

Who Wins a Trade War?

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ABSTRACT.

A trade war provides an economic rationale for the existence of barriers to trade. The main result in this literature is that “big countries win trade wars.” This paper extends this result by considering a wider range of factors that determine the outcomes of trade wars. In a purely non-cooperative two-country Heckscher-Ohlin model of trade, the country size result is confirmed. However, a country whose preferences exhibit a sufficiently large degree of substitutability relative to those of its rival may win a trade war regardless of its size. In particular we demonstrate that a small country can win a trade war against a larger rival if its preferences exhibit sufficient substitutability. Separately, we also demonstrate that the more similar the relative factor endowments of two countries, the smaller the welfare gains or losses from a trade war will be to each.

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1. INTRODUCTION

It is well known that, relative to free trade, countries can gain from imposing optimal non-zero tariffs even in the face of retaliation by their trading partners. A trade war occurs when all countries choose levels of protection that maximise their own welfare given the trade barriers of other nations. A country wins a trade war if it experiences higher welfare in a world of optimal protection than it would under global free trade. The concept of a trade war therefore provides a purely economic rationale for the observed presence of barriers to free trade. If a country wins a trade war, then it will most likely oppose moves to introduce free trade, and is unlikely to agree to the abolition of trade barriers without a compensatory transfer payment.

The literature addressing these issues is somewhat sparse. This is, at least in part, due to the complexity of modelling and analysing trade wars. Johnson (1953-54) demonstrates that a country can gain relative to free trade from setting a non-zero tariff, even in the face of retaliation by its trading partner.¹ In particular, he finds that a country with a sufficiently high elasticity of import demand relative to their trading partner will win a trade war. Of course, the elasticity of import demand is itself dependent on more fundamental country characteristics. The aim of this paper is to determine how the fundamental characteristics of countries affect the outcome of a trade war. The characteristics analysed here include country size and the international distribution of endowments of factors of production, as well as the structure of consumer preferences.

We simulate a 2-country, 2-good, 2-factor general equilibrium model of world trade. The results of our simulations suggest that:

1. a country that is sufficiently large relative to its trading partner will win a trade war;
2. in a Heckscher-Ohlin model of trade, the magnitude of a country's welfare gain or

¹The literature following Johnson (1953-54) and considered in this paper has generally assumed tariff setting to be a simultaneous move game in continuous strategies, however other researchers have relaxed this structure. Syropoulos (1994) and Raimondos-Moller and Woodland (2000) model tariff setting as a dynamic game in which the timing of sequential tariff choice is chosen endogenously. Kuga (1973) considers discrete tariff strategies and presents an example with a mixed strategy tariff equilibrium. Neither of these approaches has dealt with trade war outcomes in a way that differs from the Johnson approach.

loss from a trade war will shrink the more similar are its relative factor endowments to those of its trading partner;

3. a country with a sufficiently large degree of substitutability in its preferences will win a trade war; and
4. contrary to the existing literature, a small country can in some circumstances win a trade war against a larger rival.

There are few general results linking the welfare impact of a trade war to the characteristics of the countries involved. What few results exist concentrate on the role of relative country size in determining the outcome of a trade war. The elasticity of import demand has been widely interpreted as a measure of the degree of relative monopoly/monopsony power that a country holds in world commodity markets. The size of a country relative to its trading partners has strong intuitive appeal as a fundamental determinant of a nation's market power on world markets. However, a satisfactory definition of "relative size" has proved somewhat elusive.

Analytical results have been derived by Kennan and Riezman (1988) for the special case of a pure exchange trading world in which consumers have Cobb-Douglas preferences. From the resulting linear expenditure system they derive the condition for each country to win a tariff war as a function of each country's share of the world endowment of each good. Kennan and Riezman (1988) conclude that a "big country can expect to gain by starting a tariff war." Their definition of country size is the relative size of the elements of a country's endowment vector. Whether this definition makes sense is contingent on whether different goods are valued on the same basis. In general this will not be true. A possible solution to this problem would be to value each country's endowment at world or domestic prices, allowing a common basis of comparison between non-identical endowment vectors.

Syropoulos (2002), in presenting the literature's most general treatment yet of the role of country size, points out the specificity of the Kennan and Riezman (1988) case. He adopts a definition of country size as a scalar multiple of a fixed factor endowment vector. That is, he specifies a per capita endowment vector for each country, then treats

a change in size as a change in population, holding the elements of this endowment vector constant. Therefore, population size is a scalar multiple of the endowment vector and so the relative populations of countries can be used as the basis for comparison of size. Using this definition of country size, Syropoulos (2002) shows the effects of differing relative country sizes on trade war outcomes in a two country, two good model where countries have identical and homothetic preferences and constant returns to scale technology. The benefit of his approach is that it does not rely on functional forms for technology or preferences, so long as the structure described above holds.

Syropoulos (2002) shows that country size unambiguously determines whether or not a country gains from a trade war in the limit. Using limit arguments, he show that an infinitely large country will (i) have identical per capita welfare in autarky, free trade or a trade war, (ii) experience an increase in per capita welfare with an infinitesimal increase in the relative size of the other (infinitely small) country in a trade war; and (iii) experience no change in per capita welfare with an infinitesimal increase in the relative size of the other (infinitely small) country under free trade. He also shows thast there exists a threshold relative size above which the relatively large country will unambiguously win a trade war.

As Syropoulos (2002) himself acknowledges, the definition of country size employed assumes that per capita endowments remain fixed. Thus any role that endowment distributions play in determining trade war outcomes are ignored, as varying country size is equivalent to the equi-proportional variation of all factor endowments. This contrasts with the flexibility of the Kennan and Riezman (1988) approach, which allowed them to use a definition of country size based on combinations of goods endowment shares. Both approaches lead to the same result in the limit.

Hamilton and Whalley (1983) seek to calculate optimal tariff rates for comparison with observed tariff levels. They numerically simulate a model which uses a similar definition of country size to Syropoulos (2002). Their simulations show that a sufficiently large country relative to its trading partner will win a tariff war. Unfortunately they make no mention of this in their discussion, since their emphasis is on calculating optimal tariff rates and comparing them to observed tariff rates. However, using their results it is possible to

calculate the threshold level of relative country size as approximately 1.8 times as large as the country's trading partner.

Other country characteristics have also been briefly considered in the literature. Hamilton and Whalley (1983) simulate the welfare effects of variations in consumption substitution elasticities, production elasticities and the distribution of goods endowments as well as size characteristics other than size. However, since their main aim is to calculate optimal tariff rates, they do not interpret these results from the point of view of trade war outcomes. Besides these results, Gros (1987) mentions the impact of varying the elasticity of substitution in consumption on the threshold relative country size in the context of a monopolistically competitive model of intra-industry trade. However this is not the focus of his work, as he only computes the threshold size for four different elasticities. Nevertheless, these simulations suggest that the threshold size decreases as the elasticity of substitution increases. That is, when all countries have a higher elasticity, a country may be more likely to gain from a tariff war. Importantly, Gros maintains the assumption of identical preferences between countries, so his results reveal little about how differences in preferences between countries affect trade war outcomes.

2. THE GENERAL MODEL

We build up a standard perfectly competitive trade model of N countries that trade M goods. Trade is restricted by tariffs. A positive tariff term is a tax on imports or a subsidy on exports, depending on whether it corresponds to a negative or positive net export term. On the other hand, a negative tariff is either an import subsidy or an export tax.

