International Journal of Development and Conflict
5(2015) 76–100

A TWO-PERIOD MODEL OF NATURAL RESOURCES AND INTER-COUNTRY CONFLICTS: EFFECTS OF TRADE SANCTIONS

MD. DIDARUL HASAN* AND SAJAL LAHIRI**
Department of Economics,
Southern Illinois University Carbondale,
Carbondale, IL 62901, U.S.A.

We develop a two-period general equilibrium model linking natural resources to inter-country conflict, treating resource extraction and wage rate are endogenous. First, we characterize the war equilibrium and derive a number of properties of it. Second, we examine the effects of different types of trade sanctions imposed by the international community on war efforts of the two countries. We find that a temporary current sanction on both countries, or even on one of the countries, will be counter-productive, and an anticipated future sanction on both countries will unambiguously reduce war intensity. Whether an anticipated future sanction on one of countries will reduce war intensity will depend on the level of resource stock; the effect of a permanent sanction on both countries is ambiguous: war intensities will fall only if the resource stocks of the countries are sufficiently high.

Keywords: Natural Resources, Inter-State Conflicts, Sanctions

JEL Classification: C72, D74, O13, Q34

1 Introduction

Most of the recent theoretical and empirical literature on the relationship between natural resource and conflict focus mainly on civil wars. However, war between independent nations over natural resources are not uncommon. Bakeless (1921) studies the causes of several wars between the years 1878 to 1918 and finds that 14 of the 20 major wars had significant economic motivations, often related to conflicts over resources. In recent history, the most cited examples of the role of natural resources in inter-state wars are the Iran-Iraq war, Iraq's invasion of Kuwait, and the Falklands war. Many other historical examples of militarized inter-state dispute seem to be about natural resources. Examples include Algerian war of independence (with France, oil), Algeria and Morocco (Western Sahara, phosphate and possibly oil), Argentina and Chile (Beagle Channel, fisheries and oil), Argentina and Uruguay (Rio de la Plata, minerals), Bolivia and Paraguay (Chaco War, oil), Bolivia, Chile, and Peru (War of the Pacific, minerals and sea access), China

*Email: hasan@siu.edu **Email: lahiri@siu.edu

and Vietnam (Paracel Islands, oil), Ecuador and Peru (Cordillera del Condor, oil and other minerals), Nigeria and Cameroon (Bakassi peninsula, oil), and many others.[1]

Klare (2001) argues that, following the end of the Cold War, control of valuable natural resources has become increasingly important, and these resources will become a primary motivation for wars in the future. Like blood diamonds that are believed to fuel African civil wars, many people think blood oil to be a major determinant of international aggression (Kaldor et al., 2007). Some recent and ongoing tensions involving territorial claims are thought to be mineral resource related. Examples of such tensions include Bangladesh-Myanmar, Bangladesh-India, Guyana-Suriname, Nicaragua-Honduras, Guinea-Gabon, Chad-Libya, Oman-Saudi Arabia, Algeria-Tunisia, Eritrea-Yemen, Guyana-Venezuela, Congo-Gabon, Equatorial Guinea-Gabon, Greece-Turkey, Colombia-Venezuela, Southern and Northern Sudan (Caselli et al., 2013; Carter Center, 2010).[2]

Though there are some case studies about the role of natural resources in inter-state wars, there are very limited theoretical and empirical studies about underlying mechanism of these wars. The literature on inter-state conflicts so far has emphasized the role of trade (e.g., Skaperdas and Syropoulos, 2001; Syropoulos, 2006; Becsi and Lahiri, 2007; Martin et al., 2008; Rohner et al., 2013; Garfinkel et al., 2015), domestic institutions (e.g., Maoz and Russett, 1993; Conconi et al., 2012), development (e.g., Gartzke, 2007; Gartzke and Rohner, 2011), and stocks of weapons (e.g., Chassang and Padró i Miquel, 2010). Surprisingly, natural resources have received little systematic attention in terms of both modeling and empirical investigations.

Many researchers study conflict between two countries in trade-theoretic framework and show how globalization and trade affects conflict efforts. For example, Skaperdas and Syropoulos (2001) develop a simple model with two small countries disputing over a resource used in the production of tradeables. They show that if the international price of the contested resource is lower than a country's autarkic price, the opportunity cost of arming rises, and thus, the introduction of trade softens the intensity of competition for the contested resource, reduces arming, and raises welfare relative to autarky. The opposite can occur, however, when the international price of the contested resource is higher than its autarkic price. Syropoulos (2006) also examines the relationship between trade openness and inter-state conflict for contested resources in a general equilibrium framework. He shows that depending on world prices and their effect on domestic factor prices, it is possible for trade to reduce the opportunity cost of arming and thereby intensify conflict. Becsi and Lahiri (2007) use a three country framework to examine how third country can use policies to influence the conflict between two other countries. Garfinkel et al. (2015) combine a standard trade model with a contest function to study interstate disputes over resources. They show that conflict over resources affects the pattern of comparative advantage, and free trade may intensify conflicts so much that autarky may be preferable to free trade. Acemoglu et al. (2012) study the war between a resource rich and a resource

[1] See Acemoglu et al., 2012; Caselli et al., 2013; Carter Center, 2010; De Soysa et al., 2011.

[2] Recently a U.N. Tribunal has settled the dispute over maritime boundary between Bangladesh-Myanmar, and Bangladesh-India in the Bay of Bengal.

poor countries in a dynamic framework to see under what conditions such war can be prevented. They find that in the case of inelastic resource demand, war incentives increase over time and war may become inevitable; and under monopolistic situations, regulation of prices and quantities by the resource-rich country can prevent war. De Soysa et al. (2011) develop a set of models to study a strategic perspective on petroleum and interstate conflict. In contrast to the popular belief that oil is a catalyst for war, they argue that oil exporters actually experience less wars as powerful petroleum importers protect petro-states. Caselli et al. (2013) study how the geographic location of natural resource endowments affects the likelihood of inter-state wars. They find the likelihood of war increases if the resources of the warring countries are closer to the border.

Unlike the case of cross-country conflicts, there is sizable theoretical and empirical literature on the role of natural resources in civil conflicts.[3] The main theme of this literature is that natural resource abundance is often the principal cause of civil wars. Our paper is complementary to the existing literature in the sense that we emphasis the role of natural resource in the inter-state war as well. Most of the theoretical work on conflicts assumes the fighting motives as given; the objective is to study the determinants of fighting efforts (Caselli et al., 2013). In our paper, we also do not focus on the causes of conflict, rather we examine the factors that determine the relative war efforts of the two warring countries. At the same time we examine how international sanctions on resource exports affect the intensity of war.

Most of the existing literature use a static one-period framework to study the relationship between natural resource and inter-state conflict.[4] Besides, resource stocks are considered exogenous during conflict in the existing literature on inter-state conflict, i.e., it does not consider the possibility that natural resources can be extracted and sold during the conflict. Janus (2012) however develops a two-period model for civil conflict between two social groups and considers the possibility that resource extraction is endogenous. Following Janus (2012), we develop a two-period model for inter-state conflict, where resource extraction is endogenous. However, unlike Janus (2012) who employs a partial equilibrium framework, we treat wage rates as endogenous. In other words, we employ a general equilibrium model where two neighboring countries fight to acquire each other's natural resource stock. In our model in each country labor force is used for three purposes: agricultural production, resource extraction, and war. The two competitive labor markets in the two countries determine equilibrium wage rates in them, which in turn determine their relative war efforts.[5]

Under our framework, first of all, we examine the determinants of relative war efforts in the two asymmetric countries. We find that regardless of the differences in initial ownership of resource stocks, the war efforts of the two countries will be the same, *ceteris paribus*; a country with larger labor force exerts more war efforts; and a country with

[3] Summarized by Ross (2004), Collier and Hoeffler (2007), Blattman & Miguel (2010), Van der Ploeg (2011).

[4] The only exception is Acemoglu et al. (2012), who consider a dynamic framework.

[5] This framework is also applicable in an intra-state conflict, where labor market is segmented between two regions of a country and two regions fight with each other.

larger land endowment or higher productivity exerts lower war efforts (i.e., paradox of power). Second, we examine the effects of different types of international sanctions on war efforts of the two countries. We find that a temporary current sanction on both countries, or even on one of the countries, will be counter-productive (i.e., increases the war intensity); an anticipated future sanction on both countries will reduce war intensity; whether an anticipated future sanction on one country will reduce war intensity depends on the level of resource stock; and finally, the effect of a permanent sanction on both countries is in general ambiguous, but war intensity will fall only if the resource stocks of the countries are sufficiently high.

The rest of the paper is organized as follows. In section 2, we describe the basic setup of the model. Section 3 analyses the equilibrium conditions and compare the equilibrium war efforts of the two countries. In section 4, we discuss the effects of international sanctions on war efforts. In section 5, we introduce uncertainty about future sanction. Finally, section 6 concludes the paper.

