War, Trade and Economic Resources

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Abstract

This paper will analyse the effects of trade on the incentives for nations to engage in extortive or appropriative wars with one another given specific resource endowments and production functions. In a relatively simple model, I explore how resource asymmetries will explain incidence of war. I further show that, where wars are fought to expropriate economic resources, the extent to which trade reduces conflict is proportional to the gains from trade. Thus gains from trade are twofold; there are the economic gains, as well as the gains that stem from a peaceful community of nations.

1 Introduction

This paper will analyse the effects of trade on the incentives for nations to engage in extortive or appropriative wars with one another given specific resource endowments and production functions. I argue that wars are often fought for natural or other economic resources, and war is more likely where returns to the resources gained are highest for the countries concerned. Thus, resource asymmetries are an important factor influencing the incidence of war. In a simple two-country, two-good model, I explore how wars become harder to prevent as countries' resources become more asymmetric, and how trade in these resources can help explain peace.

Game theoretic perspectives on war argue that countries fight when the gains outweigh the costs.[**?**] Much research in international relations has focused on nation-states as rational actors who benefit from certain assets that can be gained from war. These assets may be territory, resolution of a dispute in their favour, international or domestic prestige, or greater security. States, as rational actors, weigh these gains against the costs of war, such as the cost of military operation, destruction of capital, distruption of economic activity, or the loss of territory or other assets in the event of defeat. The costs of war can also be less tangible, such as lost or disrupted alliances, reputational costs, or increased risks of war with other countries.

A crucial type of the gain from war has historically been the acquisition of economic resources. Wars are often fought to sustain the huge demand for primary inputs needed by growing economies. Thus resource-rich countries can be an attrative target for aggressors.

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Examples of wars in which the presence of large resource deposits has been an important incentive for aggressors include Saddam Hussein's invasion of Kuwait in 1991, Hitler's invasion of the Soviet Union, largely to secure the oil-rich Caucausus in 1942, the importance of the coal and iron-ore deposits in the Ruhr and Alsace-Lorraine during the successive wars fought between France and Germany between 1870 and 1945, and Japan's targeting of mineral-rich islands in the South Pacific in the initial stages of its 1941 campaign.

Now, wars are costly; in addition to the costs of military build-up and waging a war, natural and other productive resources are often destroyed during war-fighting. Consider, for example, the Soviet Union's scorched-earth policy during 1941-42, or the budget deficits incurred by the United States during the recent war in Iraq. Reputational losses and international approbation must also be considered; consider the reputational difficulties encountered by Britain and France during their abortive attempt to seize the Suez canal in 1956. Given these deadweight losses, we are at pains to explain why countries face such strong incentives to go to war for resources. I argue that economic heterogeneity can be important part of an explanation of this.

Economic asymmetries are instances where countries of similar gross output might be possessed of very resource endowments; Germany may have coal, France iron, or Japan may have high-skilled labour and capital while China may have low-skilled labour and land. This should result in increased incentives for countries to wage wars in instances where their would-be opponent has a relatively large amount of a resource they lack.

Trade, however, can allow natural resources to be shared between countries on an international market. Often, countries will prefer to buy resources their economy needs from another country rather than take them by force. Thus free trade can be a key mechanism in reducing the incentives for countries to go to war. Where trade is feasible (where tariffs and shipping costs are low enough, and where economic resources are tradable) it can be cheaper to buy goods than to appropriate them by force. I will show that the gains to peace from trade are largest when war is most likely, and that the gains to peace are directly proportional to the 'gains from trade', familiar from trade models.

An important way in which this paper differs from the extant literature is the mechanism through which trade reduces the incidence of war. In many papers in the literature on trade and conflict [**?**], it is argued that trade reduces war because high trade volumes could be disrupted by war which provides a disincentive for countries to engage in conflict. Countries may want to go to war, but are discouraged by the disruption a war would have on their economy. This paper models how trade can diminish the incentives to wage war in the first place. High levels of trade imply high levels of mutual need for goods, which can often be appropriated faster and more securely by purchase than by conflict. Thus, rather than providing a disincentive to fighting, high levels of trade can provide an indiciaton that war incentives are high, but are being diminished by trade. My model aims to show that conditions under such incentives will prevail. Section 2 of this paper reviews the literature. Section 3 introduces the basic model, while Section 4 provides for the possibility of trade. Section 5 concludes and discusses some potential extensions.

2 Literature Review

The impact of trade and interdependence on propensities for war and peace has been a topic of considerable discussion for IR scholars over the years. Much of the literature on trade has focused on the Kantian idea of the 'liberal peace', that is, the idea that in a world with ubiqutous democracy and free trade, nations would be at peace with one another. The work in this paper also speaks to the literature on power and

interdependence; the idea that in an interdependent world, military force becomes a less pervasive means by which countries achieve their goals. [**?**]

2.1 Formal Literature

Formal approaches have tried to provide a more detailed explanation of how interdependence and trade can impact on the indcidence of conflict.

