, only foreign tariffs are fixed to be zero and home tariffs to vary. (T.FX(I,'F')=0;) Moreover, we set up an objective function that tries to maximize home utility. (OBJ=E=U('H');) We solve the model maximizing OBJ, and the result is as follows.

	Good	Utility	Trade Tax(Subsidy)	Prices	Consumption	Output	Trade	GDP
Home	1	278.2	-2.73E-11	1	146.5	185.8	39.3	293.0
	2		0.231	1.1	132.1	88.5	-43.6	
Foreign	1	269.6	0	1	127.9	88.6	-39.3	255.9
	2		0	0.9	142.0	185.6	43.6	

<Home Country Optimal Tariff>

The optimal level of tariff is to impose approximately 23% of import tariff, in this case, on good 2. As a result, trade level decreases on both goods. We observe that the utility of the home country has increased, and that of the foreign country has decreased by the optimal tariff imposed by home country. The total value of utility of both countries is less than that of free trade scenario. This implies that there is a deadweight loss through trade intervention. GDP of the home country has increased, whereas GDP of the foreign country has decreased. The total amount of GDP is slightly lower than the GDP level under free trade regime.

In addition, we wanted to see the effect of elasticity of substitution on optimal tariff. Since the production function has CES form with elasticity parameter rho, the elasticity of substitution equals 1/(1-rho). We know that the optimal tariff depends only on the foreign elasticity. We simulated both infinite elasticity and lower elasticity case in foreign country. Results are as follows:

	Good	Utility	Trade Tax(Subsidy)	Prices	Consumption	Output	Trade	GDP
Home	1	275	0	1	137.5	200	62.5	275
	2		0	1	137.5	75	-62.5	
Foreign	1	275	0	1	137.5	75	-62.5	275
	2		0	1	137.5	200	62.5	

<Rho(I,'F')=1, infinite elasticity>

	Good	Utility	Trade Tax(Subsidy)	Prices	Consumption	Output	Trade	GDP
Home	1	285.6	-1.26E-14	1	152.3	182.3	30.0	304.5
	2		0.603	1.137	134.0	91.6	-42.3	
Foreign	1	258.2	0	1	108.7	78.7	-30.0	217.4
	2		0	0.71	153.3	195.6	42.3	

<Rho(I,'F')=-10, low elasticity>

When the foreign elasticity of substitution is infinitely high, then the result is exactly same as free trade. This is same as home country being small country, which is price-taker. In this case, any kind of tariff will worsen the utility of the home country because foreign country can react elastically to the change. Therefore, the optimal tariff level of the home country is zero, and all the variables have exact same values as free trade case.

On the other hand, the optimal tariff is higher when the foreign elasticity of substitution is lower than the base scenario. Import tariff imposed by the home country increased from 23.1% in the base scenario to 60.3% in low elasticity case. When the country is inelastic to the change in tariff, it is more vulnerable to be worse off since its production cannot change freely according to the price change due to tariff. Therefore, foreign country's loss is much bigger in this case. The utility of the foreign country has dropped from 269.6 to 258.2. In contrast, the utility of the home country has even more increased than before from 278.2 to 285.6. Overall level of trade has decreased due to the increase in tariff.

3.4 Retaliatory Trade War

Since in both cases, the parameters for each economy are symmetric, the optimum tariff instituted by the first country to move and the optimum retaliation tariff of the second country to move will be identical for H and F. Each country will respond to the other country's tariff at the previous time period with their optimum tariff maximizing their utility conditional on the other country instituting the same tariff as in the previous time period. As each nation responds, their tariff rates, though on different goods, will converge to the same level. As we will show, the GAMS simulation shows a relatively quick convergence of tariffs, with tariff levels being effectively the same after only six steps in the trade war. We will call this the tariff war equilibrium.