2 The Model

Consider two neighboring countries which are endowed with some initial stock of natural resources. The government of each country is motivated by greed, and fight with each other to capture more resources. There are three sectors in each economy: government sector, resource extraction sector, and agricultural sector.[6] Each country is also endowed with fixed amount of labor force and land. The government of each country recruits labor as soldiers. The extraction sector hires labor to extract natural resources. The agricultural sector uses land and also hires labor to produce agricultural goods. Thus, the aggregate demand for labor is the sum of the labor demands from all three sectors. The model works in two stages: in the first stage the governments decide how many soldier to have; in the second stage extraction sector and agricultural sector decide how much labor to employ. Labors move freely between sectors but not between countries, implying that the wage rate is same in all sectors within a country. We consider two periods: in the first period each country extracts some of the resources it possesses and fight with each other; if a country wins the war, in the second period it gets all the remaining resource stock. Each government finances war costs by imposing lump sum tax on both the extraction and agricultural sectors.[7]

Let, country i ($i = 1, 2$) possesses an initial resource stock, y_i, and hires l_{ci} amount of labor for fighting. Then, the country i's winning probability in war is given by the conventional ratio-form contest success function: $q_i = l_{ci}/(l_{ci} + l_{cj})$, $i = 1, 2$, and $j \neq i$. This function implies that for given amount of soldiers of country j, the winning probability of country i increases with its' number of soldiers and vice versa. The extraction sector hires l_{ri} amount of labor for extraction and the resource extraction function is given by $r_i = 2l_{ri}^{1/2}$. There is also a private agricultural sector in each country, and it hires l_{ai} amount of labor from the labor

[6] The third sector could be any other sector not involved directly in the war.

[7] This is done to simplify the analysis. One could in principle assume that revenue for resources finance war efforts as in Lahiri (2010) and Janus (2012).

market. The agricultural production function is given by: $A_i = 2\lambda_i l_{ai}^{1/2} V_i^{1/2} (i = 1, 2)$, where V_i is the fixed amount of land the economy has and l_i is the productivity parameter of the agricultural sector.

We consider that each country is a small open economy and exporter of natural resources in the world market. Thus, world market price is given for the country. Let p_1 be the world price of natural resource in period 1, and p_2 the world price of natural resource in period 2. We shall assume the prices to be the same and denote the common price by p, i.e., $p_1 = p_2 =$ p. However, later we shall consider changes in p_1 but not in p_2, and vice versa. Therefore, we shall keep the separate notations for that purpose.

The expected return of the extraction sector of country i is:

$$\begin{aligned} R_{ri} &= p_1 r_i - w l_{ri} + q_i p_2 (y_i + y_j - r_i - r_j) \\ &= p_1 (2 l_{ri}^{1/2}) - w l_{ri} + \frac{l_{ci}}{l_{ci} + l_{cj}} p_2 (y_i + y_j - 2 l_{ri}^{1/2} - 2 l_{rj}^{1/2}), i = 1, 2; j \neq i, \end{aligned} \tag{1}$$

where w_i is the domestic market wage rate in country i, and $p_1 r_i - w l_{ri}$ is the net revenue in period 1. $(y_i + y_j - r_i - r_j)$ is the resource stock that country i get at the beginning of the 2nd period, if it wins the war. For simplicity, we also assume no discounting for period 2. Since q_i is the winning probability of country i in the conflict, the expected value of resource stock in the 2nd period is $q_i p_2 (y_i + y_j - r_i - r_j)$.[8]

The country is an importer of agricultural goods. Let, p_a is the international market price of agricultural goods. Then, the profit of agricultural sector is given by:

$$R_{ai} = 2\lambda_i l_{ai}^{1/2} V_i^{1/2} - w_i l_{ai}, i = 1, 2 \tag{2}$$

The government of each country imposes lump sum tax T_i on both extraction and agricultural sectors to finance its war cost. Then, the budget balance equation of the government is given by:

$$w_i l_{ci} = T_i, i = 1, 2 \tag{3}$$

and total income of all agents in the country i is given by:[9]

$$I^i = w_i L_i + R_{ri} + R_{ai} - T_i, i = 1, 2 \tag{4}$$

where L_i is the fixed supply of labor in country i.

The labor market equilibrium condition in country i is given by:

$$l_{ri} + l_{ci} + l_{ai} = L_i, i = 1, 2 \tag{5}$$

Equations (1) to (5) describe the basic structure of model. In the next section we derive equilibrium conditions of the two countries.

---

[8] We do not consider second period extraction of resources, because it does not affect our analysis.

[9] We abstract from the possibility that conflict adversely affects the lives, infrastructures, and thus lower the productive capacity of a country.

3 The Equilibrium

We assume that the sequence of decision making is as follows:

Stage 1: The labor market clears,

Stage 2: Two governments simultaneously decide on war efforts to maximize national incomes of the countries.

Stage 3: For given war efforts and winning probability of the government, extraction sector of each country decides how much resource to extract in period 1 and how much to leave for period 2. At the same time, the agricultural sector also decides how much to produce in period 1.

We solve the game by backward induction method. In stage 3, we derive the optimal level of extraction for extraction sector, given the war efforts and winning probability of the government. At the same time, we derive the optimal level of employment in the agricultural sector. Then in stage 2, we derive optimal level of war efforts for the two governments who play a simultaneous move game to maximize national incomes.

From equation (1) we derive optimal extraction labor for country *i*. The first order condition for optimal l_{ri} is:

$$p_1 l_{ri}^{-1/2} = w_i + q_i p_2 l_{ri}^{-1/2}, i = 1, 2 \tag{6}$$

which states that marginal benefit of extraction labor (the left-hand side) must equal marginal cost of extraction labor (the right-hand side). Marginal benefit of extraction equals the value of marginal product of extraction labor in the first period, while marginal cost equals wage cost of labor plus opportunity cost of extracting now instead of conserve it for the future. The opportunity cost of extraction is equal to the probability of winning the conflict (q_i) times the value of marginal product of labor in period 2 $(p_2 l_{ri}^{-1/2})$. From equation (6) we get optimal l_{ri} as follows:

$$l_{ri} = \left(\frac{p_1 - q_i p_2}{w_i}\right)^2, i = 1, 2$$

From equation (2) we derive optimal agricultural labor for country *i*. The first order condition for optimal l_{ai} is:

$$p_a \lambda_i l_{ai}^{-1/2} V_i^{1/2} = w_i, i = 1, 2 \tag{7}$$

Equation (7) equates marginal benefit of agricultural labor to the marginal cost, where marginal benefit is the value of marginal product of agricultural labor and marginal cost is just wage cost of labor. From (7) we get the optimal l_{ai} as follows:

$$l_{ai} = \frac{p_a^2 \lambda_i^2 V_i}{w_i^2}, i = 1, 2$$

Substituting the optimal solution of l_{ri} into equation (1), we get optimal expected return for the extraction sector as follows:

$$R_{ri} = w l_{ri} + q_i p_2 (y_i + y_j - 2 l_{rj}^{1/2}), i = 1, 2; j \neq i \tag{8}$$

Substituting the optimal solution of l_{ai} into equation (2), we get optimal return for the agricultural sector as follows:

$$R_{ai} = w_i l_{ai}, i = 1, 2 \tag{9}$$

Substituting (8) and (9) into equation (4), we get total income of the country i as:

$$\begin{aligned} I^i &= w_i L_i + w l_{ri} + q_i p_2 (y_i + y_j - 2 l_{rj}^{1/2}) + w_i l_{ai} - w_i l_{ci} \\ &= w_i L_i + w_i \left(\frac{p_1 - q_i p_2}{w_i} \right)^2 + \frac{l_{ci}}{l_{ci} + l_{cj}} p_2 \left(y_i + y_j - 2 \frac{p_1 - q_j p_2}{w_j} \right) \\ &+ w_i \left(\frac{p_a^2 \lambda_i^2 V_i}{w_i^2} \right) - w_i l_{ci} (i = 1, 2; \ j \neq i) \end{aligned} \tag{10}$$

At the second stage, each government maximize I^i to choose l_{ci}. From (10) we get first-order condition for l_{ci} as (see appendix A.1):

$$\frac{\partial q_i}{\partial l_{ci}} p_2 (y_i + y_j - r_i - r_j) - q_i p_2 \frac{\partial r_j}{\partial l_{ci}} = w_i,$$

which gives

$$\frac{l_{cj}}{(l_{ci} + l_{cj})^2} p_2 (y_i + y_j - 2 l_{ri}^{1/2} - 2 l_{rj}^{1/2}) - 2 \frac{p_2^2 l_{ci} l_{cj}}{w_j (l_{ci} + l_{cj})^3} = w_i, (i = 1, 2; \ j \neq i) \tag{11}$$

The left hand side of equation (11) is the marginal benefit of conflict labor. The first term of left hand side is the change in the likelihood of winning the conflict ($\partial q_i / \partial l_{ci}$) times the value of resource stock after initial extraction of two countries ($p_2(y_i + y_j - r_i - r_j)$). Note, country j changes the level of extraction in response to change in the conflict efforts of country i. As a result marginal benefit of country i changes by $q_i p_2 (\partial q_i / \partial l_{ci})$, which is the second term of the left hand side. The right hand side of (11) is marginal cost of war, which is simply the wage cost of additional soldier.