2.1. Consumption. Let superscripts index countries, subscripts commodities. Country i has a single representative consumer with a utility function:

$$U^i = U^i(x^i), \quad i = 1, 2 \quad (1)$$

where x^i is an $M \times 1$ vector of goods consumed in country i . The representative consumer in country i owns all firms and factors of production in country i , and therefore receives the Gross Domestic Product (GDP) of country i as income. The representative consumer's maximisation problem can be written as:

$$\max_{x^i} U^i(x^i) \quad \text{s.t.} \quad p^{iT} x^i - p^{iT} y^i + R^i = 0, \quad (2)$$

where y^i is a $M \times 1$ vector of outputs (with elements y_j^i), p^i a $M \times 1$ vector of domestic prices (elements p_j^i), and R^i the tariff revenue in country i . T denotes a transposed matrix. Tariff revenue is redistributed lump-sum to consumers. The domestic price of good j in country i is given by $p_j^i = p_j^w (1 + t_j^i)$, where p_j^w is the world price of good j and t_j^i is the tariff levied by country i on good j .

The solution to this maximisation problem is country i 's vector of Marshallian demands:

$$x^i = x^i(p^w, t^i, y^i, R^i), \quad (3)$$

where t^i is the $M \times 1$ vector of tariffs in country i , of which the j -th element is t_j^i , and p^w is the $M \times 1$ vector of world prices with elements p_j^w .

However, tariff revenue can be rewritten as:

$$R^i = \sum_{j=1}^M t_j^i \cdot p_j^w (x_j^i - y_j^i). \quad (4)$$

Therefore equation (3) can be expressed as:

$$x^i = x^i(p^w, t^i, y^i). \quad (5)$$

2.2. Production. The j -th element of the $M \times 1$ vector of country i outputs is given by:

$$y_j^i = f_j^i(v_j^i), \quad (6)$$

where f_j^i is industry j 's production function in country i , and $\underset{\sim}{v}_j^i$ is a $H \times 1$ vector of factor inputs for industry j of country i .

Firms choose $\underset{\sim}{v}_j^i$ in order to minimise their $M \times 1$ vector of cost functions. Thus the producers' problem becomes:

$$\min_{v_j^i} C_j^i = w^{iT} \cdot v_j^i \quad \text{s.t.} \quad f_j^i(v_j^i) = y_j^i, \quad (7)$$

where w^i is a $H \times 1$ vector of factor prices in country i . This yields the $H \times 1$ vector of conditional factor demands in industry j :

$$v_j^i = v_j^i(w^i, y_j^i). \quad (8)$$

The profit maximising problem for each industry j in country i is:

$$\max_{y_j^i} \pi_j^i = p_j^{iT} \cdot y_j^i - w^{iT} \cdot v_j^i, \quad (9)$$

where π_j^i is industry j 's profit in country i , and v_j^i is the $H \times 1$ vector of factors demanded by industry j in country i . Since production is perfectly competitive, we can rewrite (9) as the following zero profit condition:

$$\pi_j^i = p_j^{iT} \cdot y_j^i - w^{iT} \cdot v_j^i = 0, \quad (10)$$

The solution to these conditions is the supply of good j in country i :

$$y_j^i = y_j^i(p_j^w, t^i, w^i), \quad (11)$$

remembering that domestic price is a function of the world price and domestic tariff rate.

The factor market in country i clears if:

$$\sum_{j=1}^M v_j^i(w^i, y_j^i) = Q^i, \quad (12)$$

where Q^i is the $H \times 1$ vector of factor endowments in country i . Equation (12) states that the sum of demands for each factor by each industry must equal the endowment of that factor for all factors of production in country i . Solving these equations for output yields an alternative specification for output in country i :

$$y_j^i = y_j^i(w^i, Q^i). \quad (13)$$

2.3. Equilibrium. Given the optimising behaviour of agents as set out, the following conditions will determine a competitive general equilibrium:

$$\sum_{i=1}^N x_j^i(p^w, t^i, y^i) = \sum_{i=1}^N y_j^i(w^i, Q^i), \quad j = \{1, \dots, M-1\} \quad (14)$$

$$\pi_j^i = p_j^w (1 + t_j^i) \cdot y_j^i - w^i \cdot v_j^i = 0, \quad \forall i \in [1, N], \forall j \in [1, M] \quad (15)$$

where y^i is the $M \times 1$ vector of industry supplies, the j -th element of which is y_j^i . These conditions state that all but one commodity market clears (14), and all industries in all countries make zero profit (15). Since the representative consumers' budget constraints hold with strict equality, Walras' Law states that the value of aggregate excess demand in the world is identically equal to zero. Therefore, if $M-1$ commodity markets clear, then the M -th market must clear also. As a result, there are only $M-1$ independent prices in the model, so good M is chosen as the numeraire good with price normalised to unity. All other commodity and factor prices are determined relative to this price.

Solving the equation system (14) and (15) yields solutions for all world prices, p^w , and each country's factor price vector, w^i , in terms of tariffs and of world prices and the parameters of the model, i.e. $p^w = p^w(t^1, \dots, t^N)$ and $w^i = w^i(t^1, \dots, t^N)$.

In the case of a trade war (TW) in which all countries stand alone, each country chooses its tariff rates so as to maximise its policymaker's objective function. The policymaker is assumed to be benevolent, so that her objective function is national welfare, measured as the utility level of the representative consumer. Therefore the policymaker's problem in country i becomes:

$$\max_{t^i} V^i(p^w, t^i, w^i, Q^i), \quad (16)$$

where $V^i = V^i(p^w, t^i, w^i, Q^i)$ is the representative consumer's indirect utility function, obtained by substituting the commodity demand vector (5) into the consumer's direct utility function (1), evaluated at $\hat{y}^i = \hat{y}^i(w^i, Q^i)$. Note that by the goods market clearing condition (14), p^w will depend on the tariff rates in each country.

Therefore the policymaker's problem can be written:

$$\max_{t^i} V^i(p^w(t^i, t^{-i}), t^i, w^i, Q^i), \quad (17)$$

where t^{-i} is a $M \times (N - 1)$ matrix of tariffs set on every good by countries other than i . Since the tariff rates of other countries implicitly enter the policymaker's objective function through their impact on world prices, the tariff choices of the policymaker will depend on the tariff choices of other policymakers. Hence tariff rates are strategic variables, and optimal tariff choice requires that policymakers play a game in tariff strategies.

There are $M \times N$ players, one for each country and good, so that each country's policymaker acts as M players. The strategy set for each player is $t_j^i \in \mathbb{R}^1$.

The first order conditions for the policymaker in country i are:

$$\frac{dV^i}{dt_j^i} = 0, \quad \forall j \in [1, M]. \quad (18)$$

These implicitly define a best response function for t_j^i :

$$t_j^i = t_j^i(t_{-j}^i, t^{-i}), \quad (19)$$

where t_{-j}^i are the tariff rates set by the policymaker in country i on goods other than j . Therefore the Nash equilibrium in tariff strategies is given by the simultaneous solution of (18). At this point each policymaker is choosing their best response tariff rate on each good, holding all other tariff choices by themselves and other policymakers fixed. Therefore the equilibrium under a trade war must satisfy condition (18), the optimal tariff conditions, $\forall i \in [1, N]$, along with conditions (14), the goods market clearing conditions and (15), the zero profit conditions. A trade-war equilibrium is defined as a set of factor and commodity price vectors, and optimal tariff vectors that satisfy these conditions.