Authors such as Polachek, Robst and Chang [**?**] model conflict as a black-box parameter which can affect trade flows. Their paper allows countries to choose a level of conflict with their neighbours without regard to the level of conflict the other countries will choose. This conflict will disrupt trade flows, so those countries between whom trade is very valuable will remain at peace. Chang [**?**] also models a trade-conflict tradeoff in a similar manner, but incorporates again a price mechanism in the trading environment, which allows for comparative statics in the market power of actors. As with the Polachek, Robst and Chang paper, conflict is parameterised as a 'black-box' phenomenon and is not characterised as an inherently appropriative action. Thus no specific motivation is offered for conflict, and trade improves the probability of peaceful outcomes by increasing the costs of making war, not by decreasing the benefits.

Other papers attempt to model conflict in a similar manner to the popular 'Gravity Model' of trade, allowing contiguity and distance to affect conflict outcomes [**?**]. Dorrussen allows for the decision to go to war or not, while also allowing for the possibility for trade, and for multiple numbers of actors in an international setting [**?**]. His model does not, however, allow for specfied production functions or for the deadweight losses of resources from waging war. Hegre builds on the Dorrussen model in an intertemporal setting; he incorporates heterogeneity as a potential factor influencing incidences of conflict. The asymmetry he discusses is however, size asymmetry in a single resource, as opposed to two. Interestingly he also prescibes very specific returns to scale; returns to scale will be an important influencing factor in our discussion as well. [**?**]

A paper by Gartzke, Li and Boehmer provides an unexplored departure from the common 'opportunity cost' perspective on the liberal peace by arguing that trade can create pacific outcomes not via any fear of the trade losses than come with engaging in conflict, or by improving the equality of resources resulting from peace,but by the increased facility it provides for costly signalling by states about intentions and resolve. This improved information about values and utilities created by trade provides for less war resulting from uncertainity. [**?**].

The distribution of economic resources have entered discussions of war outcomes in other ways too. Papers such as Morelli and Jackson focus on the incentives for countries to build up their armament levels, and the extent to which this commits them to war later[**?**]. Morelli and Jackson do not however, discuss the extent to which trade can reduce conflict in equilibrium. Finally, Hausken develops a two-period model in which the possibility of trade is combined with the possibility of conflict. His paper includes a decision, similar to that developed in Morelli and Jackson, of how much of a given set of resources to allocate to productive and military uses [**?**]. Nor does he model the decision to fight or not fight explictly. Interestingly, however, his model separates out offensive and defensive war technologies, and incorporates a variety of specfic production functions.

2.2 Empirical Literature

In addition to formal appraoches, a wide literature has attempted to empirically assess the impact of trade on the instances of war, as well as the effect of trade on war. Some of this literature focuses on 'politically relevant dyads' [**?**] and takes into account such factors as contiguity and geographic location[**?**] [**?**][**?**] the separation of importers and exporters from governments [**?**], levels of foreign investment [**?**] and the presence of preferential trading agreements [**?**]. Other work assesses the impact of alliances [**?**] [**?**] and expectations of interdependence [**?**]. Others still cite democracy or political power as an important variable in determining the extent to which trade will reduce conflict[**?**][**?**].

In the main, this literature has assessed the impact of war on trade from an opportunity cost persepctive, arguing that the negative impacts of conflict on trade values and volume could have an unobserved pacifying effect due to the disruption of trade that occurs during war. This literature does not, by and large, consider the prospect of trade being another means (in addition to conflict) for nations to achieve their goals.

The dependent variable in these analyses has not been limited to the outbreak of war. Crescenzi, for instance, focuses on the effect trade volumes have on the duration of conflict. His formal and empircal method are based, however, on the standard 'opportunity costs' argument about trade and conflict. [**?**] The literature reaches various conclusions about the relationship between trade and conflict and between conflict and trade. Some argue that the effects are negligible, some that they are trade decreases conflict [**?**][**?**], others than the effects of trade on conflict depend on the level of extant hostility between nations [**?**]. Barbieri argues that the relationship is non-monotonic, that limited amounts of trade will reduce conflict, but that extensive interdependence will increase it [**?**]. Barbieri and Levy argue that while conflict can sometimes diminish trade over the short term, it seldom reduces trade, and many even increase trade over the long-term[**?**].

There is, in sum, very little work empirically or formally that focuses on the interactive effect of trade *and* resource endowments on war. Nor is there significant work that deals with trade as an amelorative factor in the context of appropriative wars. Enpirically, there is also relatively little work that disaggregates trade into consistuent components, say by industry or type of goods, or work that looks at the strategic importance of trade in terms of securing countries' demand for natural resources. This paper aims to fill this gap.

International Relations Literature Barbieri and Schnieder provide a more extensive (though a little outdated) review of the trade and conflict literature [**?**], as does Reuveny [**?**] and Mansfield and Pollins [**?**].

3 The Model

The game is first described under autarky; we include the possbility of trade after having explored the autarky equilibrium.