Equation (11) gives us the reaction functions for the two countries. Using these, we derive the following relationship between l_{c1} and l_{c2} (see appendix A.2):

$$w_1 l_{c1} = w_2 l_{c2} \Leftrightarrow l_{c2} = \frac{w_1}{w_2} l_{c1} \tag{12}$$

Equation (12) implies that relative war efforts of the two countries depends on the relative wage rate, and in equilibrium two countries war costs are same even though the two countries can be asymmetric in many ways

Using (12) we can derive optimal l_{r1} and l_{r2} in terms of wage rates and exogenous parameters as follows:

$$l_{r1} = \left[\frac{p_1}{w_1} - \frac{p_2 w_2}{w_1 (w_1 + w_2)} \right]^2$$

$$l_{r2} = \left[\frac{p_1}{w_2} - \frac{p_2 w_1}{w_2 (w_1 + w_2)} \right]^2$$

Substituting (12) in to (11) we get optimal values of l_{c1} and l_{c2} as follows:

$$l_{c1} = \frac{w_2}{(w_1 + w_2)^2} B, l_{c2} = \frac{w_1}{(w_1 + w_2)^2} B$$

where $$B = p_2\left(y_1 + y_2 - \frac{2p_1}{w_1} + \frac{2p_2 w_2}{w_1(w_1 + w_2)} - \frac{2p_1}{w_2} + \frac{2p_2 w_1}{w_2(w_1 + w_2)} - \frac{2p_2}{w_1 + w_2} \right)$$

Substituting the optimal l_{c1}, l_{r1}, and l_{a1} in to equation (5) we get labor market equilibrium condition of country 1 as follows:

$$\frac{w_2}{(w_1 + w_2)^2} B + \left[\frac{p_1}{w_1} - \frac{p_2 w_2}{w_1(w_1 + w_2)} \right]^2 + \frac{p_a{}^2 \lambda_1{}^2 V_1}{w_1{}^2} = L_1 \tag{13}$$

Substituting the optimal l_{c2}, l_{r2}, and l_{a2} in to equation (5) we get labor market equilibrium condition of country 2 as follows:

$$\frac{w_1}{(w_1 + w_2)^2} B + \left[\frac{p_1}{w_2} - \frac{p_2 w_1}{w_2(w_1 + w_2)} \right]^2 + \frac{p_a{}^2 \lambda_2{}^2 V_2}{w_2{}^2} = L_2 \tag{14}$$

Equations (13) and (14) simultaneously determine optimal w_1 and w_2. Though we don't have explicit solutions for w_1 and w_2, we can determine the relative magnitude of the two. The relative magnitudes of w_1 and w_2 will depend on the relative values of different parameters of the two countries. Relative wage rate determines the relative war efforts of the two countries. Now we will examine the relative war efforts of the two countries if they are non-symmetric in terms of different parameters. With $p_1 = p_2 = p$ the optimal l_{ri} and l_{ci} are as follows:

$$l_{r1} = l_{r2} = \left(\frac{p}{w_1 + w_2} \right)^2$$

$$l_{c1} = \frac{w_2}{w_1} l_{c2} = \frac{w_2}{(w_1 + w_2)^2} B$$

where $B = p_2\left(y_1 + y_2 - \dfrac{6p}{w_1 + w_2} \right)$.

Using these results and Combining equations (13) and (14) we can derive the following equation (see appendix A.3):

$$(L_1 - L_2) + \frac{B}{(w_1 + w_2)^2}(w_1 - w_2) + \left(\frac{a_2}{w_2{}^2} - \frac{a_1}{w_1{}^2} \right) \tag{15}$$

where $a_1 = p_a{}^2 \lambda_1{}^2 V_1, a_2 = p_a{}^2 \lambda_2{}^2 V_2$.

Using equation (15) we can compare the Nash equilibrium war efforts of the two countries under different scenarios on the extent on asymmetry between the two countries.

Case 1: *Benchmark case*: Two countries are perfectly symmetric i.e., $L_1 = L_2$, $V_1 = V_2$, $\lambda_1 = \lambda_2$, $y_1 = y_2$.

In this case from (15) we get:[10]

$$\left[\frac{B}{(w_1+w_2)^2}+\frac{a(w_1+w_2)}{w_1{}^2w_2{}^2}\right](w_2-w_1)=0 \Rightarrow w_1=w_2$$

As $w_1 = w_2$, we also have $l_{c1} = l_{c2}$. The interpretation is straightforward that if two countries are symmetric in all respects, in equilibrium their wage rate, war efforts and winning probabilities will be same. Now we can compare the war efforts of two countries when they are non-symmetric.

Case 2: Country 1 and country 2 are same in all respects except that the former possesses a bigger resource stock than latter, i.e., $y_1 > y_2$, but $L_1 = L_2$, $V_1 = V_2, \lambda_1 = \lambda_2$.

In this case from (15) we get the same result as of case 1, that is $w_1 = w_2$, and thus $l_{c1} = l_{c2}$. It implies that even if the initial resource endowment is different between two countries their equilibrium war efforts and winning probabilities will be same. In the absence of property rights, insecurity neutralizes the effects of cross-sectional variation in the resource endowment on individual countries' war efforts. Hirshleifer (1991) calls this tendency the *paradox of power*, that the relatively poorer side viewing the marginal return from appropriation to be relatively higher than the marginal product from useful production.

Case 3: Country 1 has a larger labor force than country 2, they are same in all other aspects, i.e., $L_1 > L_2$,but $V_1 = V_2, \lambda_1 = \lambda_2, y_1 = y_2$.

In this case from (15) we get:

$$\left[\frac{B}{(w_1+w_2)^2}+\frac{a(w_1+w_2)}{w_1{}^2w_2{}^2}\right](w_2-w_1)=L_1-L_2 \Rightarrow w_1<w_2$$

As $w_1 < w_2$, $l_{c1} > l_{c2}$. The interpretation of this result is that a country with a relatively larger labor force will have a lower wage rate. A lower wage rate implies lower marginal cost or opportunity cost of conflict. Thus a country with larger labor force (i.e., population) will exert more war efforts. This prediction is consistent with the empirical findings that the countries with the larger population are more likely to engage in conflict (Collier & Hoeffler 1998, 2004; Fearon, 2005).

Case 4: Country 1 has a larger endowment of land, but they are the same in all other aspects, i.e., $V_1 > V_2$, but $L_1 = L_2, \lambda_1 = \lambda_2, y_1 = y_2$.

In this case from (15) we get:

$$\frac{w_2}{(w_1+w_2)^2}B+\frac{p_a^2\lambda^2V_1}{w_1{}^2}=\frac{w_1}{(w_1+w_2)^2}B+\frac{p_a^2\lambda^2V_2}{w_2^2}$$

which implies $\left[\frac{B}{(w_1+w_2)^2}+\frac{p_a^2\lambda^2V_2(w_1+w_2)}{w_1^2w_2^2}\right](w_2-w_1)=\frac{p_a^2\lambda^2(V_2-V_1)}{w_1^2}$

Thus, $V_1 > V_2 \Leftrightarrow w_1 > w_2 \Leftrightarrow l_{c1} < l_{c2}$. A country with a large endowment of productive land will have large agricultural sector. The demand for labor and employment in the

[10] Under symmetry $a_1 = a_2 = a$.

agricultural sector will be high, as a result wage rate will be high. A high wage rate means higher opportunity cost of conflict and hence leads to lower level of war efforts. This prediction is also supported by empirical findings that countries with low level of per capita income tend to engage in more conflict (Collier & Hoeffler 1998, 2004; Fearon, 2005).

Case 5: Country 1 has higher productivity in agriculture sector than that of country 2, they are same in all other aspects, i.e., $l_1 > l_2$, but $L_1 = L_2$, $V_1 = V_2, y_1 = y_2$.

This case is very similar to Case 5, and following similar arguments, we can show that $\lambda_1 > \lambda_2 \Leftrightarrow w_1 > w_2 \Leftrightarrow l_{c1} < l_{c2}$.

4 Effects of Trade Sanctions

Having discussed the equilibrium war efforts of the two countries, now we will discuss how war efforts change with international sanctions on resource exports. A sanction on resource exports reduces the export price received by the sanctioned country. Thus, we will examine how war efforts change with the change in resource price. Now we examine the effects of sanctions on war efforts of the two countries. We consider different types of sanctions on resource exports (for both countries and for one of the two countries): (i) temporary sanction, (ii) sanction threat or expected future sanction, and (iii) permanent sanction.

In order to simplify our analyses, we assume that two countries are symmetric so that in the initial equilibrium $w_1 = w_2 = w$. Earlier we have also assumed that, at the initial equilibrium, resource prices to be the same in the two periods (i.e., $p_1 = p_2 = p$).

In general, a change in the price of exports affects the war efforts directly for given wage rates, and indirectly through change in wage rates.