2.4. Global Free Trade. The case of global free trade imposes the following restriction on the tariff matrix:

$$t = \begin{pmatrix} t_1^1 & \cdots & \cdots & \cdots & t_1^N \\ \vdots & \ddots & & & \vdots \\ \vdots & & t_j^i & & \vdots \\ \vdots & & & \ddots & \vdots \\ t_M^1 & \cdots & \cdots & \cdots & t_M^N \end{pmatrix} = \begin{pmatrix} 0 & \cdots & \cdots & \cdots & 0 \\ \vdots & \ddots & & & \vdots \\ \vdots & & 0 & & \vdots \\ \vdots & & & \ddots & \vdots \\ 0 & \cdots & \cdots & \cdots & 0 \end{pmatrix}. \quad (20)$$

That is, all elements of the $M \times N$ tariff matrix are set equal to zero. In this case $p^i = p^w \forall i \in [1, N]$, since any deviation from this price vector would present opportunities for profitable arbitrage in commodities. No tariffs are determined strategically, so policy-makers do not play a tariff setting game. Hence the conditions for equilibrium under FT can be written by substituting a vector of zeroes for each t^i into conditions (14) and (15). This yields the equilibrium conditions, choosing good M as the numeraire:

$$\sum_{i=1}^N x_j^i(p^w, y^i) = \sum_{i=1}^N y_j^i(w^i, Q^i), \quad j = \{1, \dots, M-1\} \quad (21)$$

$$\pi_j^i = p_j^w \cdot y_j^i - w^i \cdot v_j^i = 0, \quad \forall i \in [1, N], \forall j \in [1, M] \quad (22)$$

A competitive free trade equilibrium is a vector of world prices and the matrix of factor prices p^w, w that satisfy these conditions.

3. SIMULATING A H-O MODEL

The model introduced in the previous section is naturally too general to answer the question of what types of countries win trade wars with other countries. Syropoulos (2002) has shown that general results on country size are possible if the model is simplified to two countries and two goods. The method he uses, however, is not suitable for investigating endowment changes in two dimensions or differences in preferences, and can offer no insight into the magnitude of relative size differences required for a country to win a trade war. As a result, this section simulates a stylised model of world trade, in order to more finely investigate the effects on trade war outcomes of a wider range of country characteristics.

Take the model introduced in the previous section and set $M = N = H = 2$ (the 2

x 2 x 2 case). Denote countries one and two by superscript and goods one and two by subscript as previously. Without loss of generality, choose good 2 as the numeraire. The two factors of production are capital (K) and labour (L), and their prices rent (r) and wages (w) respectively. Unlike previous models of retaliatory trade wars (see for example Kennan and Riezman (1988)) no specific pattern of trade is assumed – either country may import or export either good. Trade is balanced at world prices by virtue of the representative consumer’s budget constraint:

$$p_1^w (1 + t_1^i) x_1^i + (1 + t_2^i) x_2^i - p_1^w (1 + t_1^i) y_1^i - (1 + t_2^i) y_2^i - R^i = 0 \quad (23)$$

Substituting in the value of the tariff revenue, $R^i = p_1^w t_1^i (x_1^i - y_1^i) + t_2^i (x_2^i - y_2^i)$ and rearranging yields:

$$p_1^w (x_1^i - y_1^i) + (x_2^i - y_2^i) = 0. \quad (24)$$

This is the balanced trade condition for country i .

3.1. Consumer Preferences. The representative consumer in each country is assumed to have a Constant Elasticity of Substitution (CES) utility function of the form:

$$U^i = \left(\sum_{j=1}^2 \phi_j^i x_j^i \frac{\sigma_C^i - 1}{\sigma_C^i} \right)^{\frac{\sigma_C^i}{\sigma_C^i - 1}} \quad (25)$$

σ_C^i is the elasticity of substitution in consumption of the representative consumer in country i , and ϕ_j^i is a parameter that determines the contribution of each good to the consumer’s utility. The economic interpretation of σ_C^i is discussed in detail in section 2.6. The assumption of this functional form is restrictive, particularly as it imposes the restriction that the elasticity of substitution is constant across all levels of consumption. It does, however, incorporate several functional forms often assumed in analysis. As $\sigma_C^i \rightarrow 0$ the CES utility function approaches the Leontief utility function, as $\sigma_C^i \rightarrow \infty$ it approaches the linear utility function, and as $\sigma_C^i \rightarrow 1$ it approaches the Cobb-Douglas functional form. Therefore the CES functional form is more general than any of these

forms, and is in particular more general than the Cobb-Douglas utility function assumed by much of the optimal tariff literature, both with and without trade agreements, following Kennan and Riezman (1988, 1990).

Solving the consumer's maximisation problem with this functional form, and with good 2 designated the numeraire, yields demand functions of the form:

$$\begin{aligned}\hat{x}_1^i &= \frac{(\phi_1^i (1 + t_2^i))^{\sigma_C^i} (p^w y_1^i + y_2^i)}{p^w (\phi_1^i (1 + t_2^i))^{\sigma_C^i} + (\phi_2^i p^w (1 + t_1^i))^{\sigma_C^i}} \\ \hat{x}_2^i &= \frac{(\phi_2^i p^w (1 + t_1^i))^{\sigma_C^i} (p^w y_1^i + y_2^i)}{p^w (\phi_1^i (1 + t_2^i))^{\sigma_C^i} + (\phi_2^i p^w (1 + t_1^i))^{\sigma_C^i}}\end{aligned}\tag{26}$$

These demand functions depend on the endogenous parameters of tariff rates, world prices, and the level of output.

3.2. Technology. The incorporation of production into this trade war model adds a layer of complexity and realism to the analysis of Johnson (1953-54) and Kennan and Riezman (1988), who both assume a pure exchange setting. Syropoulos (2002) does incorporate production into his analysis of trade wars, however he does not provide any simulated examples that illustrate the threshold sizes for trade war outcomes that he derives. The model of trade wars used in this section can therefore be used to answer previously neglected questions related to the process of production in trade war outcomes.

Firms in each industry in each country are assumed to produce with a CES production function:

$$y_j^i = \left(\gamma_{K_j}^i K_j^i \frac{\sigma_{P_j}^i - 1}{\sigma_{P_j}^i} + \gamma_{L_j}^i L_j^i \frac{\sigma_{P_j}^i - 1}{\sigma_{P_j}^i} \right)^{\frac{\sigma_{P_j}^i}{\sigma_{P_j}^i - 1}}\tag{27}$$

This function has the same features as the CES utility function, with $\sigma_{P_j}^i$ being the elasticity of substitution between capital and labour in the production process. $\gamma_{L_j}^i$ and $\gamma_{K_j}^i$ are the weights on labour and capital respectively in production. The function is homogeneous of degree one, and therefore production exhibits constant returns to scale.

Solving the cost minimisation problem for each firm yields the conditional factor demand functions:

$$K_j^i = k_j^i y_j^i \quad L_j^i = l_j^i y_j^i \quad (28)$$

for unit factor requirements:

$$k_j^i = \left(\gamma_{Kj}^i + \gamma_{Lj}^i \left(\frac{r\gamma_{Lj}^i}{w\gamma_{Kj}^i} \right)^{\sigma_{Pj}^i - 1} \right)^{\frac{-\sigma_{Pj}^i}{\sigma_{Pj}^i - 1}} \quad (29)$$

$$l_j^i = \left(\frac{r\gamma_{Lj}^i}{w\gamma_{Kj}^i} \right)^{\sigma_{Pj}^i} \left(\gamma_{Kj}^i + \gamma_{Lj}^i \left(\frac{r\gamma_{Lj}^i}{w\gamma_{Kj}^i} \right)^{\sigma_{Pj}^i - 1} \right)^{\frac{-\sigma_{Pj}^i}{\sigma_{Pj}^i - 1}}$$

Equation (28) is a corollary of constant returns to scale, as demand for factors will be a linear function of output for any given factor prices. As a result of this linearity, it is possible to solve the factor market clearing conditions in equation (12) explicitly for output in each industry in each country:

$$y_1^i = \frac{k_2^i L^i - l_2^i K^i}{k_2^i l_1^i - l_2^i k_1^i}, \quad y_2^i = \frac{l_1^i K^i - k_1^i L^i}{k_2^i l_1^i - l_2^i k_1^i} \quad (30)$$