3.1 Endowments and Consumption

Total endowment is $X = 1$ and $Y = 1$. Country 1 gets $x \sim [0, 1]$ and $y \sim [0, 1]$. Country 2 gets endowments of $1 - x$ and $1 - y$.

Consumption is given by a Cobb-Douglas production function. For simplicity, I have made the marginal rate

of substitution the same from country to country; neither country has a productive advantage in the use of a particular resource.

Utility for both countries is given by the volume a single good produced using both resources according to a Cobb-Douglas production function less any war costs. Thus utility for Country 1 is given by $U_1 = C_1 - c = (x_1^*)^\alpha (y_1^*)^{(1-\alpha)} - c$. Utility for Country 2 is given by $U_2 = C_2 - c = (x_2^*)^\alpha (y_2^*)^{(1-\alpha)} - c$, where z_i^* is the amount of resource z acquired by country i over the course of the game and c is a war cost parameter, which takes a value of 0 if there is no war and $c \geq 0$ otherwise.

3.2 War Technology and Conflict

Countries can choose to go to war or not. War ensues if either country decides to go to war, peace ensues if both countries decide not to go to war. However, there is no first-mover or aggressor (or defensor) advantage. The payoffs from war are the same for each country regardless of whether they initiated the conflict or not. Thus, countries make the decision to fight or not to fight without reference to what they think the other player will do. There is also perfect information about everyone's endowments, and about the resulting probabilites of success given war.

The game proceeds as follows, Nature chooses x and y, thus choosing the endowments of resources assigned to both countries. Countries are fully informed of these endowments. Countries both make decisions about whether to fight or not. If either countries decide to fight, then a war ensues and the victor receives the entirety of the pie, the loser receives nothing. Both countries pay a cost c. The victor uses the pie to produce the consumption good, and the game then ends. If neither country chooses to go to war, then the countries' employ their respective resource endowments to produce the consumption good and gain utility from it.

The probability of victory is given by a standard contest success function (CSF). This function implies that the probability of success in a war is increasing in a countries productive capacity relative to the country it fights against. Thus

$$P_1 = \frac{x^\alpha y^{(1-\alpha)}}{x^\alpha y^{(1-\alpha)} + (1-x)^\alpha (1-y)^{(1-\alpha)}} = \frac{Y_1}{Y_1 + Y_2} \tag{1}$$

and

$$P_2 = \frac{(1-x)^\alpha (1-y)^{(1-\alpha)}}{x^\alpha y^{(1-\alpha)} + (1-x)^\alpha (1-y)^{(1-\alpha)}} = \frac{Y_2}{Y_1 + Y_2} \tag{2}$$

3.3 Solution

The solution concept employed is Nash Equilibrium. For each country, choosing not to fight is a best response if the expected utility from war is less than the utility from peace, regardless of what the other country does as there is no first-mover advantage. The game is essentially decision-theoretic, not game-theoretic, in this respect. Thus Country 1 will choose not to fight if and only if

$$\frac{Y_1}{Y_1 + Y_2} - Y_1 \leq c \tag{3}$$

while Country 2 will choose not to fight if and only if

$$\frac{Y_2}{Y_1+Y_2} - Y_2 \leq c \tag{4}$$

Thus peace will ensue if

$$max\left\{\left(\frac{Y_1}{Y_1+Y_2} - Y_1\right), \left(\frac{Y_2}{Y_1+Y_2} - Y_2\right)\right\} \leq c \tag{5}$$

and countries 1 and 2 will receive utilities $U_1 = Y_1 = x^{\alpha}y^{(1-\alpha)}$,$U_2 = Y_2 = (1-x)^{\alpha}(1-y)^{(1-\alpha)}$ respectively.

However, if

$$max\left\{\left(\frac{Y_1}{Y_1+Y_2} - Y_1\right), \left(\frac{Y_2}{Y_1+Y_2} - Y_2\right)\right\} > c \tag{6}$$

then war will ensue, and countries will have expected utilities $U_1 = \frac{Y_1}{Y_1+Y_2} - c$ and $U_2 = \frac{Y_2}{Y_1+Y_2} - c$.

3.4 Heterogeneous Resources and War Incentives

This section illustrates one of the important points of this research design; that economically heterogenous countries are more likely to engage in conflict than economically homogenous ones. To do this we consider a cost, c_i^A, the cost of war at which countries are indifferent between peace and war for a given set of endowments. Thus we have

$$\frac{Y_1}{Y_1+Y_2} - Y_1 = c_1^A \tag{7}$$

and

$$\frac{Y_2}{Y_1+Y_2} - Y_2 = c_2^A \tag{8}$$

Where c_i^A is high for both i, then war is difficult to avoid; war must be very destructive indeed for countries not want to use it as a means to expropriate resources. Where c_i^A is low, even a relatively 'cheap' war will be avoided by countries as the resources to be gained are not substantive enough. A key result of this paper is that c_i^A is lower where countries are economically similar; where the ratio of x to y and of $1-x$ to $1-y$ are near 1. Economically heterogeneous countries, where economic hetergeneity is expressed in terms of economic resource endowments, are 'more likely' to fight. Note here that economic resources are not necessarily 'natural' resources, they can be any economically valuable asset such as people, land, sea access, human or industrial capital and so on. The result is expressed in the follwing proposition