We first look at how wage rates are affected by change in resource prices. Totally differentiate equations (13) and (14) we get (see appendix A.4):

$$\alpha_1 dw_1 + \alpha_2 dw_2 = \beta_1 dp_1 + \gamma_1 dp_2 \tag{16}$$

$$\alpha_3 dw_1 + \alpha_4 dw_2 = \beta_2 dp_1 + \gamma_2 dp_2 \tag{17}$$

where

$$\alpha_1 = \alpha_4 = \frac{2p(2wy - 3p) - p^2 + 16a}{8w^3}$$

$$\alpha_2 = \alpha_3 = -\frac{p^2}{8w^3}$$

$$\beta_1 = \beta_2 = 0$$

$$\gamma_1 = \gamma_2 = \frac{wy - 2p}{2w^2}$$

Equations (16) and (17) constitute a system of equations, and these give, for any change in the prices this system, the corresponding changes in w_1 and w_2.

Totally differentiating optimal lc_1 and lc_2 with respect to $p_t (t = 1, 2)$ we get:

$$\frac{dl_{c1}}{dp_t} = \frac{\partial l_{c1}}{\partial p_t} + \frac{\partial l_{c1}}{\partial w_1}\frac{dw_1}{dp_t} + \frac{\partial l_{c1}}{\partial w_2}\frac{dw_2}{dp_t} \tag{18}$$

$$\frac{dl_{c2}}{dp_t} = \frac{\partial l_{c2}}{\partial p_t} + \frac{\partial l_{c2}}{\partial w_1}\frac{dw_1}{dp_t} + \frac{\partial l_{c2}}{\partial w_2}\frac{dw_2}{dp_t} \tag{19}$$

Equations (18) and (19) state that a change in resource price changes the war efforts of each country via three channels: first, it changes the war efforts directly; second, it changes the wage rate of the country under consideration and thus changes the war efforts; and third, it changes the wage rate of rival country and thus changes the war efforts of the country.

(i) Temporary sanction: A temporary sanction on resource exports reduces the price of resource in period 1, p_1, in the international market. If only p_1 changes, solving the system of equations (16) and (17) we get the changes in w_1 and w_2 as follows (see appendix A.5):

$$\Delta.\frac{dw_1}{dp_1} = \beta_1\alpha_4 - \beta_2\alpha_2$$

$$\Delta.\frac{dw_2}{dp_1} = \beta_2\alpha_1 - \beta_1\alpha_3$$

where $\Delta = a_1\, a_4 - a_2\, a_3 > 0$ from the Walrasian stability of the labor market. Under the assumptions of symmetry ($w_1 = w_2 = w$) and $p_1 = p_2 = p$, we get $\beta_1 = \beta_2 = 0$ (see the expressions after equation (17)), and thus $dw/dp_1 = 0$.

Now the change in conflict efforts of each country for a change is p_1 is (see appendix A.6.1):

$$\frac{dl_c}{dp_1} = \frac{\partial l_c}{\partial p_1} + \frac{\partial l_c}{\partial w}\frac{dw}{dp_1} = \frac{\partial l_c}{\partial p_1} = -\frac{p}{w^2} < 0 \tag{20}$$

This result implies that a temporary current sanction that reduces the price of resource in period 1 will increase conflict efforts of both countries.[11] In this case, reduction in resource price decreases extraction of resources in the period 1, leaving more prize for conflict. Wage rate may increase or decrease depending on the relative price of resource in two periods. A change in wage rate may increase or decrease the conflict depending on the resource stocks. However, overall effect of temporary resource price decrease on conflict is positive. Thus, temporary sanction is counter-productive.

Now suppose international community imposes sanction to one country, say country 1. It implies that in period 1 the resource price for country 1, p_{11}, will fall. But, the resource price for country 2, p_{12}, will be unchanged. Now under the assumption of symmetry, from (16) and (17) we get (see appendix A.6.2):

$$\frac{dw_1}{dp_{11}} = -\frac{dw_2}{dp_{11}} = \frac{2pw}{8a + p(2wy - 3p)} > 0$$

and the change in war efforts of country 1 is:

$$\frac{dl_{c1}}{dp_{11}} = -\frac{p}{2w^2} - \frac{p^2(2wy - 3p)}{2w^2[8a + p(2wy - 3p)]} < 0 \tag{21}$$

since $l_c = p(2wy - 3p)/4w^2 > 0$ implies $(2wy - 3p) > 0$.

[11] This result holds even if two countries are non-symmetric. This is because if. $p_1 = p_2$, we get $\beta_1 = \beta_2 = 0$. In this case, $dw_1/dp_1 = dw_2/dp_1 = 0$ i.e., a temporary change in resource price will not affect wage rate. Then $dl_{c1}/dp_1 = dl_{c2}/dp_1 = 0$.

Equation (21) implies that temporary sanction on one country is surely counter-productive in the sense that it increases the war efforts of that country. In this case, a reduction of resource price for country 1 decreases extraction of that country and thus induces more conflict efforts. Decrease in resource price for country 1 reduces wage rate in country 1 and increases wage rate in country 2 (as their conflict efforts increases). The combined effects on the changes in two wage rates is negative on the conflict. Thus, overall effect of temporary sanction on one country must be negative on that country.

Now we will examine how the war efforts of the other country changes if a temporary sanction is imposed on one country. In this case the change in war efforts of country 2 as a result of sanction on country 1 is as follows (see appendix A.6.3):

$$\frac{dl_{c2}}{dp_{11}} = -\frac{8ap}{2w^2[8a + p(2wy - 3p)]} < 0 \tag{22}$$

since $(2wy - 3p) > 0$.

Equation (22) indicates that a temporary sanction on country 1 increases the war efforts of country 2 as well. This is because a reduction of extraction in country 1 increases conflict prize, thus induces more war efforts by country 2. Decrease in wage rate in country 1 and increase in wage rate in country 2 together reduces the country 2's war efforts somewhat. But, negative effect dominates positive effect, yielding a net increase in war efforts.

Thus, the policy implication is that if resource extraction is endogenous during the conflict, a temporary sanction on resource exports is always counter-productive.

(ii) An anticipated future sanction: Suppose the international community announces a sanction threat to the warring countries that it will impose sanction on resource exports if the resources are acquired by war. If the threat is credible then warring countries would expect resource price in period 2, p_2, to fall. If only p_2 changes then by solving the system of equations (16) and (17) we get:

$$\Delta.\frac{dw_1}{dp_2} = \gamma_1\alpha_4 - \gamma_2\alpha_2$$

$$\Delta.\frac{dw_2}{dp_1} = \gamma_2\alpha_1 - \gamma_1\alpha_3$$

If two countries are symmetric and if initially $p_1 = p_2 = p$, we get the change in wage rate with respect to p_2 as follows (see appendix A.6.4):

$$\frac{dw}{dp_2} = \frac{2w(wy - 2p)}{\Lambda}$$

Then the change in war efforts of each country with respect to p_2 would be as follows:

$$\frac{dl_c}{dp_2} = \frac{\partial l_c}{\partial p_2} + \frac{\partial l_c}{\partial w}\frac{dw}{dp_2} = \frac{4a(wy - p) + p^2(2wy - 3p)}{w^2\Lambda} > 0 \tag{23}$$

since $wy - p > 2wy - 3p > 0$, and $\Lambda = p(2wy - 3p) - p^2 + 8a > 0$.[12]

---

[12] $\Lambda > 0$, since $\Delta = \Lambda(p(2wy - 3p) + 8a)/16w^6 > 0$ and $2wy - 3p > 0$.

Equation (23) implies that an anticipated future sanction on resource exports reduces the conflict efforts of the countries involved in conflict. In this case, an expected reduction of resource price in period 2 reduces expected conflict prize, thus diminishes war efforts. Wage rate may increases or decreases in each country depending on the level of resource stock. War efforts may increase or decrease with the change in wage rate depending on the level of resource stock. But, whatever the effects of wage change on conflict, overall conflict efforts fall due to decrease in resource price in period 2. Thus, an anticipated future sanction is effective in reducing the intensity of conflict in our model.

Now suppose international community declares sanction threat to only one country, say country 1. It implies that in period 2 the resource price for country 1, p_{21}, will fall. But, the resource price for country 2, p_{22}, will be unchanged. Again if two countries are symmetric and initially $p_1 = p_2 = p$, from (16) and (17) we get (see appendix A.6.5):

$$\frac{dw_1}{dp_{21}} = \frac{w(wy-2p)[2p(2wy-3p)-p^2+16a]}{\Omega}$$

$$\frac{dw_2}{dp_{21}} = \frac{w(wy-2p)3p^2}{\Omega}$$

Then the change in war efforts of country 1 with respect to p_{21} as follows:

$$\frac{dl_{c1}}{dp_{21}} = \frac{4p^2(p(2wy-3p)+8a)(wy-2p)+\Theta}{4w^2\Omega} \tag{24}$$

where $\Omega = (p(2wy-3p)+8a)\Lambda > 0, \Theta = (p^2(2wy-3p)+16a(wy-p))\Lambda + 8p^2a(wy-p) > 0$ (as we have shown earlier that $wy - p > 2wy - 3p > 0$ and $L > 0$).