3.3. Tariff Choice. For simplicity and without loss of generality, each country will set its tariff on exports equal to zero. However, which goods are exported will depend on the endogenously determined pattern of trade. In general it will not be possible to explicitly solve for each country's tariff reaction function without imposing quite restrictive functional forms on the preferences of the representative consumers.²

Each country's tariff reaction function can be obtained, however, by totally differentiating its indirect utility function, contained in equation (17) with respect to t_j^i :

²This is done by Kennan and Riezman (1988, 1990), amongst others in order to derive analytical welfare results.

$$\frac{dV^i}{dt_j^i} = V_{p_1^w}^i \cdot \frac{dp_1^w}{dt_j^i} + V_{w^i}^i \cdot \frac{dw^i}{dt_j^i} + V_{r^i}^i \cdot \frac{dr^i}{dt_j^i} + V_{t_j^i}^i = 0 \quad (31)$$

where good j is country i 's imported good. It is necessary, however to derive the total derivatives $\frac{dp_1^w}{dt_j^i}$, $\frac{dw^i}{dt_j^i}$ and $\frac{dr^i}{dt_j^i}$, in order to write down the implicitly defined tariff reaction function for country i . This is possible by totally differentiating and simultaneously solving the world excess demand function for good 1 (the non-numeraire good) and the zero profit conditions in country i . This allows (31) to be written in terms of partial derivatives which can be explicitly solved for using the equilibrium conditions stated below.

So the equilibrium conditions that describe a Nash equilibrium in tariff strategies for the $2 \times 2 \times 2$ case are given by equations (14) and (15) with $M = N = H = 2$, and (31), for $i, j = 1, 2$ and $Q^i = (K^i, L^i)$. Equation (14) can be rewritten as:

$$z_1 = \sum_{i=1}^2 x_1^i (p^w, t_1^i, y^i) - \sum_{i=1}^2 y_1^i (w^i, Q^i) = 0 \quad (32)$$

This is the world excess demand function for good 1.

In the simulations that follow the free trade equilibrium is given by the simultaneous solution of equations (32), the goods market clearing condition, and (22), the four zero profit conditions for $M = N = H = 2$. The Nash equilibrium in tariffs is given by the simultaneous solution of those five equations plus the two optimal tariff conditions (31). These systems of equations were solved numerically in GAUSS, using the "nlsys" procedure to solve the non-linear system by a Newton-Raphson algorithm.

A welfare comparison between the Nash equilibrium and the equilibrium under global free trade determines the outcome of a trade war, as set out in definition 1:

Definition 1

Country i wins (loses) a non-cooperative trade war (TW) iff:

$$V_{TW}^i > (\leq) V_{FT}^i,$$

where V_{FT}^i is country i 's indirect utility under global free trade (FT) and V_{TW}^i is country i 's indirect utility in a non-cooperative trade war.

Definition 1 states that to win a trade war, a country must strictly improve its welfare above its free trade level. If this does not occur, the country is said to lose the trade war.

4. THE COUNTRY-SIZE EFFECT

Parameter values are set such that consumer preferences and production technology are identical in each country. However, technology differs between the two industries, such that industry one uses labour relatively intensively, and industry two uses capital relatively intensively in the absence of factor intensity reversals. The parameter values used are set out in Table 1 below.

Parameter (equal in both countries)	Symbol	Value
Weight on Consumption of Good 1	ϕ_1^i	0.5
Weight on Consumption of Good 2	ϕ_2^i	0.5
Elasticity of Substitution in Consumption	σ_C^i	1.5
Weight on Capital in Production of Good 1	γ_{K1}^i	0.1
Weight on Capital in Production of Good 2	γ_{K2}^i	0.9
Weight on Labour in Production of Good 1	γ_{L1}^i	0.9
Weight on Labour in Production of Good 2	γ_{L2}^i	0.1
Elasticity of Substitution in Production of Good 1	σ_{P1}^i	0.99
Elasticity of Substitution in Production of Good 2	σ_{P2}^i	0.99

Table 1: Parameter values used in the simulation

The world endowment of capital and the world endowment of labour are both normalised to unity. This can be done without loss of generality due to constant returns to scale in production. Within the range set by the world endowments of each factor of production, each country's endowment of each factor is varied from 0.1 to 0.9 by increments of 0.1, and both the free trade and trade war equilibria are simulated for each pair of capital and labour endowments.

Some difficulty was encountered in simulating the TW equilibrium, since the system exhibited multiple equilibria. Considerable care was taken in selecting equilibria for each (K^i, L^i) pair that were related in such a way that the endogenous variables of the system are of comparable magnitude and sensibly related to the variables determined at neighbouring values of (K^i, L^i) . This laborious process greatly limited the number of simulations that it was feasible to run, but is a necessary and not unexpected consequence of the complexity of this model. In particular, the incorporation of production into this model increases the number of relative prices from one to five, and greatly complicates the optimal tariff conditions of each country when compared to the pure exchange case.

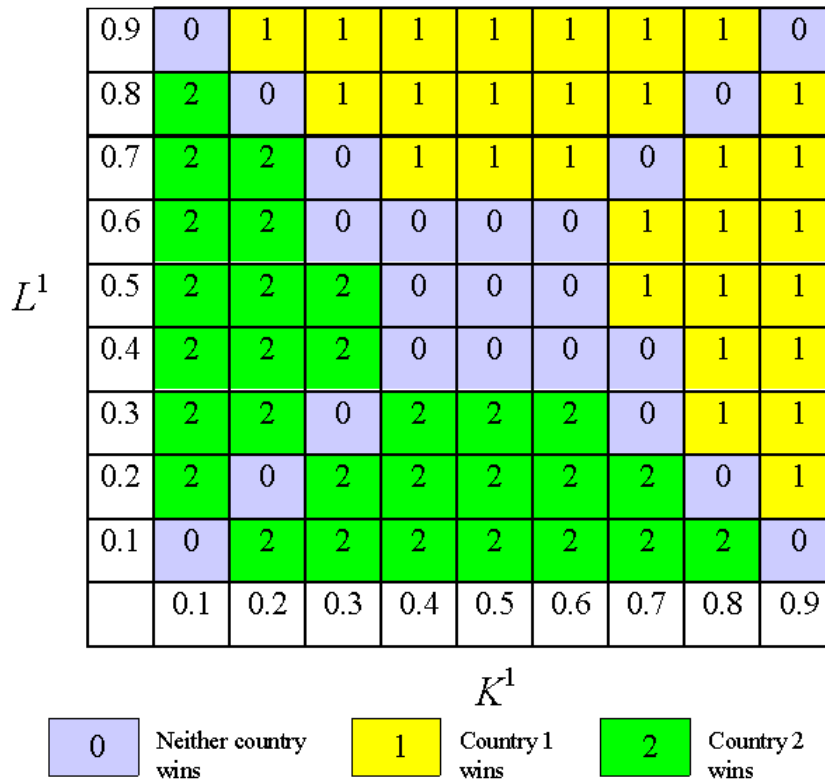


Figure 1: Trade war outcomes in a Heckscher-Ohlin model.

The results of the simulations are presented in Figure 1, using Definition 1 to determine the outcomes. This figure measures country 1’s endowment of capital along the horizontal axis, and its endowment of labour along the vertical. At each point country 2’s endowment

of each factor can be calculated by subtracting country 1's endowment from unity. Thus, moving towards the north-east corner of the diagram, the absolute magnitude of country 1's endowment vector approaches the world endowment vector, and likewise for country 2 moving towards the south-west.