Proposition 1 *c_i is minimized where $\frac{y}{x} = \frac{1-y}{1-x}$*

Proof. See Appendix. ■

The intutition behind this proposition is as follows. Where countries have heterogeneous resources, the marginal returns to country A from acquiring country B's resources are larger than when the countries' resources are similar. If country 1 for instance, has a lot of good x, but very little of good y, then acquiring country 2's store of y will increase the productivity of country 1's stock of x. In such a case, country 1 may

be willing to pay the costs of war because the marginal returns are so high. By contrast, when country 1 has even amounts of x and y, then acquiring country 2's stock of x or y will not increase the returns to country 1's stock of x or y very much. In such a case, the marginal returns to war are lower.

This result holds even if country 1 is much larger than country 2. For instance, if country 1 has larger amounts of good x and good y than country 2, but the amounts it has of good x and of good y are similar to one another, then even though it may be very likely to win a war with country 2, the gains are too small to make it worthwhile. Essentially, when resources are symmetric and a country is likely to win, the gains are to small. Increasing the gains while keeping resources symmetric involves reducing the likelihood of victory. In order to provide incentives for countries to fight, the acquired resources must improve the productivity of the resources they already own.

3.5 Comparative Statics

To illustrate these ideas further, we examine some benchmark cases for illustration. In each case, c^A is the lowest cost that would be necessary to discourage both parties from war. For robustness, we relax the assumption of that the production function is of the form $Y_1 = x^{\alpha}y^{1-\alpha}$. Here we allow $Y_1 = x^{\alpha}y^{\beta}$, where β need not equal $1-\alpha$. This allows us to examine three different types of returns to scale; increasing ($\alpha+\beta>1$), diminishing ($\alpha+\beta<1$) and constant ($\alpha+\beta=1$). To illustrate, we examine three sample resource distributions; the case of total homogeneity, a case where countries have advantages in one good each, and the case where a single country has an advantage in both goods. Calculations are omitted.

1. Increasing returns to scale $\alpha = 2$, $(1-\alpha) = 2$
   (a) If $x = \frac{1}{2}$ and $y = \frac{1}{2}$ then $c^A = .4375$
   (b) If $x = \frac{9}{10}$ and $y = \frac{9}{10}$ then $c^A = .34385$
   (c) If $x = \frac{1}{10}$ and $y = \frac{9}{10}$ then $c^A = .4919$
2. Decreasing returns to scale $\alpha = \frac{1}{2}$,$(1-\alpha) = \frac{1}{2}$
   (a) If $x = \frac{1}{2}$ and $y = \frac{1}{2}$ then $c^A = 0$
   (b) If $x = \frac{9}{10}$ and $y = \frac{9}{10}$then $c^A = 0$
   (c) If $x = \frac{1}{10}$ and $y = \frac{9}{10}$ then $c^A = .2$
3. Constant returns to scale $\alpha = 1$,$(1-\alpha) = 1$
   (a) If $x = \frac{1}{2}$ and $y = \frac{1}{2}$ then $c^A = .25$
   (b) If $x = \frac{9}{10}$ and $y = \frac{9}{10}$ then $c^A = .09$
   (c) If $x = \frac{1}{10}$ and $y = \frac{9}{10}$ then $c^A = .41$

As is clear from these comparative statics, regardless of the degree of returns to scale of the respective goods, costs must be highest to prevent war in situations where there is resource heterogeneity. Further, it can be seen that the greater the returns to scale, the greater the incentive to engage in appropriative conflict.

We can illustrate this further using Figure 1 which shows the distribution of x and y, as well as the costs necessary to sustain peace between the two countries given those resources. As we can see, peace can be sustained when war is almost costless, but only when resources are evenly distributed. This occurs in the

two corners $(1,1)$ and $(0,0)$, where almost all resources are owned by one country or other, and along the diagonal between these two corners, where resources are distributed evenly between countries. In the two corners $(1,0)$ and $(0,1)$, war must cost over 40% of the resources in the world economy in order for countries to be discouraged from fighting.