Note, the sufficient condition for $dl_{c1}/dp_{21} > 0$ is $y > 2p/w$. This condition satisfies if $\partial w_1 / dp_{21} = \gamma_{11} > 0$ i.e., if wage rate in country 1 falls due to decrease in expected future price of resources. A decrease in p_{21} due to sanction on country 1 reduces conflict efforts of the country, but it also increases extraction in the current period. Whether wage rate will falls, it depends on the relative magnitude of two effects. $\gamma_{11} > 0$ also implies that wage rate in country 2 will increase and thus tend to increase the war efforts of country 1. However, if resource stock is sufficiently high, the overall effect of anticipated future sanction on conflict efforts will be positive (i.e., an anticipated future sanction on one country will reduce its' war efforts). On the other hand, if resource stock is low, there is possibility that an anticipated sanction can be counter- productive.

The change in war efforts of country 2 with respect to p_{21} is (see appendix A.6.6):

$$\frac{dl_{c2}}{dp_{21}} = \frac{p^2(p(2wy-3p)+6pwy+48a)(wy-2p)}{4w^2\Omega} \tag{25}$$

In this case, $dl_{c1}/dp_{21} > 0$ if and only if $y > 2p/w$. In our model, if two countries are symmetric future sanction on country 1 will not affect the conflict efforts of country 2 directly. However, changes in wage rates of country 1 and country 2 will affect the war efforts of country 2. If $y > 2p/w$, wage rate in country 1 falls and wage rate of country 2 increases, and then the war efforts of country 2 falls. Thus, an anticipated future sanction on country 1 will reduce the war efforts of country 2 only if resource stock is sufficiently high. On the other hand, if resource stock is low, then anticipated sanction on country 1 will increase the war efforts of country 2.

(iii) Permanent sanction: Suppose initially $p_1 = p_2 = p$. A permanent sanction implies that price of resource falls in both period 1 and period 2. If two countries are symmetric, the change in wage rate with respect to price will be (see appendix A.6.7):

$$\frac{dw}{dp} = \frac{2w(wy - 2p)}{\Lambda}$$

Then the change in war efforts of each country with respect to price would be as follows:

$$\frac{dl_c}{dp} = \frac{\partial l_c}{\partial p} + \frac{\partial l_c}{\partial w}\frac{dw}{dp} = \frac{4a(wy - 3p)}{w^2 \Lambda} \tag{26}$$

In this case, $dl_c/dp > 0$ if and only if $y > 3p/w$. Thus, a permanent sanction on resource exports reduces the war efforts of the countries only if the resource stock is sufficiently high. A current sanction increases the war efforts, while a future sanction reduces the war efforts. Which effect will dominate, it depends on the resource stock.

The above analyses imply that whether sanctions on resource exports will be effective in reducing war intensity depends on the types of sanctions. A temporary sanction is not effective, an anticipated future sanction might be effective, and finally the effect of permanent sanction is uncertain.

5 Uncertain Future Sanction

In section 3, we derive the equilibrium levels of conflict efforts without considering any possibility of future sanction. In this section the question is: if the warring nations anticipate that international community will impose a sanction, what happens to the levels of conflicts? In particular, we assume that the warring countries are uncertain about possible sanction, they only know the probability of sanction being imposed. For simplicity, we only examine the case when the second period sanction is uncertain and no sanction in the first period. Suppose, the countries consider that probability of future sanction is θ, and expected future price of resources under sanction is p_2'. In this case, the expected total income of country i will be:

$$\begin{aligned} E(I^i) = \theta \Bigg[& w_i L_i + w_i \left(\frac{p_1 - q_i p_2'}{w_i} \right)^2 + \frac{l_{ci}}{l_{ci} + l_{cj}} p_2' \left(y_i + y_j - 2\frac{p_1 - q_j p_2'}{w_j} \right) \\ & + w_i \left(\frac{p_a{}^2 \lambda_i{}^2 V_i}{w_i^2} \right) - w_i l_{ci} + (1-\theta)[w_i L_i + w_i \left(\frac{p_1 - q_i p_2}{w_i} \right)^2 \\ & + \frac{l_{ci}}{l_{ci} + l_{cj}} p_2 \left(y_i + y_j - 2\frac{p_1 - q_j p_2}{w_j} \right) + w_i, \left(\frac{p_a{}^2 \lambda_i{}^2 V_i}{w_i^2} \right) - w_i l_{ci} \Bigg], (i = 1, 2) \end{aligned} \tag{27}$$

Each government maximizes $E(I^i)$to choose l_{ci}. Then the first order condition for l_{ci} is:

$$\frac{l_{cj}}{(l_{ci}+l_{cj})^2}\theta p_2'\left(y_i+y_j-2\frac{p_1-q_i p_2'}{w_i}-2\frac{p_1-q_j p_2'}{w_j}-\frac{2p_2' l_{ci}}{l_{ci}+l_{cj}}\right)$$

$$+\frac{l_{cj}}{(l_{ci}+l_{cj})^2}(1-\theta)p_2\left(y_i+y_j-2\frac{p_1-q_i p_2}{w_i}-2\frac{p_1-q_j p_2}{w_j}-\frac{2p_2 l_{ci}}{l_{ci}+l_{cj}}\right)=w_i,\ (i=1,2) \quad (28)$$

Equation (28) gives us the reaction functions for the two countries. Using these, we get the following relationship between l_{c1} and l_{c2}:

$$w_1 l_{c1}=w_2 l_{c2}\Leftrightarrow l_{c2}=\frac{w_1}{w_2}l_{c1}$$

Using the above relationship, we can derive optimal l_{c1} and l_{c2} in terms of wage rates and exogenous parameters as follows:

$$\tilde{l}_{c1}=\frac{w_2}{(w_1+w_2)^2}D$$

$$\tilde{l}_{c2}=\frac{w_1}{w_2}\tilde{l}_{c1}=\frac{w_1}{(w_1+w_2)^2}D$$

where $$D=\theta p_2'\left(y_1+y_2-\frac{2p_1}{w_1}+\frac{2p_2'w_2}{w_1(w_1+w_2)}-\frac{2p_1}{w_2}+\frac{2p_2'w_1}{w_2(w_1+w_2)}-\frac{2p_2'}{w_1+w_2}\right)$$

$$+(1-\theta)p_2\left(y_1+y_2-\frac{2p_1}{w_1}+\frac{2p_2w_2}{w_1(w_1+w_2)}-\frac{2p_1}{w_2}+\frac{2p_2w_1}{w_2(w_1+w_2)}-\frac{2p_2}{w_1+w_2}\right).$$

Again, if we assume that two countries are symmetric (i.e., $w_1 = w_2 = w$), and at the initial equilibrium $p_1 = p_2 = p$, then the equilibrium war efforts of each country will be (see appendix A.7):

$$\tilde{l}_c=\frac{1}{4w^2}[p(2wy-3p)+\theta(p_2'-p_2)(2wy-3p+p_2')$$

Note, without any anticipated sanction the equilibrium war efforts of each country is:

$$l_c=\frac{p(2wy-3p)}{4w^2}$$

Since $p_2'<p_2$, and $2wy-3p>0$ (as $l_c>0$), $\tilde{l}_c<l_c$. Thus, probability of future sanction on both countries reduces the equilibrium war efforts of each country. The higher the probability of sanction, the lower the equilibrium war efforts. This result is consistent with our comparative static result in the case of certain future sanction on both countries that a future sanction reduces conflict efforts (see equation (23)).

6 Conclusion

In this paper, we developed a two-country, two-period general equilibrium model linking natural resources to inter-state war. Contrary to the existing literature, we consider resource extraction and wage rates to be endogenous. First of all, we examine the relative war efforts of two non-symmetric countries. We find that regardless of initial procession of resource stocks the war efforts of two countries will be same; a country with larger labor force exerts more war efforts; and a country with larger land endowment or higher productivity exerts lower war efforts (i.e., paradox of power). Second, we examine the effects of different types of international sanctions on war efforts of the two countries. We find that a temporary current sanction on both countries or even on one country will be counter-productive (i.e., increases the war intensity); an anticipated future sanction on both countries will reduce war intensity; whether an anticipated future sanction on one country will reduce war intensity depends on the level of resource stock; and finally the effect of a permanent sanction on both countries is uncertain and war intensity will fall only if the resource stocks of the countries are sufficiently high.

The broad policy prescription of our analysis is that while implementing trade sanction, the international community needs to work out the exact nature of the sanction, and a future sanction may be more effective than a current one. Current sanction can in fact increase war efforts. Furthermore, taking sides in a conflict by imposing sanction on one of the warring countries can increase war intensities.

Acknowledgments

We are grateful to an anonymous referee for helpful comments.

References

Acemoglu, D., Golosov, M., Tsyvinski, A., and Yared, P. 2012. "A Dynamic Theory of Resource Wars." *The Quarterly Journal of Economics* 127(1): 283–331.

Bakeless, J. E. 1921. *The Economic Causes of Modern War: A Study of the Period: 1878–1918*. New York: Mofatt, Yard, and Company.

Blattman, C., and Miguel, E. 2010. "Civil War." *Journal of Economic Literature* 48(1): 3–57

Becsi, Z., and Lahiri, S. 2007. "Bilateral war in a multilateral world: carrots and sticks for conflict resolution." *Canadian Journal of Economics* 40(4): 1168–1187.