Figure 1 confirms the existing result in the literature, that a country which is of sufficient size relative to its opponent can win a trade war. This is true by the commonly used definition of country size in the literature (Kennan and Riezman, 1988, 1990), of the relative size of a country's endowments.³⁴ It is also true by more sensible definitions of country size. A country whose Gross Domestic Product (GDP) is greater at domestic prices than its rival will not be the sole loser from a trade war, although both countries may lose. An equivalent to GDP as a measure of country size in this model is the value of a country's factor endowment at domestic TW factor prices, since domestic industries make zero profit. Valuing a country's factor endowment at free trade prices yields identical results. The value of a country's factor endowment is an appealing definition of country size, since it provides a basis of comparison between the relative contribution of two distinct factors of production to country size. Finally, defining country size as GDP valued at world prices does not alter the results.⁵

It is not possible to directly compare the results of these simulations to the analysis of Syropoulos (2002), who uses a definition of country size which requires the relative abundance of each factor endowed to a country be fixed. This is because it is not possible to hold the per capita endowment of capital (K^i/L^i) constant for both countries whilst varying L^i , except along the path where $K^i/L^i = (K^1 + K^2) / (L^1 + L^2)$ for both countries, as the world endowment of each factor is fixed at a given level, in this case 1 unit of each factor. In order to precisely examine Syropoulos' result it would be necessary to allow the size of the world endowment of each factor to vary.

³Since Kennan and Riezman study models of pure exchange, their definition of country size is couched in terms of goods rather than factor endowments. Interpreting the output of each good in a country as the 'endowment' of that good (ignoring the change in production between FT and NE), their result is confirmed in these simulations.

⁴Why this is not an adequate definition of country size: explain.....

⁵These country size results are also confirmed by simulations using a model with inter-country differences in technology.

Examining the role of country size along the path where $K^i/L^i = (K^1 + K^2)/(L^1 + L^2)$ is not feasible, since in the Heckscher-Ohlin framework assumed there will be no trade along this path, which may be termed the zero-trade line. The reason for this is that along this path the countries will be have an identical relative abundance of each factor, and therefore produce goods in the same proportion. Since their preferences are identical, this removes any incentive to trade. This can be seen in Figure 1, as along the zero-trade line (running from north-east to south-west) neither country wins the trade war. Since the countries do not trade along this line, welfare levels in each country under both FT and TW are equal to the autarky level of welfare. The next section will more fully discuss the zero-trade line and its influence on trade war outcomes.

Notwithstanding the difficulty in replicating the country size result of Syropoulos (2002), the spirit of his result can be seen. As a country's share of the world endowment of each factor approaches unity, only that country wins the trade war. There are no examples in which the winner of a trade war reverses as the relative share of a country in the world factor endowment approaches a total share. Although this is only an indicative replication, it does seem to confirm Syropoulos' country size results.

The customary interpretation of the country size result is that larger countries can use their monopoly/monopsony power to alter the terms of trade in their favour by setting positive tariffs. The degree of this market power is interpreted as increasing with country size. In wider international trade theory a small country is one that cannot influence world prices (and thus its terms of trade), while a large country can. The market power interpretation of the country size result shows the reasoning behind the 'large/small' country definitions. Of course, in this model all countries are 'large', but the results of this section show that the market power definition of 'large' and the GDP/factor endowment definition of large are related.

The results of this section are summarised and generalised in Conjecture 1.

Conjecture 1

In the context of the Heckscher-Ohlin model of trade, a country with a sufficiently high value of its endowed factors will win a trade war, except where it has the same relative

factor endowments as its rival. In this latter case, both will lose.

5. THE TRADE-CHANNEL EFFECT

It is obvious from an inspection of Figure 1 that there is another effect than simply country size influencing trade war outcomes. Whereas the line running from north-west to south-east marks the path along which the countries are of approximately equal size,⁶ the line running from north-east to south-west is the path along which the countries have identical capital/labour ratios, as noted previously. Neither country wins a trade war along this latter path, a phenomenon designated the *trade-channel effect* for reasons that were discussed in the previous section. Figure 2 shows the relationship between the pattern of trade and capital/labour ratios under free trade for 10,000 combinations of the latter simulated using the model of this section.⁷ Country 1's capital/labour ratio is reported on the vertical axis, country 2's on the horizontal. The white line along the diagonal is the locus of points at which the two countries have identical capital/labour ratios, that is $K^i/L^i = (K^1 + K^2) / (L^1 + L^2)$.

Along the path where $K^i/L^i = (K^1 + K^2) / (L^1 + L^2)$, there is no incentive to trade for either country, since autarky prices are equal in the two countries that have identical technology and tastes, and that are endowed with factors of production in the same proportion. For this reason, call this path the *zero-trade line*. Above and to the left of the zero-trade line country 1 is relatively well endowed with capital and hence by the Heckscher-Ohlin-Samuelson theorem exports good 2 (the capital intensive good) and imports good 1. This feature is illustrated in Figure 2 by the yellow shading. Below and to the right of the zero-trade line (the green shaded area), country 2 is relatively well endowed with capital, and will export good 2 and import good 1.

Returning to Figure 1, the north-east to south-west line is the zero-trade line, to the north-west of which country 2 is relatively abundant in capital and will tend to export good 2, and to the south-east of which, country 1 will tend to export good 2.⁸ Along the zero-trade line there is neither gain nor loss to either country from a trade war, since it will

⁶Along this line the GDP/value of endowment of each country at free trade is equal.

⁷Each country's capital/labour ratio was varied by increments of 0.1 in a range of 0.1 to 10.

⁸The tariff equilibria selected did not alter the pattern of trade between FT and TW.

result in autarky, just as a free trade situation would. This was confirmed in simulation, in which an equilibrium was found for each point along the zero-trade line at which Nash equilibrium tariffs were zero. Other equilibria were found at which non-zero tariffs were levied, however since these equilibria involved at least one country being worse off than at autarky, they were disregarded as not feasible since a country could unilaterally choose autarky and improve its welfare.

Figure 2: around here

The impact of this zero-trade line can most clearly be seen in cross-sections of the welfare gains (losses) that each country experiences moving from FT to a TW. Figure 3 shows two of these cross-sections as the endowment of capital is held constant in each country but the endowment of labour is varied from 0.1 to 0.9 in country 1, and from 0.9 to 0.1 in country 2. In both diagrams the vertical axis measures the welfare gain calculated by subtracting the utility of the representative consumer at FT from her utility in a TW. In (a) the endowment of capital in country 1 is equal to 0.9, in (b) it is equal to 0.5.

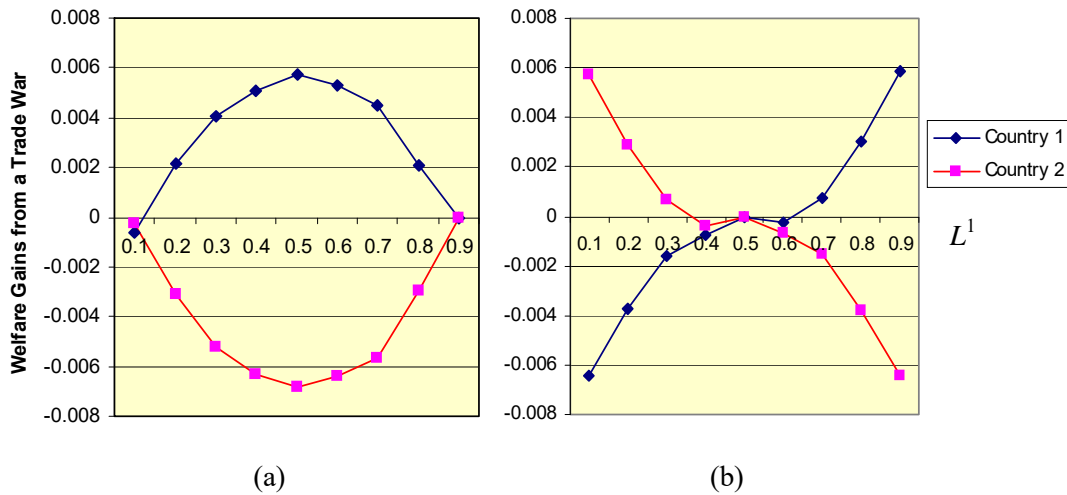


Figure 3: Welfare gains moving from FT to NE, varying L^1 from 0.1 to 0.9, holding K^1 constant at (a) 0.9; (b) 0.5.