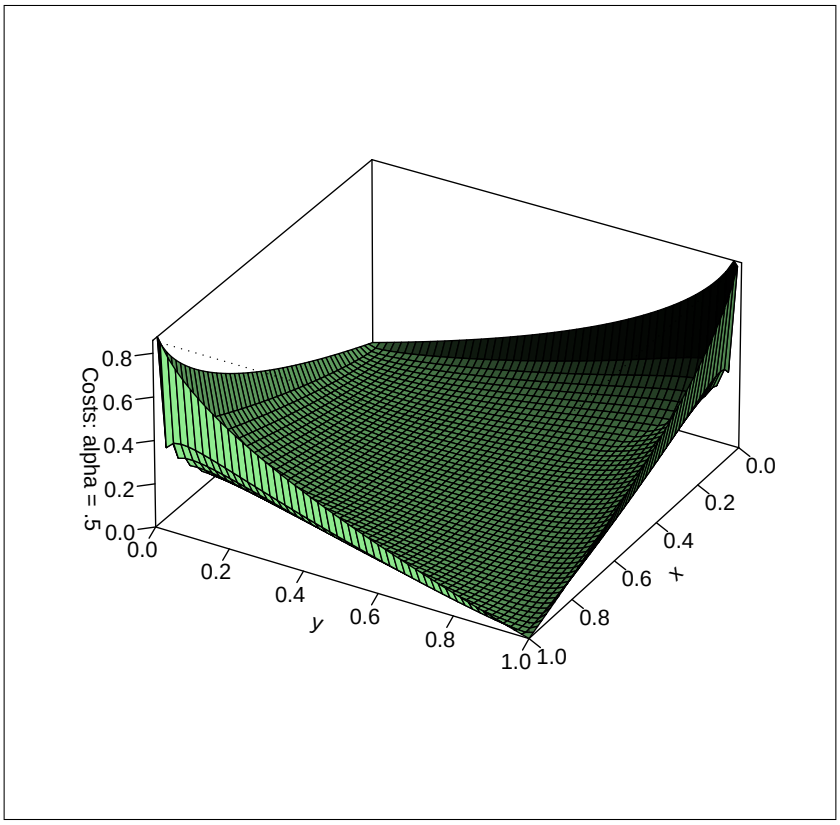

Figure 1: Costs Necessary For Peace Under Autarky

4 The Addition of Trade

4.1 Equilibrium

In this section, we examine the effects of allowing the two countries to trade on a global market. We develop a very simple Walrasian two-actor, two-good equilibrium. The equilibrium allocations are as follows:

- $x_1^* = \alpha x + (1-\alpha)y$
- $y_1^* = \alpha x + (1-\alpha)y$
- $x_2^* = \alpha(1-x) + (1-\alpha)(1-y)$

- $y_2^* = \alpha(1-x) + (1-\alpha)(1-y)$

where x_i^* is demand for good x by country i and y_i^* is demand for good y by country i. x and y without subscripts denote endowments of the two goods to country 1 as before. Details of the equilibrium are in appendix B. We again compare the costs that would be necessary for countries not to engage in war, however, this time, we compare the costs needed to sustain peace when trade is an option. In this instance Country 1 will choose not to fight if and only if

$$1 \cdot \frac{x^{\alpha} y^{(1-\alpha)}}{x^{\alpha} y^{(1-\alpha)} + (1-x)^{\alpha} (1-y)^{(1-\alpha)}} - [\alpha x + (1-\alpha)y] = \frac{Y_1}{Y_1 + Y_2} - Y_1^* \leq c \tag{9}$$

where x_i^* is country i's Walrasian allocation of good x and Y_i^* is country i's output given free trade.Country 2 will choose not to fight if and only if

$$1 \cdot \frac{(1-x)^{\alpha} (1-y)^{(1-\alpha)}}{x^{\alpha} y^{(1-\alpha)} + (1-x)^{\alpha} (1-y)^{(1-\alpha)}} - [\alpha(1-x) + (1-\alpha)(1-y)] = \frac{Y_1}{Y_1 + Y_2} - Y_1^* \leq c \tag{10}$$

Thus peace will ensue if

$$max \left\{ \left(\frac{Y_1}{Y_1 + Y_2} - Y_1^* \right), \left(\frac{Y_1}{Y_1 + Y_2} - Y_1^* \right) \right\} \leq c \tag{11}$$

and parties will receive utilities $U_1 = \alpha x(1-\alpha)y$,$U_2 = \alpha(1-x)(1-\alpha)(1-y)$.
However, if

$$max \left\{ \left(\frac{Y_1}{Y_1 + Y_2} - Y_1^* \right), \left(\frac{Y_1}{Y_1 + Y_2} - Y_1^* \right) \right\} > c \tag{12}$$

then war will ensue, and, as before countries will have expected utilities
$U_1 = \frac{Y_1}{Y_1+Y_2} - c$ and $U_2 = \frac{Y_2}{Y_1+Y_2} - c$.

4.2 Comparative Statics with Trade

An obvious conclusion here is that trade will facilitate each country equalising their resources. Say for instance that country 1 has large amounts of good x relative to good y. It will trade good x in exchange for y. Country 2 will happy to facilitate this, as it must have large amounts of good y relative to good x. Thus trade removes what is one of the primary causes of war in the model; resource heterogeneity. This is the intuition behind the major result in the paper.

Proposition 2 *For any given set of endowments, the costs necessary to ensure an equilibrium peaceful outcome are lower under autarky than under trade.*

Proof. See Appendix C. ■

We compare c^T with c^A for each of the previously-used selective examples, where c^T is the cost needed to sustain peace when Walrasian allocations in addition to autarkic allocations are available and c^A is the cost needed to sustain peace when only war or autarkic allocations are available.