Carter Center (2010). "Approaches to Solving Territorial Conflicts: Sources, Situations, Scenarios, and Suggestions." Mimeo. Carter Center.

Chassang, S., and Padró i Miquel, G. 2010. "Conflict and Deterrence under Strategic Risk." *Quarterly Journal of Economics* 125: 1821–1858.

Caselli, F., Morelli, M., and Rohner, D. 2013. "The Geography of Inter-State Resource Wars." NBER Working Paper No. 18978, Centre for Economic Performance, London School of Economics and Political Science.

Collier, P., and Hoeffler, A. 2007. "Civil War." In *Handbook of Defense Economics: Defense in a Globalized World,* Volume 2, eds. Todd Sandler, and Keith Hartley, 711–40. Amsterdam and Oxford: Elsevier, North-Holland.

Conconi, P., Sahuguet, N., and Zanardi, M. 2012. "Democratic Peace and Electoral Accountability." Mimeo. Université Libre de Bruxelles.

De Soysa, I.,Gartzke, E. and Grete Lie, T. 2011. "Oil, Blood, and Strategy: How Petroleum Influences Interstate Conflict." Mimeo. Norwegian University of Science and Technology, Trondheim, and UCSD.

Garfinkel, M.R., Skaperdas, S., and Syropoulos, C. 2015. "Trade and Insecure Resources." *Journal of International Economics* 95(1): 98–114

Gartzke, E. 2007. "The Capitalist Peace." *American Journal of Political Science* 51: 166–91.

Gartzke, E., and Rohner, D. 2011. "The Political Economy of Imperialism, Decolonization, and Development." *British Journal of Political Science* 41: 525–556.

Hirshleifer, J. 1991. "The Paradox of Power." *Journal of Economic Theory* 53(2): 304–327

Janus T. 2012. "Natural resource extraction and civil conflict." *Journal of Development Economics* 97: 24–31.

Lahiri, S. 2010. "Blood Diamond: International Policy Options for Conflict Resolution." *Indian Growth and Development Review* 3 (1): 5–20

Maoz, Z. and Russett, B. 1993. "Normative and Structural Causes of Democratic Peace, 1946-1986." *American Political Science Review* 87: 624–38.

Martin, P., Mayer, T., and Thoenig, M. 2008. "Make Trade not War?" *Review of Economic Studies* 75: 865–900.

Rohner, D., Thoenig, M., and Zilibotti, F. 2013. "War Signals: A Theory of Trade, Trust, and Conflict." *Review of Economic Studies* 80 (3): 1114–1147

Ross, M. 2004. "What do we know about natural resources and civil war?" *Journal of Peace Research* 41 (3): 337–356.

Syropoulos, C. 2006. "Trade Openness, International Conflict and the "Paradox of Power." Mimeo. Department of Economics and International Business, LeBow College of Business, Drexel University.

Skaperdas, S. and Syropoulos C. 2001. "Guns Butter, and Openness: On the Relationship Between Security and Trade." *American Economic Review* (*Papers and Proceedings)* 91, 353–357.

Van der Ploeg, F. 2011. "Natural Resources: Curse or Blessing?" *Journal of Economic Literature* 49(2): 366–420.

Appendix

A.1 Derivation of $\partial I^i / \partial l_{ci} > 0$:

$$\frac{\partial I^I}{\partial l_{cj}} = -\frac{l_{cj}p_2}{(l_{ci}+l_{cj})^2}2l_{ri}^{1/2} + \frac{l_{ci}}{(l_{ci}+l_{cj})^2}p_2(y_i + y_j - 2l_{rj}^{1/2}) - 2\frac{p_2{}^2 l_{ci} l_{cj}}{(l_{ci}+l_{cj})^3} - w_i$$

$$= \frac{l_{ci}}{(l_{ci}+l_{cj})^2}p_2(y_i + y_j - 2l_{ri}^{1/2} - 2l_{rj}^{1/2}) - 2\frac{p_2{}^2 l_{ci} l_{cj}}{(l_{ci}+l_{cj})^3} - w_i \qquad \text{(A-1)}$$

A.2 Derivation of (12):

From (11) we get two reaction functions of the two countries as follows:

$$\frac{l_{c2}}{(l_{c1}+l_{c2})^2}p_2(y_i + y_j - 2l_{r1}^{1/2} - 2l_{r2}^{1/2}) - 2\frac{p_2{}^2 l_{c1} l_{c2}}{w_2(l_{c1}+l_{c2})^3} = w_1 \qquad \text{(A-2)}$$

$$\frac{l_{c2}}{(l_{c1}+l_{c1})^2}p_2(y_i + y_j - 2l_{r1}^{1/2} - 2l_{r2}^{1/2}) - 2\frac{p_2{}^2 l_{c1} l_{c2}}{w_2(l_{c1}+l_{c1})^3} = w_2 \qquad \text{(A-3)}$$

From (A-2) and (A-3) we can derive the followings:

$$\frac{2p_2^2}{(l_{c1}+l_{c2})^3 w_2}+\frac{w_1}{l_{c2}}=\frac{2p_2^2}{(l_{c1}+l_{c2})^3 w_1}+\frac{w_2}{l_{c1}}\Rightarrow\frac{2p_2^2}{(l_{c1}+l_{c2})^3}\left(\frac{l_{c1}}{w_2}-\frac{l_{c2}}{w_1}\right)=\left(\frac{w_2}{l_{c1}}-\frac{w_1}{l_{c2}}\right)$$

$$\Rightarrow\frac{2p_2^2}{(l_{c1}+l_{c2})^3}\left(\frac{w_1 l_{c1}-w_2 l_{c2}}{w_1 w_2}\right)=\left(\frac{w_1 l_{c1}-w_2 l_{c2}}{w_1 w_2}\right)$$

$$\Rightarrow(w_1 l_{c1}-w_2 l_{c2})\left[\frac{2p_2^2}{(l_{c1}+l_{c2})^3 w_1 w_2}+\frac{1}{l_{c1}l_{c2}}\right]=0 \tag{A-4}$$

$$\Rightarrow(w_1 l_{c1}-w_2 l_{c2})=0$$

$$\Rightarrow l_{c2}=\frac{w_1}{w_1}l_{c1}$$

A.3 Derivation of (14):

With $p_1=p_2=p$ the optimal l_{ri} and l_{ci} are as follows:

$$l_{r1}=l_{r2}=\left(\frac{p}{w_1+w_2}\right)^2$$

$$l_{c1}=\frac{w_2}{w_1}l_{c2}=\frac{w_2}{(w_1+w_2)^2}B$$

where $$B=p_2\left(y_1+y_2-\frac{6p}{w_1+w_2}\right).$$

Then from (13) and (14) we get:

$$\frac{w_2}{(w_1+w_2)^2}B+\left(\frac{p}{w_1+w_2}\right)^2+\frac{p_a^2\lambda_1^2V_1}{w_1^2}-L_1=\frac{w_1}{(w_1+w_2)^2}B+\left(\frac{p}{w_1+w_2}\right)^2\frac{p_a^2\lambda_2^2V_2}{w_2^2}-L_2 \tag{A-5}$$

$$\Rightarrow L_1-\frac{w_2}{(w_1+w_2)^2}B-\frac{a_1}{w_1^2}=L_2-\frac{w_1}{(w_1+w_2)^2}B-\frac{a_2}{w_2{}^2}$$

$$\Rightarrow(L_1-L_2)+\frac{B}{(w_1+w_2)^2}(w_1-w_2)+\left(\frac{a_2}{w_2^2}-\frac{a_1}{w_1^2}\right)$$

where $a_1=p_a^2\lambda_1^2V_1, a_2=p_a^2\lambda_2^2V_2$,

A.4 Derivation of (16) and (17):

Totally differentiate (13) and using the symmetry (i.e., $w_1=w_2=w$, and $p_1=p_2=p$) we get:

$$\frac{B}{4w^2}dw_2-\frac{B}{4w^2}dw_1-\frac{B}{4w^2}dw_2+\frac{dB}{4w}+\frac{p}{w^2}dp_1-\frac{p}{w^2}dw_1-\frac{p^2}{2w^2}dp_2-\frac{p^2}{w^3}dw_2$$

$$+\frac{p^2}{w^3}dw_1+\frac{p^2}{4w^3}dw_1+\frac{p^2}{4w^3}dw_2-\frac{2a}{w^3}dw_2=0 \tag{A-6}$$

$$\Rightarrow\frac{p}{w^2}dp_1-\frac{p^2}{2w^2}dp_2-\left(\frac{B}{4w^2}+\frac{p^2}{4w^2}+\frac{2a}{w^3}\right)dw_1-\frac{p^2}{4w^3}dw_2+\frac{dB}{4w}=0$$

where $dB = -\frac{4p}{w}dp_1 + \frac{Bw + p^2}{wp}dp_2 + \frac{3p^2}{2w^2}dw_1 + \frac{3p^2}{2w^2}dw_2$

Substituting dB in to (A-6) and rearranging we get:

$$\alpha_1 dw_1 + \alpha_2 dw_2 = \beta_1 dp_1 + \gamma_1 dp_2 \tag{A-7}$$

where

$$\alpha_1 = \frac{B}{4w^2} + \frac{p^2}{4w^3} + \frac{2a}{w^3} - \frac{3p^2}{8w^3}$$

$$= \frac{p(2wy - 3p)}{4w^3} - \frac{p^2}{8w^3} + \frac{2a}{w^3}$$

$$= \frac{2p(2wy - 3p) - p^2 + 16a}{8w^3}$$

$$\alpha_2 = \frac{p^2}{4w^3} - \frac{3p^2}{8w^3} = -\frac{p^2}{8w^3}$$

$$\beta_1 = \frac{p}{w^2} - \frac{p}{w^2} = 0$$

$$\gamma_1 = \frac{Bw + p^2}{wp} - \frac{p}{2w^2}$$

$$= \frac{p(2wy - 3p) + p^2 - 2p^2}{8w^3}$$

$$= \frac{wy - 2p}{2w^2}$$

Similarly, totally differentiate (14) we can get:

$$\alpha_3 dw_1 + \alpha_4 dw_2 = \beta_2 dp_1 + \gamma_2 dp_2 \tag{A-8}$$

where $\alpha_3 = \alpha_2, \alpha_4 = \alpha_1, \beta_2 = \beta_1$, and $\gamma_2 = \gamma_1$ (because of symmetry).