In Figure 3(a) the zero-trade line cuts the graph at $L^1 = 0.9$, in Figure 3(b) it cuts the graph at $L^1 = 0.5$. In both graphs the size of country 1(2) is increasing (decreasing) from left to right, since its endowment of labour is increasing (decreasing) and its endowment of capital is non-decreasing (non-increasing). In both graphs the gains or losses of each country from NE shrink to zero at the zero-trade point. In Figure 3(b) it is easy to observe the previous result on country size, as country 1 moves from a welfare loss to a smaller welfare loss to increasing welfare gains as its endowment of labour increases. In Figure 3(a) country 1 is weakly larger throughout, since each element of its factor endowment vector is at least as great as the corresponding element of country 2's factor endowment vector. The country size effect of the previous section seems to dominate up to $L^1 = 0.5$, however once L^1 increases beyond 0.5 country 1's gains and country 2's losses both decrease in magnitude towards zero at the zero-trade point.

The intuition behind the decreasing welfare gains/losses as countries move towards the zero-trade line can be understood in terms of the traditional decomposition of the welfare effects of tariffs, shown below.

$$E_U dU = tdm - mdp^w \quad (33)$$

Here E is the expenditure function, U utility, t the vector of specific tariff rates, m the vector of net imports and p^w the vector of world prices. Although this decomposition does not consider the welfare effects of strategic interaction, and is couched in terms of specific rather than ad valorem tariffs, it is still useful for interpreting the results of this section. The first term, tdm is the volume of trade effect and measures the welfare loss created by increasing tariffs due to shrinking trade volumes. The second term mdp^w is the terms of trade effect, which measures the potential welfare gain a country with monopoly/monopsony power can extract by improving its terms of trade through increasing tariffs. The analysis of this section is primarily concerned with this second term.

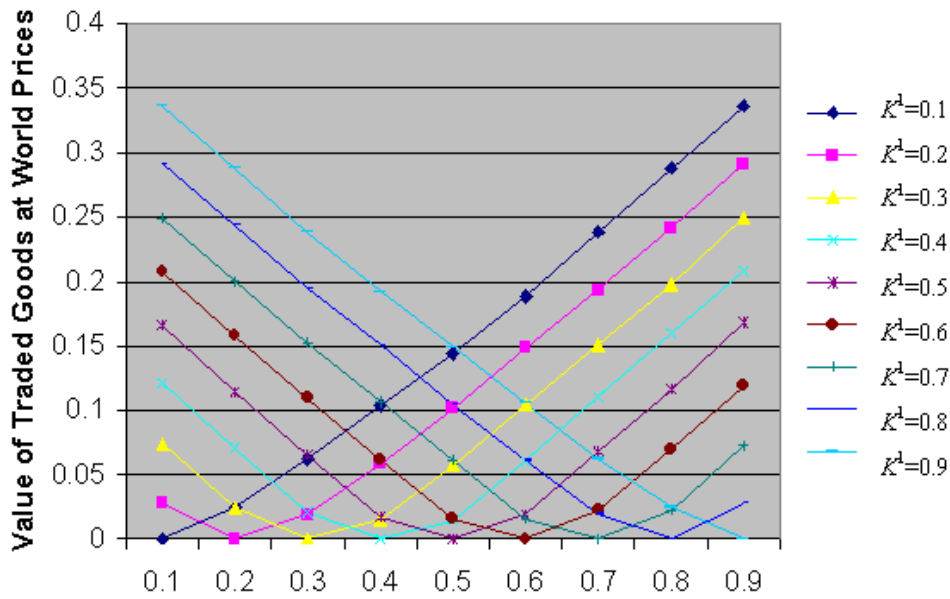


Figure 4: Factor endowments and the volume of trade

The previous section confirmed that larger countries can win trade wars, and offered the intuition that this is possible due to their size giving them monopoly/monopsony power to improve their terms of trade. The second effect involving the zero-trade line is not concerned with market power as such, but the channel through which market power can be exerted. This is why the effect is named the trade channel effect. Note that the terms of trade effect depends on the size of the import vector m , as well as the extent to which a country can affect the terms of trade. Approaching the zero trade line, m approaches a vector of zeroes. Therefore, even if a country has enough market power to significantly improve its terms of trade, because the channel through which it can exploit this power (that is, the trade channel) is shrinking, the gains it can extract approach zero. This can be clearly seen Figure 3(a), in which the welfare gains of a significantly larger country (by any definition) shrink to zero as it approaches the zero trade line.⁹

Figure 4 shows the relationships between the endowment of each factor and trade volumes in a trade war equilibrium. The vertical axis shows the volume of trade, measured

⁹Kennan and Riezman (1988) note a similar effect in a footnote, that in the context of a pure exchange model gains shrink to zero approaching a line of no trade. They do not discuss or interpret this result however.

by the value of imports (exports) of one good by one country. Due to the fact that trade is balanced, this is equal to the value of exports (imports) of the other good by that country. By symmetry, both countries' trade volumes are equal by this measure.

The points at which each level curve reaches zero lie on the zero-trade line, and it is clear that the volume of trade monotonically increases as the distance from the zero trade line increases. This suggests that the trade channel effect operates uniformly throughout the range of factor endowments, and not just in the neighbourhood of the zero-trade line. The results of simulations presented above bear out this prediction, and suggest the following conjecture, which summarises the results of this section. In this conjecture size is defined in terms of the free trade value of a country's endowment (free trade GDP).

Conjecture 2

In the context of the Heckscher-Ohlin model of trade, the magnitude of a country's welfare gain or loss from a trade war relative to free trade will decrease (increase) as it approaches (moves away from) the zero-trade line, holding the relative sizes of the country and its rival constant.

6. NET IMPACT OF THE COUNTRY-SIZE AND TRADE-CHANNEL EFFECTS

The previous two sections have identified and discussed the economic intuition behind the country size and the trade channel effects. The country size effect is that a larger country will tend to win a trade war because it has greater market power. The trade channel effect in the Heckscher-Ohlin model is that countries which have similar factor endowment patterns will tend experience smaller welfare gains and losses in a trade war. This is because the channel through which market power can be exerted is smaller.

Figure 3(a) clearly demonstrates that the effects can oppose one another, since country 1's relative size advantage increases from left to right, but its welfare gains are not monotonically increasing. On the other hand, Figure 3(b) gives an example where the effects reinforce one another so that each country experiences monotonically increasing welfare gains as it moves from the zero-trade point in the direction of increasing size. It is therefore of interest and importance to investigate the net impact of these effects on trade war outcomes as they oppose or reinforce one another.

