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OPTIMAL TARIFF CALCULATIONS IN TARIFF GAMES WITH CLIAMTE CHANGE CONSIDERATIONS

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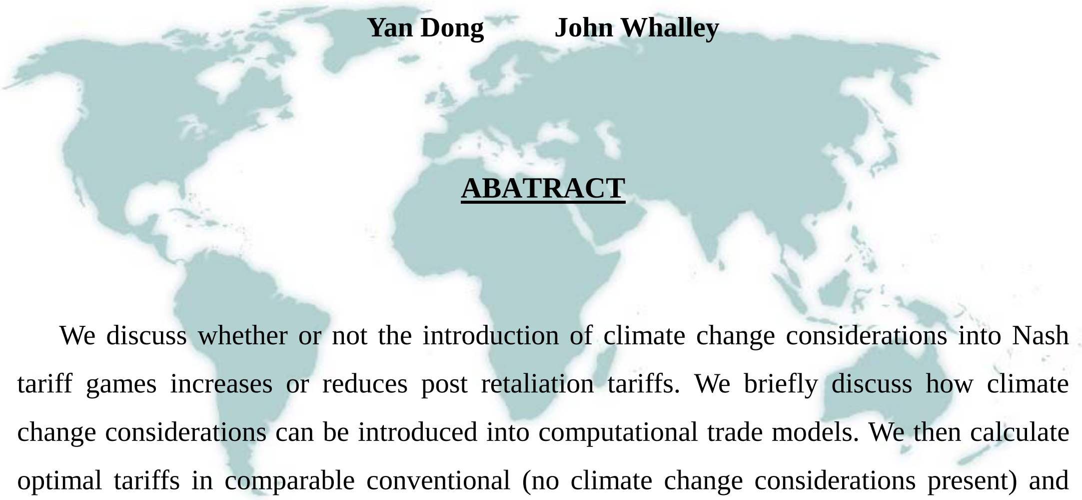

ABATRACT

We discuss whether or not the introduction of climate change considerations into Nash tariff games increases or reduces post retaliation tariffs. We briefly discuss how climate change considerations can be introduced into computational trade models. We then calculate optimal tariffs in comparable conventional (no climate change considerations present) and with climate change trade models. Results show that compared to conventional trade models, adding climate change considerations reduces the level of optimal tariffs, but this only occurs when the damage effects involved are large.

1. INTRODUCTION

Global warming is an important issue facing the world economy, and after the UNFCCC Bali Meeting (Dec 2007), there is increased discussion as to how trade and environment regimes may need to be more closely linked in a post Kyoto world. There is concern that protectionism linked to the perceived need to offset increased costs for domestic producers in countries to taking on larger commitments will grow.

In this paper, we discuss whether or not the introduction of climate change considerations into conventional Nash tariff games models will increase or reduce post retaliation Nash tariffs. We present a simple 2 good, 2 country climate change-trade model in which the utility of each country is influenced not only by consumption, but also by temperature change. We assume that countries can reduce global emissions by forgoing consumption, but the benefit of that reduction accrues also to other countries. Each country's optimal tariff is influenced by each country's choice of use of its endowment which affects emissions, an extension to the conventional Nash tariff games model.

Using numerical simulation techniques, we report some numerical results showing that adding climate change considerations reduces the level of post retaliation optimal tariffs, but this only occurs when climate change damage is large. We thus compare optimal tariffs in a general equilibrium climate change-trade model with those in classical trade models as in Johnson(1953), Gorman(1958), Kuga(1973), Hamilton and Whalley(1983), Markusen and Wigle(1989),and Kennan and Riezman(1990) .

2. NASH TARIFF CALCULATIONS IN A SIMPLE 2 GOOD, 2 COUNTRY CLIMATE-TRADE MODEL

We consider a two country (i=1,2) and two good (l=1,2) pure exchange general equilibrium model. Each country has a single representative consumer with endowments of the two goods, E_{il} ($i= l$). We consider a single time period of several decades in which there is growth in the economy which induces temperature change ΔT . Countries can mitigate temperature change by not selling all of their endowments which confers a benefit on both countries. Unlike in a conventional trade model, the added decision is how much to consume with endowments remaining unsold.