A.5 Derivation of dw_i/dp_1 and dw_i/dp_2 ($i = 1, 2$):

From (16) and (17) we get:

$$\begin{pmatrix} \alpha_1 & \alpha_2 \\ \alpha_3 & \alpha_4 \end{pmatrix} \begin{pmatrix} dw_1 \\ dw_2 \end{pmatrix} = \begin{pmatrix} \beta_1 \\ \beta_2 \end{pmatrix} dp_1 + \begin{pmatrix} \gamma_1 \\ \gamma_2 \end{pmatrix} dp_2 \tag{A-9}$$

Now applying Cramer's rule from (A-9) we get: $\Delta.\frac{dw_1}{dp_1} = \beta_1\alpha_4 - \beta_2\alpha_2$, $\Delta.\frac{dw_2}{dp_1} = \beta_2\alpha_1 - \beta_1\alpha_3$, $\Delta.\frac{dw_1}{dp_2} = \gamma_1\alpha_4 - \gamma_2\alpha_2$, $\Delta.\frac{dw_2}{dp_{21}} = \gamma_2\alpha_1 - \gamma_1\alpha_3$, where $\Delta = \alpha_1\alpha_4 - \alpha_2\alpha_3 > 0$ for Walrasian stability of the labor market.

Note, Under symmetry and $p_1 = p_2 = p$, $\Delta = (\alpha_1 + \alpha_2)(\alpha_1 - \alpha_2) = \Lambda(p(2wy - 3p) + 8a)/16w^6$, where $\Lambda = p(2wy - 3p) - p^2 + 8a > 0$ (as $\Delta > 0$, and $2wy - 3p > 0$ which follows from $l_c = p(2wy - 3p)/4w^2 > 0$).

A.6 Effects of sanctions:

A.6.1 Derivation of dl_c/dp_1:

The change in wage rate ($w_1 = w_2 = w$) with respect to p_1 is:

$$\Delta.\frac{dw_1}{dp_1} = 0$$

since under symmetry $\beta_1 = \beta_2 = 0$. Under symmetry the conflict effort of each country is:

$$l_c = \frac{p_2(2wy - 4p_1 + p_2)}{4w^2}$$

Then, the change in conflict effort with respect to p_1 is:

$$\frac{dl_c}{dp_1} = \frac{\partial l_c}{\partial p_1} + \frac{\partial l_c}{\partial w}\frac{dw}{dp_1} = \frac{\partial l_c}{\partial p_1} = -\frac{p}{w^2} < 0 \qquad \text{(A-10)}$$

A.6.2 Derivation of dl_{c1}/dp_{11} :

If the price of period 1 in country 1 (p_{11}) changes only, then from (16) we get:

$$\beta_{11} = \frac{2p_1}{w_1^2} - \frac{2p_2 w_2}{w_1^2(w_1 + w_2)} - \frac{2p_2 w_2}{w_1(w_1 + w_2)^2} = \frac{2p}{w^2} - \frac{p}{w^2} - \frac{p}{2w^2} = \frac{p}{2w^2}$$

and from (17) we get:

$$\beta_{11} = -\frac{2p_2}{(w_1 + w_2)^2} = -\frac{p}{2w^2}$$

Then,

$$\frac{dw_1}{dp_{11}} = -\frac{dw_2}{dp_{11}} = \frac{\beta_{11}(\alpha_1 + \alpha_2)}{\Delta} = \frac{\beta_{11}}{\alpha_1 - \alpha_2}$$

where

$$\alpha_1 - \alpha_2 = \frac{2p(2wy - 3p) - p^2 + 16a}{8w^3} - \frac{p^2}{8w^3}.$$
$$= \frac{p(2wy - 3p) - p^2 + 8a}{4w^3} > 0$$

Then,

$$\frac{dw_1}{dp_{11}} = -\frac{dw_2}{dp_{11}} = \frac{2pw}{8a + p(2wy - 3p)} > 0$$

From (18) we can write,

$$\frac{dl_{c1}}{dp_{11}} = \frac{\partial l_{c1}}{\partial p_{11}} + \frac{\partial l_{c1}}{\partial w_1}\frac{dw_1}{dp_{11}} + \frac{\partial l_{c1}}{\partial w_2}\frac{dw_2}{dp_{11}} \qquad \text{(A-11)}$$

where

$$\frac{\partial l_{c1}}{\partial p_{11}} = -\frac{2p_2}{w_1(w_1 + w_2)} = -\frac{p}{2w^2}$$

$$\frac{\partial l_{c1}}{\partial w_1} = -\frac{2Bw_2}{(w_1+w_2)^3} + \frac{p_2 w_2}{(w_1+w_2)^2}\left[\frac{2(p_1-p_2)(w_1^2+2w_1w_2)+2p_1w_1^2}{w_1^2(w_1+w_2)^2} + \frac{4p_2}{(w_1+w_2)^2}\right]$$

$$= \frac{p(2wy-3p)}{4w^3} + \frac{3p^2}{8w^3} = \frac{9p^2-4pwy}{8w^3}$$

and

$$\frac{\partial l_{c1}}{\partial w_2} = -\frac{B(w_1-w_2)}{(w_1+w_2)^3} + \frac{p_2 w_2}{(w_1+w_2)^2}\left[\frac{2(p_1-p_2)(w_1^2+2w_1w_2)+2p_1w_1^2}{w_1^2(w_1+w_2)^2} + \frac{4p_2}{(w_1+w_2)^2}\right] = \frac{3p^2}{8w^3}$$

Then,

$$\frac{dl_{c1}}{dp_{11}} = \frac{\partial l_{c1}}{\partial p_{11}} + \frac{dw_1}{dp_{11}}\left(\frac{\partial l_{c1}}{\partial w_1} - \frac{\partial l_{c1}}{\partial w_2}\right)$$

$$= -\frac{p}{2w^2} + \frac{2pw}{8a+p(2wy-3p)}\left(\frac{9p^2-4pwy}{8w^3} - \frac{3p^2}{8w^3}\right)$$

$$= -\frac{p}{2w^2} - \frac{p^2(2wy-3p)}{2w^2[8a+p(2wy-3p)]} < 0 \tag{A-12}$$

A.6.3 Derivation of dl_{c2}/dp_{11}:

From (19) we can write,

$$\frac{dl_{c2}}{dp_{11}} = \frac{\partial l_{c2}}{\partial p_{11}} + \frac{\partial l_{c2}}{\partial w_1}\frac{dw_1}{dp_{11}} + \frac{\partial l_{c2}}{\partial w_2}\frac{dw_2}{dp_{11}} \tag{A-13}$$

Using the above derivations we can write (A-13) as:

$$\frac{dl_{c2}}{dp_{11}} = \frac{\partial l_{c2}}{\partial p_{11}} + \frac{dw_1}{dp_{11}}\left(\frac{\partial l_{c2}}{\partial w_1} - \frac{\partial l_{c2}}{\partial w_2}\right)$$

$$= -\frac{p}{2w^2} + \frac{2pw}{8a+p(2wy-3p)}\left(\frac{3p^2}{8w^3} - \frac{9p^2-4pwy}{8w^3}\right)$$

$$= -\frac{p}{2w^2} + \frac{p^2(2wy-3p)}{2w^2[8a+p(2wy-3p)]} \tag{A-14}$$

$$= \frac{-8ap}{2w^2[8a+p(2wy-3p)]} < 0$$

A.6.4 Derivation of dl_c/dp_2:

Under symmetry the change in wage rate with respect to p_2 is:

$$\frac{dw}{dp_2} = \frac{\gamma_1(\alpha_1-\alpha_2)}{\Delta} = \frac{\gamma_1}{\alpha_1+\alpha_2}$$

where $\gamma_1 = \frac{wy-2p}{2w^2}$, $\alpha_1+\alpha_2 = \frac{p(2wy-3p)-p^2+8a}{8w^3} = \frac{\Lambda}{4w^3} > 0$ (as $\Lambda > 0$ which has been shown in appendix A.5)