Figure 5 shows the interaction between the country size and trade channel effects for several values of K^1 . In addition to the welfare gains and losses in each country, it shows on the vertical axis the value of traded goods at world prices, and the absolute difference between the equilibrium tariff rates set by each country.¹⁰ The latter is a proxy for the relative differences in market power between the two countries, and is defined as $|t_j^1 - t_k^2|$, where j is country 1's and k country 2's export good respectively. When one country has greater market power it sets a higher tariff than its opponent in order to influence the terms of trade in its advantage, and the difference in market power increases. Figure 5 (a) shows the level curves for these variables when country 1 is endowed with 0.9 units of capital, (b) when country 1 is endowed with 0.7 units of capital, and (c) when country 1 is endowed with 0.5 units of capital.

Figure 5(a) and (c) illustrates the effects interacting in the situations shown in Figure 3. In Figure 5 (a), the trade volume decreases from left to right towards the zero-trade point $L^1 = 0.9$, whereas the differential in tariffs increases¹¹ as country 1 gets steadily larger and grows in market power. The interaction between these two opposing effects results in the observed rise and fall in the welfare gains (losses) of country 1(2).

In Figure 5(c), both trade volume and tariff differential decrease initially towards the zero-trade point $L^1 = 0.5$, and then increase from that point. This illustrates how the market power and zero-trade line effects reinforce one another in this case. Note that to the left of the zero trade point it is country 2 that has the higher tariff, to the right country 1 has the higher tariff. The absolute value of the difference in tariffs is taken in order to show graphically how the *size* of this effect alters, just as the value of trade is positive irrespective of the trade pattern. This allows comparison between the relative impact of the effects, which is the point of interest in analysing their interaction. The absolute size of the effects tells us their relative impact, since a larger tariff difference suggests a larger gain or loss to each country, just as a larger trade volume will increase the gain or loss to each country due to the increased channel of influence.

¹⁰The former is scaled down by a factor of fifty, the latter by a factor of twenty-five so that the curves fit on the graphs at a comparable scale to the changes in welfare.

¹¹Disregarding the autarky (zero-trade) point, at which tariff levels are meaningless (and at which an equilibrium where zero tariffs are set exists). Since tariffs are imposed only on imports it is also ambiguous as to which tariffs would be chosen at this point, since neither good is imported by either country.

Figure 5: around here

Figure 5(b) shows an intermediate cross-section at which the country size and trade channel effects oppose and reinforce one another at different ranges of L^1 . For $L^1 \leq 0.3$, that is up to the point at which the countries have equal GDP in free trade, the effects reinforce one another, causing the welfare gains and losses of each country to reduce. For $0.4 \leq L^1 < 0.7$ the effects oppose one another and the welfare gains/losses of each country first increase, then diminish to zero at the zero-trade point $L^1 = 0.7$. For $L^1 > 0.7$, the effects reinforce one another once more, and each country's welfare gain or loss increases in magnitude. The interaction of the country size and trade channel effects over the entire range of factor endowments is summarised in Figure 6.

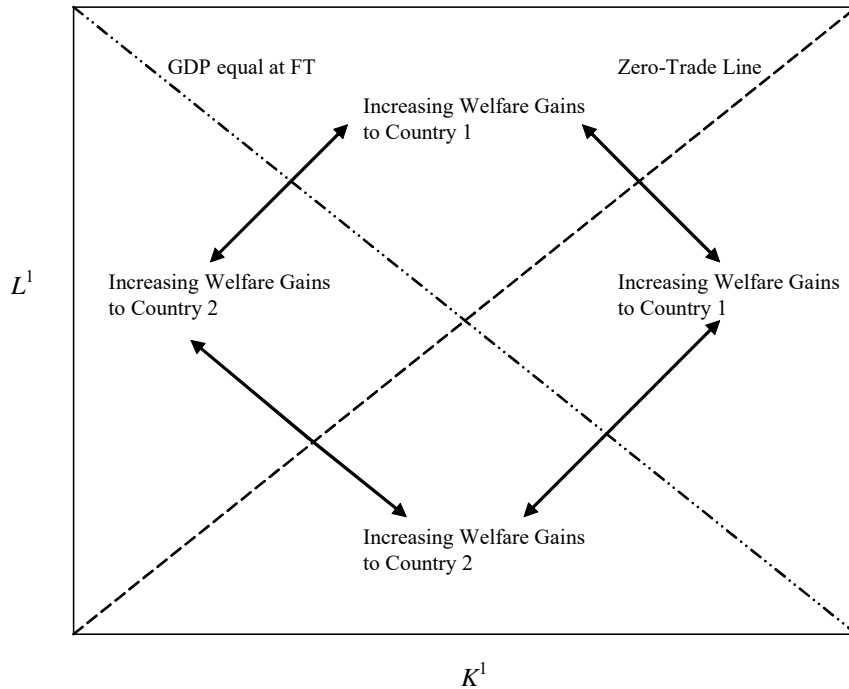


Figure 6: Welfare Outcomes in a Heckscher-Ohlin Model

7. CONSUMER PREFERENCES AND TRADE WAR OUTCOMES

The preceding sections consider the influence of the factor endowments of countries on trade war outcomes. This section addresses the question of whether any other fundamental characteristics of countries will systematically affect trade war outcomes. In particular, it is of interest to know whether a country with a less valuable factor endowment or lower GDP can win a trade war against a larger rival if they differ in other characteristics. In order to address this question, simulations were carried out in which the elasticity of substitution in consumption (σ_C^i) was varied in each country. The parameter values assumed before hold also here, with the exception that the vector of factor endowments is fixed in each country, and σ_C^i is varied.

Each country is endowed with 1 unit of labour, but whereas country 1 is endowed with 1 unit of capital, country 2 is endowed with 0.8 units of capital. These parameter values determined a single pattern of trade for the range of elasticities simulated, and meant that country 1 was the larger country by virtue of having the more valuable endowment at both FT and TW prices throughout the range.

The choice of the range of σ_C^i to simulate is somewhat problematic, as there are no estimates of this elasticity directly available in the literature. There are, however, estimates of other consumption related elasticities of substitution, such as the Armington elasticity. This elasticity is the elasticity of substitution between imported and locally produced goods. The analogy between this elasticity and σ_C^i is not perfect, since σ_C^i is an elasticity of substitution between goods and the Armington elasticity between ports of origin. However, since for the parameter ranges simulated one good is imported and the other exported for each country, σ_C^i and the Armington elasticity will not be entirely unrelated. For these reasons a range in which to vary σ_C^i is selected on the basis of estimated Armington elasticities reported in Gallaway, McDaniel and Rivera (2003). These estimates are based on disaggregated U.S. data at the industry level, and as such are not useful in suggesting the range of inter-country differences in σ_C^i . σ_C^i is varied over the range [0.7, 2.9]. This range is chosen to cover the middle 90% of positively significant Armington elasticities reported by Gallaway et al.. σ_C^i is varied by increments of 0.2 along this range in simulation.

The results of the simulations are presented in Figure 7. The vertical axis measures country 1’s elasticity of substitution in consumption, and the horizontal axis country 2’s. Definition 1 is used to determine trade war outcomes. Figure 7 shows that when either country has a high enough σ_C^i relative to its rival, it will win the trade war. In particular, for these countries of similar size, the asymmetry in elasticities of substitution is sufficient for the smaller country 2 to win the trade war for 29 of the 144 cases simulated. Remember that country 2 is smaller throughout the whole matrix of (σ_C^1, σ_C^2) combinations.