On the demand side of the model, the representative household utility function in each country is

$$U_i = U_i(X_{i1}, X_{i2}, \Delta T) = [(\alpha_{i1}^{1/\sigma} X_{i1}^{\sigma-1/\sigma} + \alpha_{i2}^{1/\sigma} X_{i2}^{\sigma-1/\sigma})^{\sigma/\sigma-1}]^{1-\beta} (\frac{C-\Delta T}{C})^{\beta} \qquad (1)$$

This utility function follows Cai, Riezman & Whalley (2009). X_{il} represents the consumption of good l for each country i, α_{il} is the share parameter for good *l* for country i, while ΔT is global temperature change. β reflects the assumed severity of damage from temperature change. In this specification, *C* can be thought of as the global temperature change at which all economic activity ceases (say, 20℃). In this formulation, as ΔT approaches *C*, utility goes to zero; and as ΔT goes to zero, there is no welfare impact of temperature change.

We assume a simple temperature change power function linking emissions to temperature change given by

$$\Delta T = g(\sum e_i R_{ii}) = a(\sum e_i R_{ii})^b + c \qquad (2)$$

where R_{ii} represents the sale of the own endowment for each country, $R_{ii} \le E_{ii}$, E_{ii} is the potential sale of each country, and countries can decide to sell less than their endowment. If we assume that emissions are associated with the sale (consumption) of their own good, e_i is the emission intensity for country i.

For any good *l*, we can define the seller's (net of tariff) price as P_l^0, and allow each country i to impose a tariff at rate T_{il} on their imported good. Tariffs are set to zero for any export i. Prices for good l in country i are:

$$P_{il} = (1+T_{il})P_l^0, \ i = 1, 2, \ l = 1, 2. \qquad (3)$$

Tariff revenues collected in country i are

$$TR_i = \sum_{l=1}^{2} T_{il} P_l^0 \max[(X_{il} - R_{il}), 0], \ l = 1, 2. \qquad (4)$$

where R_{il} denotes the use of the initial endowment of good l for country i, and the income of country i is given by

$$I_i = \sum_{l=1}^{2} P_{il} R_{il} + TR_i \qquad i = 1, 2 \qquad (5)$$

The solution to the utility maximization sub problem over goods is

$$X_{il} = \frac{\alpha_{il} I_i}{P_{il}^{\sigma} \sum_{l'=1}^{2} \alpha_{il'} P_{il'}^{1-\sigma}} \qquad i = 1, 2, \quad l = 1, 2. \qquad (6)$$

General equilibrium market clearing conditions for goods are:

$$X_{11} + X_{21} = R_{11} + R_{21} \qquad (7)$$

$$X_{12} + X_{22} = R_{12} + R_{22} \tag{8}$$

From (1) and (2), optimality with respect to R_{ii} requires

$$\frac{\partial U_i}{\partial R_{ii}} = -\frac{\partial U_i}{\partial T} \cdot \frac{\partial T}{\partial R_{ii}} \tag{9}$$

Because of the climate change effect, each country may not consume the whole endowment, E_{ii}, and the optimal value of R_{ii} is given by equation (9) .Compared to a conventional trade model, an optimal tariff in this climate-trade model requires each country to choose an optimal level of R_{ii} as well as an optimal level of T_{il}.

We can solve the model numerically for a Nash equilibrium. In order to compute an optimal tariff, we assume a predetermined direction of trade, that country 1 exports good 1 and import sgood 2, while country 2 exports good 2 and imports good 1.

We characterize a Nash equilibrium as follows. Given $R_{22} \in [0, E_{22}]$, $T_{21} \in [0, \infty]$, we can find an optimal level of $R_{11} \in [0, E_{11}]$,and thus an optimal level of $T_{12} \in [0, \infty]$, such that U_1 is maximized subject to general equilibrium conditions and optimality with respect to R_{11} in (7),(8) and (9) . For each value of $R_{22} \in [0, E_{22}]$, the optimal value of $T_{12} \in [0, \infty]$ changes with $T_{21} \in [0, \infty]$.This yields country 1's reaction curve. Given $R_{11} \in [0, E_{11}]$, $T_{12} \in [0, \infty]$,we can also find the optimal level of $R_{22} \in [0, E_{22}]$,and thus an optimal level of $T_{21} \in [0, \infty]$,such that U_2 is maximized subject to (7), (8), and (9). So at each level of $R_{11} \in [0, E_{11}]$ the optimal value of $T_{21} \in [0, \infty]$ changes with $T_{12} \in [0, \infty]$,and this yields country 2's reaction curve.