Without loss of generality, we will simulate H striking first by setting their optimum tariff, then followed by F setting their optimum retaliation tariff. We have seen earlier that the optimum tariff under the default parameters for country H is, assuming that F imposes no tariff, 23.1% on good 2. In this case the Cobb-Douglas function measuring utility gain for H rises from the default baseline of 275 to 278.24. F's utility drops to 269.58. F retaliates by setting their optimum utility maximizing tariff, conditional on H setting their tariff at 23.1% on good 2. This is done in GAMS by fixing H's tariff on good 2 at 23.1%, fixing H's tariff on good 1 at 0%, and letting F vary in their tariff, with the goal of maximizing F's utility function. This produces an optimum tariff of 15.0% for F on good 1. Utility for F rises to 271.025, while utility for H drops to 272.919. The next stage of the trade war will be H responding to F's tariff of 15.0% by setting a new optimum tariff conditional on F's tariff. Again, to simulate this, F's tariff is fixed at 15.0% for good 1, fixed at 0% for good 2, and H's tariff is allowed to vary in order to maximize H's utility function. This results in H lowering their tariff on good 2 to 17.6%. H improves their utility to 273.070, and F's utility also increases to 272.352. When F responds, they raise the tariff on good 1 to 16.7%. The utility of H decreases to 272.595 and F's utility will increase to 272.364. This retaliation will continue, reaching an equilibrium where F's tariff on good 1 and H's tariff on good 2 will be at somewhere between .169 and .170, and the utility of both countries will be around 272.54.

	Good	Utility	Trade Tax(Subsidy)	Prices	Consumption	Output	Trade	GDP

Home	1	275	0	1	137.5	200	62.5	275
	2		0	1	137.5	75	-62.5	
Foreign	1	275	0	1	137.5	75	-62.5	275
	2		0	1	137.5	200	62.5	

<Free Trade Equilibrium>

	Good	Utility	Trade Tax(Subsidy)	Prices	Consumption	Output	Trade	GDP
Home	1	272.5	0	1	147.4	178.3	30.9	294.7
	2		0.169	1.169	126.0	95.1	-30.9	
Foreign	1	272.5	0.169	1.169	126.0	95.1	-30.9	294.7
	2		0	1	147.4	178.3	30.9	

<Trade War Equilibrium>

This is our trade war equilibrium, and this is a second best result, as both nations would be better off removing tariffs completely, as their utilities are lower than the free trade equilibrium. Because we have this convergence, it does not matter who starts the trade war first. In either case, both countries will respond to each other until their tariff rates and utility equal each other. The only difference between whether H or F starts the trade war is that the first country to act will have a slight advantage in utility over the second responder until the tariffs equalize.

We can also compare the value of other variables in the economy between the equilibrium reached in a trade war and the free trade equilibrium. The price of good 1 in F, and the price of good 2 in H increase to 1.169. This changes the price ratio between goods 1 and 2 in both countries. As a result, consumption of good 1 in H and good 2 in F increases to 147.4 , while consumption of good 1 in F and good 2 in H drop to 126. This occurs because good 1 is relatively cheaper than good 2 in H and vice versa in F. Production of 2 in H and production of 1 in F increase to 95 from their previous level of 75. This happens because resources will be diverted to 2 in H and 1 in F due to the increase in price of the good that has the tariff applied on it. Domestic producers can raise their prices because of their tariff, so it is more attractive for producers to divert production over. Thus in the trade war equilibrium, more labor and capital will be used in

producing good 2 in H and good 1 in F, than in the free trade equilibrium, as is apparent in seeing the factor use levels in each country after the trade war. This diversion will bid up the price of capital in F and labor in L to 1.23, since they are the more needed factor of production in the good that has increased production. As a result, the price of labor in F and capital in L drops to .95. Trade decreases in both directions, so H exports 30.9 of good 1 to F, while F exports 30.9 of good 2 to H. In both the trade war and free trade equilibrium, the trade balance is 0. GDP increases, but since it is denoted in nominal units, it only represents the increase in prices, not an increase in output.

The trade war equilibrium is only preferable for both countries if they want to either reduce the level of imports at all costs, or if they want to raise the income of the scarce factor of production in their country.

4. Conclusion

We have used the base model from Chapter 19 to solve different problems in finding the optimum tariff. We have found the optimum tariff under default settings, under different elasticities of substitution, found effects of a countervailing duty to a tariff, and the equilibrium result of a trade war.

Computationally, we have discovered what we were taught theoretically in class, that the level of the optimum tariff depends on the elasticity of substitution in the foreign country. A higher elasticity will lead to a lower optimum tariff, and the country who pays more of the tariff is the country that is more inelastic in relation to substitution.

Finally we have seen that if both countries engage in a tit-for-tat response, leveling welfare-maximizing tariffs based on the other country's previous tariff, then both tariff levels will converge to one value. At this equilibrium level, each country is just as better off as the other country, but they are both worse off than if they engaged each other under free trade.

5. Reference

1) J. Gilbert, E. Tower, An Introduction to Numerical Simulation for Trade Theory and Policy, World Scientific Publishing Company, (Jan, 2013)