1. Increasing returns to scale $\alpha = 2$, $(1-\alpha) = 2$
   (a) If $x = \frac{1}{2}$ and $y = \frac{1}{2}$ then $c^T = .4375$
   (b) If $x = \frac{9}{10}$ and $y = \frac{9}{10}$ then $c^T = .34385$

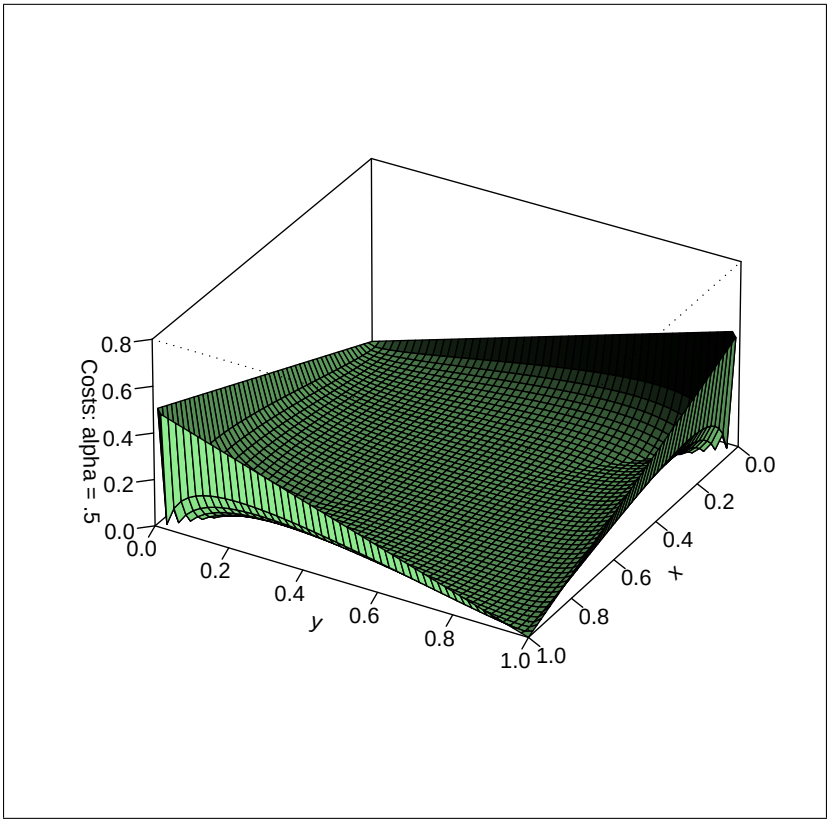

Figure 2: Costs Necessary For Peace Under Autarky

(c) If $x = \frac{1}{10}$ and $y = \frac{9}{10}$ then $c^T = .45$

2. Decreasing returns to scale $\alpha = \frac{1}{2}$,$(1 - \alpha) = \frac{1}{2}$

   (a) If $x = \frac{1}{2}$ and $y = \frac{1}{2}$ then $c^T = 0$

   (b) If $x = \frac{9}{10}$ and $y = \frac{9}{10}$then $c^T = 0$

   (c) If $x = \frac{1}{10}$ and $y = \frac{9}{10}$ then $c^T = .05$

3. Constant returns to scale $\alpha = 1$,$(1 - \alpha) = 1$

   (a) If $x = \frac{1}{2}$ and $y = \frac{1}{2}$ then $c^T = .25$

   (b) If $x = \frac{9}{10}$ and $y = \frac{9}{10}$ then $c^T = .09$

   (c) If $x = \frac{1}{10}$ and $y = \frac{9}{10}$ then $c^T = .2975$

As we can see from these comparative statics, the pacifying effect of trade only takes effect under conditions of resource heterogeneity, where the costs of war necessary to secure peace are lessened because of the availability of other means to procure the resources to sustain an economy. What is most interesting about

this is that not only does trade help secure peace under the conditions of this model, but it helps secure peace in those circumstances where war is most likely under this model.

This intuition is further confirmed by Figure 2. We can see here is that the costs of war necessary to secure peace at the corners (0,1) and (1,0) have reduced to approximately 5. By comparision, the costs in areas of comaparative resource heterogeneity, such as corners (0,0) and (1,1), have not shrunk so much. The conclusion is that trade seems to reduce the likelihood of war by when war is most tempting.

5 Conclusion, Problems and Extenstions

This paper has outlined a model studying the relationship between trade and conflict. I have shown how countries with heterogenous resources are more likely to fight one another, and that trade, by allowing for resource transfers, makes peaceful outcomes easier to sustain. This pacifying effect of trade is shown to be most prevalent when peace is hardest to sustain. The contribution of this paper to the literature on war and trade is that rather than being modelled as a 'black-box' conflict, war is explictly modelled as an expropriative activity. Thus trade facilitiates peace, not in the 'opportunity-cost' manner usually developed elsewhere, but rather as a means to appropriate legally what countries might otherwise take by force. In effect, it becomes 'cheaper' to buy than to steal.