Nash equilibria are difficult to compute and closed form solutions as to how such equilibria behave under comparative static exercises are not available. We note that most of the literature on Nash tariff games limits itself to two dimensional examples.

A Nash equilibrium in this climate-trade model is even more difficult to compute than in a traditional trade model, since it adds a new equilibrium condition: that the R_{ii} must be in equilibrium in addition to the tariff; a four-dimensional equilibrium. Since country 1's reaction curve implies a fixed R_{11} and a changing R_{22},for each R_{11} country 1 has a reaction curve. Also, country 2's reaction curve implies a fixed R_{11} and a changing R_{22}. For each R_{11}, country 2 has a reaction curve. A Nash equilibrium is obtained when there is an intersection of the two country reaction curves which also implies the same R_{11} and R_{22}.

3. SOME NUMERICAL ANALYSIS OF THE IMPACTS OF CLIMATE CHANGE ON OPTIMAL TARIFFS

We calculate optimal tariffs in both the climate-trade model and a similar conventional trade model using numerical examples with specifications based on literature sources. For the no-climate case, we use the same settings for most of the parameters in the base case as in Hamilton & Whalley(1983), and add climate related parameters from Cai, Riezman & Whalley (2009) for the with climate change case. We consider symmetric cases.

(1) Endowment points, are (75,25) in country 1, (25,75) in country 2. The dimensions of the pure exchange Edgeworth Box are thus 100×100 in quantity terms.

(2) The α_{il} ---weighting parameters in preference functions, are set at $\alpha_{i1} = \alpha_{i2}$ in each country. This places the contract curve (the locus of free trade equilibria) along the diagonal of the Edgeworth Box.

(3) The elasticity of substitution among goods in performances is 0.508 (given implied import price elasticity at free trade of -1.0), 1.2 and 2.

(4) For the parameters related to climate change, in equation (2) the values of a,b,and c are 0.0417, 0.5652, 0, from Cai et al(2009)and C=20. We assume $e_i = 2$.

(5) $\beta = [0-1]$ reflects the assumed severity of damage from temperature change, the higher β,the larger the damage from climate change. $\beta = 0$ implies no damage from temperature change, so that the optimal tariff is the same as in a conventional trade model.

We report the optimal tariff and optimal level R_{ii} for each value of β in these symmetric cases. In the symmetric case, the optimal tariff on country 1 and country 2 should be the same, $R_{11}^o = R_{22}^o$, $t_1^o = t_2^o$ .When $\beta = 0$, $\sigma = 0.508$, $t_1^o = t_2^o = 2.22$, $R_{11}^o = R_{22}^o = E_{11} = E_{22} = 75$, and each country use the upper bound of its resources. The optimal tariff is the same as the base case in Hamilton & Whalley(1983) (See pp338, table 2, first line).

In Figure 1 , we can see that increasing β, the optimal level of tariff does not change until β is very large. When $\sigma = 0.508$, the lower bound of β that has an effect on the optimal tariff is 0.969, and in the interval of $\beta = [0.969 - 0.988]$,the optimal tariff will decrease with increasing β, When β approximates 1, $R_{11}^o = R_{22}^o = 0$, since in the utility function, the only part that enters utility is temperature change, and a smaller use of endowment means smaller temperature change.

The key feature of these results is thus that adding climate change considerations to a tariff game reduces the level of optimal tariffs, but this only occurs when the climate damage parameter is large. In the climate-trade model, if country 1 imposes a tariff on good 2, country 1 will consume more of good 1, and this will cost country 1 through higher climate change, and its optimal tariff will be lower. In Figure 2, we see that the mechanism for reducing the optimal level of tariffs is decreasing optimal levels of sales $R_{11}^{o} = R_{22}^{o}$ with increasing damage.

Changing demand elasticities of substitution influences optimal tariffs, as show in Figure 2. When $\beta = [0 - 0.988]$, at each damage level, the higher the elasticity, the lower the optimal tariff; the more rigid consumer preferences results in lower retaliatory power, and flexible preferences yield economies with relatively more negotiating power. The intuition is that countries can take advantage of the more rigid preferences of its counterpart to exploit welfare gains. This result is the same as traditional trade models. When β is very high, over 0.988, the optimal tariff is independent of elasticities.