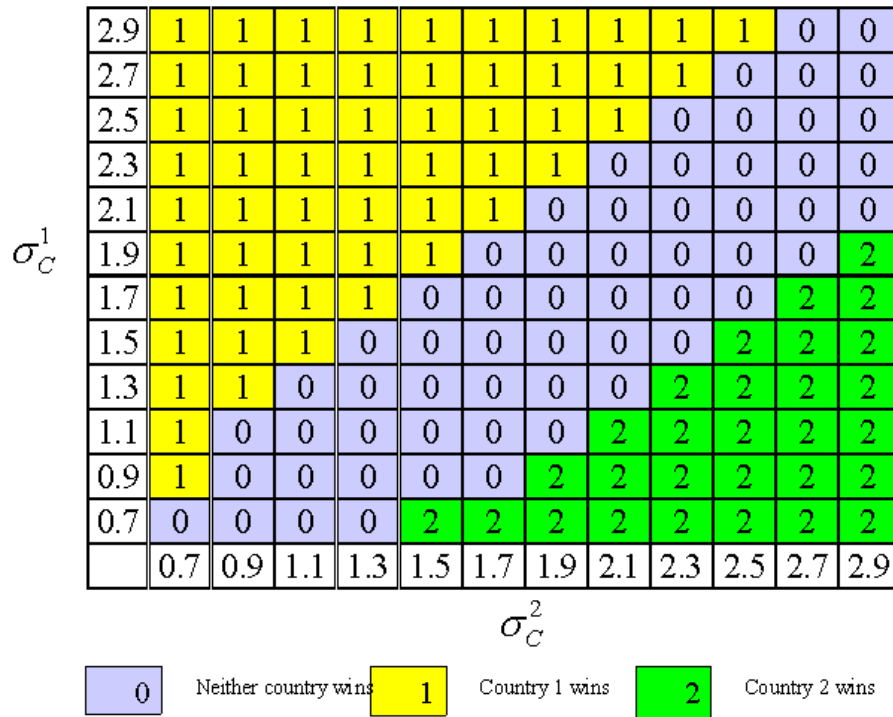


Figure 7: Trade war outcomes and the elasticity of substitution in consumption.

Figure 8 shows a cross-section of the affect on relative market power of varying σ_C^i . As before, the absolute difference in tariff rates between the two countries is used on the vertical axis to measure the relative market power of each. Figure 8 shows that country 1’s relative market power advantage diminishes as σ_C^2 increases. This indicates that the country with a relatively larger σ_C^i can win a trade war by exploiting its greater market power in tariff setting to improve its terms of trade.

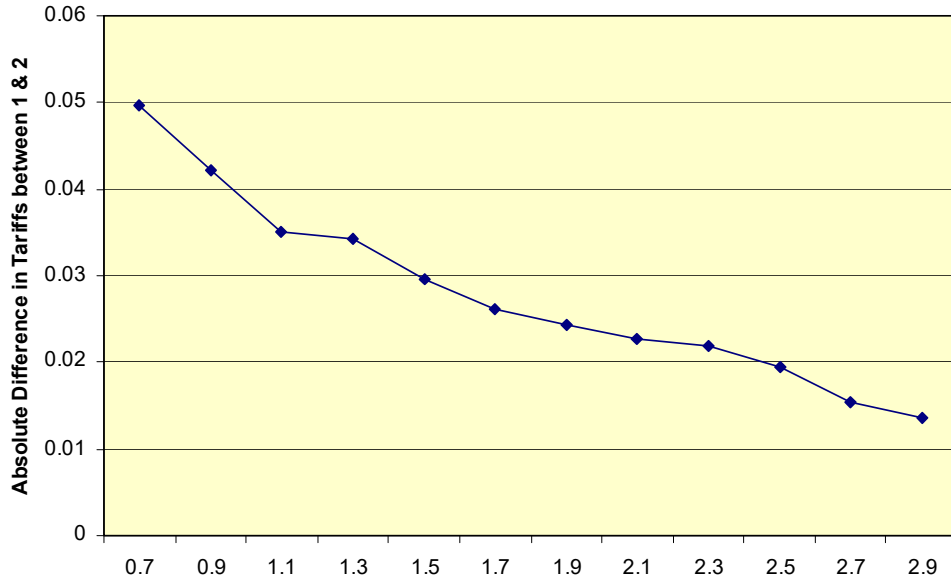


Figure 8: Difference in tariffs, $\sigma_C^2 = 2.9$

To understand the intuition note that consumers with a higher σ_C^i are more flexible in their pattern of consumption than those with a lower σ_C^i . Therefore, if the representative consumer of one country in a trade war has a higher σ_C^i , then they are more able to respond to terms of trade changes by substituting consumption of the good whose relative price has increased for the good whose relative price has decreased. This gives a country in which σ_C^i is relatively higher a strategic advantage in a trade war, as its more flexible pattern of consumption means that it is able to respond more effectively than its rival to terms of trade changes.

An interesting point to note is that the market power gained from having a high σ_C^i is able to outweigh the market power of being a larger country for the parameter values chosen in simulation. The question of whether a big country wins a tariff war has been answered, all things being equal, affirmatively. However the results of this section suggest

that this affirmative answer needs to be qualified. A big country can win a tariff war, but so can a smaller country, provided its σ_C^i is sufficiently high relative to its rival.

The results of this section and the intuition underlying them lend support to Conjectures 3 and 4 that follow.

Conjecture 3

A country with a sufficiently high elasticity of substitution in its preferences, relative to its rival, will win a trade war.

Conjecture 4

A country with a sufficiently high elasticity of substitution in its preferences, relative to its rival, can win a trade war even if it is smaller than its rival.

Conjecture 3 summarises the result that countries with a higher degree of substitutability in their preferences tend to win trade wars. Conjecture 4 strengthens Conjecture 3 to state the result that a smaller country can win a trade war.

8. CONCLUSION

This paper has introduced a stylised 2 x 2 x 2 general equilibrium model of world trade to investigate the question of what sorts of countries win trade wars. Numerical simulation results suggest that a large country, in terms of the value of its endowment, will win a trade war, all things being equal. This confirms the existing results in the literature that suggest by various other measures of country size that a big country wins a tariff war.

In the context of a Heckscher-Ohlin model it was shown that differences in the relative abundance of factors between countries will affect the magnitude of trade war gains or losses. A greater difference in relative factor abundance results in greater gains or losses to each country. This effect, the trade-channel effect, suggests that if countries with identical technology and preferences are significantly different in their endowment of one factor relative to another, then the country with greater market power will have greater opportunity to extract welfare gains from a trade war, at the expense of its rival.

In a situation such as this, the country with greater market power is likely to be a

significant opponent of a move to global free trade, far more so than if the countries were similar in the distribution of their endowments. This also leads to the surprising suggestion that where the gains from trade are larger, the greater the opposition to free trade may be. Where the volume of trade is larger, there are likely to be larger potential gains from trade underlying that trade volume. Since a higher trade volume implies greater welfare gains in a trade war for a country with more market power, that country will increase in its opposition to free trade as the potential gains from trade increase. These results, encapsulated in Conjectures 1 and 2, show the effect of a country's factor endowment on trade war outcomes.

However, the neglect of non-endowment country characteristics in the literature was also addressed. It was found that:

1. a country with a sufficiently high σ_C^i relative to its rival can in some circumstances win a trade war; and
2. a smaller country can in some circumstances win a trade war against a larger rival if its σ_C^i is sufficiently high relative to its rival.

These results suggest that there are other sources of market power than simply country size. They also suggest that this may make the identification of trade war winners more difficult in practice than simply identifying countries with relatively high GDP. However, a cautionary note is required due to the lack of available estimates of σ_C^i . In particular it would be of great interest to know whether or not σ_C^i differs between countries to any great extent. Our simulations suggest that σ_C^i could affect trade war outcomes even with inter-country differences of the order of 1 to 1.5. Unfortunately without estimates of σ_C^i it is impossible to know whether differences of substitutability in preferences could affect trade war outcomes in practice. (to be checked..... Broda and Weinstein, 2006, QJE, and Broda, Limao, Weinstein, 2007, AER.)

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