The conclusions reached in the model do, however, give rise to some important questions. The principal one is why countries would ever choose autarky over trade. We have shown that war harder to prevent under autarky and under trade, so, given the inefficiencies that arise from war, it is a puzzle as to why countries would ever reduce their security by engaging in protectionism. I offer two answers, which I hope to incorporate into future work.

The first is the possibility of trade frictions and non-tradable goods. This paper assumes that, both goods can be easily shipped from one country to another. However many goods are very costly to trade. Some economically important resources, such as land or physical capital are even impossible to move from one country to another, though they can be expropriated by war. These frictions could allow for the possibility that resource asymmetries cannot be overcome, and thus that trade cannot mitigate war to the extent suggested in this model.

The second is the possibility of strategic refusal to trade on the part of countries. Authors such as Rosecrance [**?**] have argued that trade can be seen as a substitute to force as a means of increasing a country's power and influence across the globe. This model discounts the possibility that trade can be used strategicially. One way that strategic refusal to trade could be incorporated into the model is to allow countries to strategically embargo a country in preparation for war; countries might thus pre-emptively strike their neighbours where a trading outcome might seem to be more efficient; this may be because countries cannot guarantee one another security of supply in the future. Future work will hopefully, endogenise the decision of whether to trade or not.

More broadly, the extant literature on war and conflict is very rich, and there are many aspects of other models that could be incorporated into this model. Additions such as repeated periods, multiple actors, more goods and a more general class of production functions would be interesting first steps. Another, more interesting development might be along the lines of Gartzke [**?**] who argues that trade creates pacific outcomes by facilitating costly signalling. In light of this research, it would be interesting to redevelop the

model with repeated interaction and the possibility of embargo of certain goods; embargoes might serve as effective costly signals. These extensions are left for later work.

Appendix

A Proof of Proposition 1

We consider, without loss of generality, the cost c_1^A necessary for country 1 to be indifferent between war and peace. We want to find the minimium possible value of c_1^A.We know that

$$c_1^A = \frac{Y_1}{Y_1 + Y_2} - Y_1 \tag{13}$$

Thus we take its derivative with respect to x and y and set it to zero. With respect to x this yeilds

$$\frac{\partial c_1^A}{\partial x} = \frac{\left(\frac{\partial Y_1}{\partial x}\right)[Y_1 + Y_2] - Y_1\left[\frac{\partial Y_1}{\partial x} + \frac{\partial Y_2}{\partial x}\right]}{[Y_1 + Y_2]^2} - \frac{\partial Y_1}{\partial x} = 0 \tag{14}$$

and y

$$\frac{\partial c_1^A}{\partial y} = \frac{\left(\frac{\partial Y_1}{\partial y}\right)[Y_1 + Y_2] - Y_1\left[\frac{\partial Y_1}{\partial y} + \frac{\partial Y_2}{\partial y}\right]}{[Y_1 + Y_2]^2} - \frac{\partial Y_1}{\partial y} = 0. \tag{15}$$

We thus find that

$$\left(\frac{\partial Y_1}{\partial x}\right)[Y_1 + Y_2] - Y_1\left[\frac{\partial Y_1}{\partial x} + \frac{\partial Y_2}{\partial x}\right] - \frac{\partial Y_1}{\partial x}[Y_1 + Y_2]^2 = 0 \tag{16}$$

and y

$$\left(\frac{\partial Y_1}{\partial y}\right)[Y_1 + Y_2] - Y_1\left[\frac{\partial Y_1}{\partial y} + \frac{\partial Y_2}{\partial y}\right] - \frac{\partial Y_1}{\partial y}[Y_1 + Y_2]^2 = 0 \tag{17}$$

and thus that

$$\left(\frac{\partial Y_1}{\partial x}\right)\left[Y_1 + Y_2 - [Y_1 + Y_2]^2\right] = Y_1\left[\frac{\partial Y_1}{\partial x} + \frac{\partial Y_2}{\partial x}\right] \tag{18}$$

and y

$$\left(\frac{\partial Y_1}{\partial y}\right)\left[Y_1 + Y_2 - [Y_1 + Y_2]^2\right] = Y_1\left[\frac{\partial Y_1}{\partial y} + \frac{\partial Y_2}{\partial y}\right] \tag{19}$$

and thus that

$$\frac{\left(\frac{\partial Y_1}{\partial x}\right)}{\left[\frac{\partial Y_1}{\partial x} + \frac{\partial Y_2}{\partial x}\right]} = \frac{\left[Y_1 + Y_2 - [Y_1 + Y_2]^2\right]}{Y_1} \tag{20}$$

and

$$\frac{\left(\frac{\partial Y_1}{\partial y}\right)}{\left[\frac{\partial Y_1}{\partial y} + \frac{\partial Y_2}{\partial y}\right]} = \frac{\left[Y_1 + Y_2 - [Y_1 + Y_2]^2\right]}{Y_1}$$