4. CONCLUSION

This paper discusses how optimal tariffs change in a trade model with climate change considerations. We briefly present a simple general equilibrium multi-country climate-trade model, in which each country may not consume the whole value of its endowment. Since reduced consumption lowers emissions which lowers climate change, the Nash equilibrium in this model is that the use of the endowment by each country must be optimal in addition to its tariff. Numerical simulation results show that adding climate change considerations reduces optimal tariffs, but this only occurs when environmental damage parameters are very large. Increasing the elasticity of substitution in preferences will reduce the level of optimal tariffs, as in traditional trade models.

Fig.1. The Relationship Between β and $t_{12}^{o} = t_{21}^{o}$ in Three Different Elasticity Cases

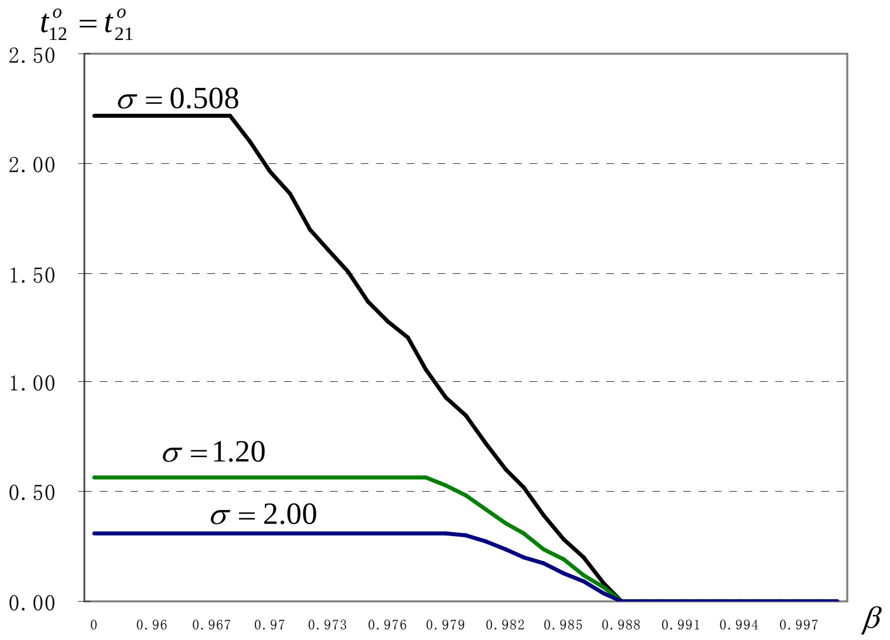

Fig.2. The Relationship Between β and $R_{11}^{o} = R_{22}^{o}$ in Three Different Elasticity Cases

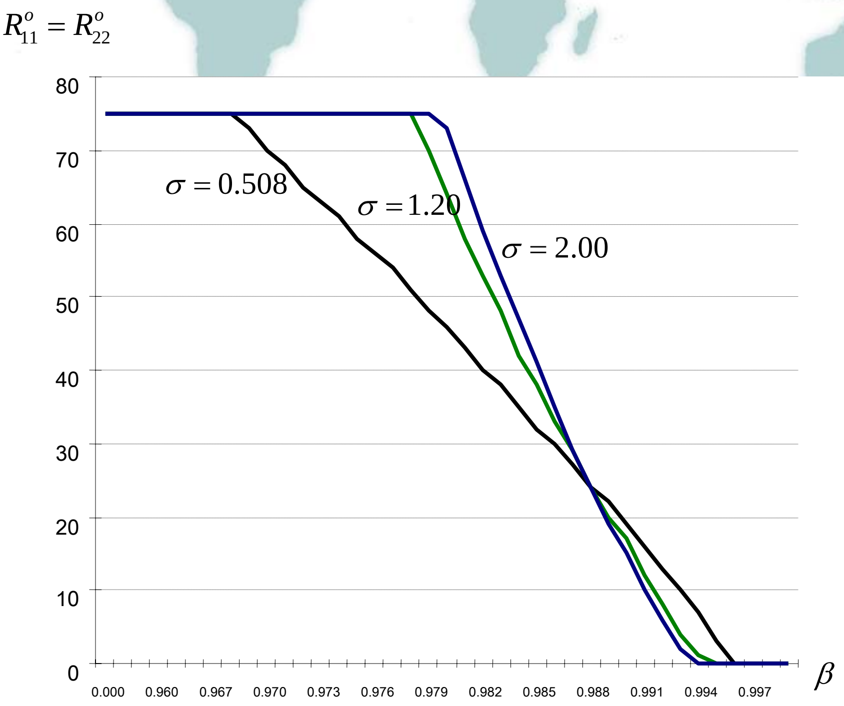

Table 1 The Optimal Value of Use of Endowment and Optimal Tariff under Different Damage Assumptions