Thus we note that, where c_1^A is minimized, we have

$$\frac{\left(\frac{\partial Y_1}{\partial x}\right)}{\left[\frac{\partial Y_1}{\partial x}+\frac{\partial Y_2}{\partial x}\right]}=\frac{\left(\frac{\partial Y_1}{\partial y}\right)}{\left[\frac{\partial Y_1}{\partial y}+\frac{\partial Y_2}{\partial y}\right]} \tag{22}$$

Thus we have

$$\frac{x^{\alpha-1}y^{1-\alpha}}{x^{\alpha-1}y^{1-\alpha}+(1-x)^{\alpha-1}(1-y)^{1-\alpha}}=\frac{x^{\alpha}y^{-\alpha}}{x^{\alpha}y^{-\alpha}+(1-x)^{\alpha}(1-y)^{-\alpha}} \tag{23}$$

which simplifies to the desired

$$\frac{y}{1-y}=\frac{x}{1-x} \tag{24}$$

.

■

B Walrasian Equilibrium

Country 1 solves the problem

$$\max_{x_1,y_1} U_1 = x_1^{\alpha}y_1^{1-\alpha} \text{ subject to } px_1+y_1=px+y \tag{25}$$

and country 2 solves

$$\max_{x_2,y_2} U_2 = x_2^{\alpha}y_2^{1-\alpha} \text{ subject to } px_2+y_2=p(1-x)+(1-y) \tag{26}$$

Respective Lagrangians are as follows:

$$\mathcal{L}_1 = x_1^{\alpha}y_1^{1-\alpha}-\lambda_1\left(px_1+y_1-px+y-0\right) \tag{27}$$

and

$$\mathcal{L}_2 = x_2^{\alpha}y_2^{1-\alpha}-\lambda_2\left(px_2+y_2-p(1-x)+(1-y)-0\right) \tag{28}$$

Under Walrasian Equilibrium, it can be easily shown that demand for the good is as follows:

- $x_1^*=\frac{\alpha(p_xx+p_yy)}{p_x(\alpha+(1-\alpha))}=\frac{\alpha(px+y)}{p}$
- $y_1^*=\frac{(1-\alpha)(p_xx+p_yy)}{p_y(\alpha+(1-\alpha))}=(1-\alpha)\left(px+y\right)$
- $x_2^*=\frac{\alpha(p(1-x)+(1-y))}{p}=\frac{\alpha(p(1-x)+(1-y))}{p}$
- $y_2^*=\frac{(1-\alpha)(p_x(1-x)+p_y(1-y))}{p_y(\alpha+(1-\alpha))}=(1-\alpha)\left(p\left(1-x\right)+(1-y)\right)$

where x_i^* is the equilibrium demand by country i for good x, and $p=p_x/p_y$, where p_x is the equilibrium price for good x. Given that $x_1^*+x_2^*=1$ and $y_1^*+y_2^*=1$, we can derive $p=\frac{\alpha}{1-\alpha}$.The allocations in the main text follow from inputting p into the demands above.

C Proof of Proposition 2

We know that under trade, war ensures where

$$max\left\{\left(\frac{Y_1}{Y_1+Y_2}-Y_2\right),\left(\frac{Y_2}{Y_1+Y_2}-Y_2\right)\right\}>c. \tag{29}$$

Thus indifference between peace and war under autarky occurs where

$$max\left\{\left(\frac{Y_1}{Y_1+Y_2}-Y_2\right),\left(\frac{Y_2}{Y_1+Y_2}-Y_2\right)\right\}=c^A. \tag{30}$$

.

Where c^A denotes the cost required for indifference. Similarly, given trade indifference between war and peace for both players occurs where

$$max\left\{\left(\frac{Y_1}{Y_1+Y_2}-Y_1^*\right),\left(\frac{Y_1}{Y_1+Y_2}-Y_1^*\right)\right\}=c^T. \tag{31}$$

Where c^T denotes the cost required for indifference.We want to show that $c^T<c^A$. This is true if and only if $max\left\{\left(\frac{Y_1}{Y_1+Y_2}-Y_1^*\right),\left(\frac{Y_1}{Y_1+Y_2}-Y_1^*\right\}<max\left\{\left(\frac{Y_1}{Y_1+Y_2}-Y_2\right),\left(\frac{Y_2}{Y_1+Y_2}-Y_2\right)\right\}$.

Now we know that $Y_i^*{}_i$. This is because given free trade, a country solves problem in equation (13) or (14), has the option of not trading. If a country chooses not to trade, then $Y_i^*=Y_i$. Thus if trade does take place, it is because it improves the welfare of country i. Thus, for all endowments. $Y_i^*\geq Y_i$. Thus $\frac{Y_i}{Y_1+Y_2}-Y_i^*\leq\frac{Y_i}{Y_1+Y_2}-Y_i$ for $i=1,2$. This proves the result.■

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