β	$RS_1^o = RS_2^o$			$T_{12}^o = T_{21}^o$		
	$\sigma = 0.508$	$\sigma = 1.2$	$\sigma = 2$	$\sigma = 0.508$	$\sigma = 1.2$	$\sigma = 2$
0.000	75	75	75	2.22	0.57	0.31
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(0.000-0.950)	75	75	75	2.22	0.57	0.31
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0.950	75	75	75	2.22	0.57	0.31
0.955	75	75	75	2.22	0.57	0.31
0.960	75	75	75	2.22	0.57	0.31
0.965	75	75	75	2.22	0.57	0.31
0.966	75	75	75	2.22	0.57	0.31
0.967	75	75	75	2.22	0.57	0.31
0.968	75	75	75	2.22	0.57	0.31
0.969	73	75	75	2.10	0.57	0.31
0.970	70	75	75	1.96	0.57	0.31
0.971	68	75	75	1.86	0.57	0.31
0.972	65	75	75	1.70	0.57	0.31
0.973	63	75	75	1.61	0.57	0.31
0.974	61	75	75	1.51	0.57	0.31
0.975	58	75	75	1.37	0.57	0.31
0.976	56	75	75	1.28	0.57	0.31
0.977	54	75	75	1.20	0.57	0.31
0.978	51	75	75	1.06	0.57	0.31
0.979	48	70	75	0.93	0.53	0.31
0.980	46	64	73	0.85	0.48	0.30
0.981	43	58	66	0.72	0.42	0.27
0.982	40	53	59	0.60	0.36	0.24
0.983	38	48	53	0.52	0.31	0.20
0.984	35	42	47	0.39	0.24	0.17
0.985	32	38	41	0.28	0.19	0.13
0.986	30	33	35	0.20	0.12	0.09
0.987	27	29	29	0.08	0.06	0.04
0.988	24	24	24	0.00	0.00	0.00
0.989	22	20	19	0.00	0.00	0.00
0.990	19	17	15	0.00	0.00	0.00
0.991	16	12	10	0.00	0.00	0.00
0.992	13	8	6	0.00	0.00	0.00
0.993	10	4	2	0.00	0.00	0.00
0.994	7	1	0	0.00	0.00	0.00
0.995	3	0	0	0.00	0.00	0.00
0.996	0	0	0	0.00	0.00	0.00
0.997	0	0	0	0.00	0.00	0.00
0.998	0	0	0	0.00	0.00	0.00
0.999	0	0	0	0.00	0.00	0.00

REFERENCES

Cai,Y,Z, Riezman, R. and Whalley,J., 2009, International Trade and the Negotiability of Global Climate Change Agreements , NBER Working Paper No.14711, Issued in February 2009.

Dong,Y. and Whalley, J., 2009, Carbon Motivated Regional Trade Arrangements: Analytics and Simulations, NBER Working Paper No.14880, Issued in April 2009.

Gorman, W. M.,1958, Tariffs, Retaliation, and the Elasticity of Demand for Imports. The Review of Economic Studies, 25, 133-162.

Hamilton, B., and Whalley, J.,1983, Optimal Tariff Calculations in Alternative Trade Models and Some Possible Implications for Current World Trading Arrangements. Journal of International Economics, 15, 323-348.

Johnson, H. G. ,1953, Optimum Tariffs and Retaliation. Review of Economic Studies 21, 142-153.

Kennan ,J.and Riezman,R.,1990, Optimal Tariff Equilibria with Customs Unions , The Canadian Journal of Economics, Vol. 23, No. 1 (Feb., 1990), pp.70-83.

Kuga, K. 1973, Tariff Retaliation and Policy Equilibrium. Journal of International Economics 3, 351-366.

Markusen,J.R. and Wigle,R.M.,1989, Nash Equilibrium Tariffs for the United States and Canada: The Roles of Country Size, Scale Economies, and Capital Mobility, The Journal of Political Economy, Vol. 97, No. 2, pp.368-386.

Whalley, J., Yu, J. and Zhang, S.M., 2009. Trade Retaliation in a Monetary-Trade Model, Cesifo Working Paper No.2526