Thus,

$$\frac{dw}{dp_2} = \frac{2w(wy - 2p)}{\Lambda}$$

Then,

$$\begin{aligned}
\frac{dl_c}{dp_2} &= \frac{\partial l_c}{\partial p_2} + \frac{\partial l_c}{\partial w}\frac{dw}{dp_2} \\
&= \frac{wy-2p}{2w^2} + \frac{p(3p-wy)}{2w^3}\cdot\frac{2w(wy-2p)}{\Lambda} \\
&= \frac{wy-2p}{2w^2} + \frac{p(3p-wy)(wy-p)+p^2(wy-p)-2p^3}{\Lambda} \\
&= \frac{wy-p}{2w^2\Lambda}[\Lambda + 2p(3p-wy)+2p^2] - \frac{2p^3}{w^2\Lambda} \\
&= \frac{wy-p}{2w^2\Lambda}[p(2wy-3p)-p^2+8a+2p(3p-wy)+2p^2] - \frac{2p^3}{w^2\Lambda} \qquad \text{(A-15)} \\
&= \frac{wy-p}{2w^2\Lambda}[8a+4p^2] - \frac{2p^3}{w^2\Lambda} \\
&= \frac{4a(wy-p)+p^2(2wy-3p)}{w^2\Lambda} > 0
\end{aligned}$$

A.6.5 Derivation of dl_{c1}/dp_{21}:

If the price of period 2 in country 1 (p_{21}) changes only, then from (16) we get:

$$\begin{aligned}
\gamma_{11} &= \frac{Bw_2}{p_2(w_1+w_2)^2} + \frac{2p_2w_2^2}{w_1(w_1+w_2)^3} - \frac{2w_2}{w_1(w_1+w_2)}\left[\frac{p_1}{w_1} - \frac{w_2p_2}{w_1(w_1+w_2)}\right] \\
&= \frac{B}{4pw} + \frac{p}{4w^2} - \frac{p}{2w^2} \\
&= \frac{2wy-3p}{4w^2} - \frac{p}{4w^2} = \frac{wy-2p}{2w^2}
\end{aligned}$$

and from (17) we get:

$$\gamma_{12} = \frac{2p_2w_2}{(w_1+w_2)^3} - \frac{2p_2w_1}{(w_1+w_2)^3} = \frac{p}{4w^2} - \frac{p}{4w^2} = 0$$

Then,

$$\frac{dw_1}{dp_{21}} = \frac{\gamma_{11}\alpha_4}{\Delta} = \frac{w(wy-2p)[2p(2wy-3p)-p^2+16a]}{\Omega}$$

and

$$\frac{dw_2}{dp_{21}} = \frac{\gamma_{11}\alpha_3}{\Delta} = \frac{w(wy-2p)3p^2}{\Omega}$$

where $\Omega = \Lambda(p(2wy-3p)+8a) > 0$.

From (18) we get,

$$\frac{dl_{c1}}{dp_{21}} = \frac{\partial l_{c1}}{\partial p_{21}} + \frac{\partial l_{c1}}{\partial w_1}\frac{dw_1}{dp_{21}} + \frac{\partial l_{c1}}{\partial w_2}\frac{dw_2}{dp_{21}} \tag{A-16}$$

where

$$\frac{\partial l_{c1}}{\partial p_{21}} = \frac{Bw_2}{p_2(w_1+w_2)^2} + \frac{2p_2 w_2^2}{w_1(w_1+w_2)^3} = \frac{wy-2p}{2w^2}$$

Then,

$$\frac{dl_{c1}}{dp_{21}} = \frac{\partial l_{c1}}{\partial p_{11}} + \frac{\gamma_{11}}{\Delta}\left(\alpha_4\frac{\partial l_{c1}}{\partial w_1} - \alpha_3\frac{\partial l_{c1}}{\partial w_2}\right)$$

$$= \frac{wy-p}{2w^2} + \frac{8w^4(wy-p)}{\Omega}\left[\frac{2p(2wy-3p)-p^2+16a}{8w^3}.\frac{p(9p-4wy)}{8w^3} + \frac{p^2}{8w^3}.\frac{3p^2}{8w^3}\right]$$

$$= \frac{wy-p}{2w^2} + \frac{p(wy-p)}{\Omega}\left[\frac{(2p(2wy-3p)-p^2+16a)(9p-4wy)+3p^3}{8w^2}\right]$$

$$= \frac{wy-p}{8w^2\Omega}[4\Omega + (2p(2wy-3p)-p^2+16a)(9p-4wy)+3p^4]$$

$$-\frac{p^2}{8w^2\Omega}[(2p(2wy-3p)-p^2+16a)(9p-4wy)+3p^3]$$

$$= \frac{wy-p}{8w^2\Omega}[(p^3(2wy-3p)+12p^2a+8a(p(2wy-3p)-p^2+8a)]$$

$$+\frac{p^2}{8w^2\Omega}[(2p(2wy-3p)-p^2+16a)-3p(p(2wy-3p)-p^2+8a)]$$

$$= \frac{p^2}{8w^2\Omega}(p(2wy-3p)+8a)(wy-2p) \tag{A-17}$$

$$+\frac{p^2(2wy-3p)+16a(wy-p)}{4w^2\Omega}(p(2wy-3p)-p^2+8a) + \frac{8p^2a(wy-p)}{4w^2\Omega}$$

$$= \frac{4p^2(p(2wy-3p)+8a)(wy-2p)+\Theta}{4w^2\Omega}$$

where $\Omega = \Lambda(p(2wy-3p)+8a) > 0$, $\Theta = \Lambda[p^2(2wy-3p)+16a(wy-p)] + 8p^2a(wy-p) > 0$.

A.6.6 Derivation of dl_{c1}/dp_{21}:

From (19) we get,

$$\frac{dl_{c2}}{dp_{21}} = \frac{\partial l_{c2}}{\partial p_{21}} + \frac{\partial l_{c2}}{\partial w_1}\frac{dw_1}{dp_{21}} + \frac{\partial l_{c2}}{\partial w_2}\frac{dw_2}{dp_{21}} \tag{A-18}$$

where

$$\frac{\partial l_{c2}}{\partial p_{21}} = \frac{2p_{22}(w_2-w_1)}{(w_1+w_2)^3} = 0$$

Then,

$$\frac{dl_{c2}}{dp_{21}} = 0 + \frac{\gamma_{11}}{\Delta}\left(\alpha_4 \frac{\partial l_{c2}}{\partial w_1} - \alpha_3 \frac{\partial l_{c2}}{\partial w_2}\right) \tag{A-19}$$

$$= \frac{8w^4(wy-2p)}{\Omega}\left[\frac{2p(2wy-3p)-p^2+16a}{8w^3} \cdot \frac{p(9p-4wy)}{8w^3} + \frac{p^2}{8w^3} \cdot \frac{3p^2}{8w^3}\right]$$

$$= \frac{p^2(wy-2p)(8pwy-3p^2+48a)}{8w^2\Omega}$$

$$= \frac{p^2(p(2wy-3p)+6pwy+48a)(wy-2p)}{8w^2\Omega}$$

A.6.7 Derivation of dl_c/dp:

Under symmetry the change in wage rate with respect to permanent change in resource price will be:

$$\frac{dw}{dp} = \frac{\gamma_1(\alpha_1-\alpha_2)}{\Delta}$$

$$= \frac{\gamma_1}{\alpha_1+\alpha_2}$$

$$= \frac{2w(wy-2p)}{\Lambda}$$

In this case,

$$l_c = \frac{p(2wy-3p)}{4w^2}$$

$$\frac{\partial l_c}{\partial p} = \frac{wy-3p}{2w^2}$$

$$\frac{\partial l_c}{\partial w} = \frac{p(3p-wy)}{2w^3}$$

Then,

$$\frac{dl_c}{dp} = \frac{\partial l_c}{\partial p} + \frac{\partial l_c}{\partial w}\frac{dw}{dp}$$

$$= \frac{wy-3p}{2w^2} + \frac{p(3p-wy)}{2w^3} \cdot \frac{2w(wy-2p)}{\Lambda}$$

$$= \frac{wy-3p}{2w^2\Lambda}[\Lambda - 2p(wy-2p)]$$

$$= \frac{wy-3p}{2w^2\Lambda}[p(2wy-3p)-p^2+8a-2pwy+4p^2]$$

$$= \frac{4a(wy-3p)}{w^2\Lambda} \tag{A-20}$$

A.7 Uncertain future sanction:

When two countries are symmetric so that $w_1 = w_2 = w$, then

$$D = (\theta p_2' + (1-\theta)p_2)\left(\frac{2wy - 4p_1}{w}\right) + \frac{\theta p_2'^2 + (1-\theta)p_2^2}{w}$$

$$= (p_2 + \theta(p_2' - p_2))\left(\frac{2wy - 4p_1}{w}\right) + \frac{p_2{}^2 + \theta(p_2'^2 - p_2^2)}{w}$$

$$= (p_2 + \theta(p_2' - p_2))\left(\frac{2wy - 3p_1}{w}\right) + \frac{p_2{}^2 + \theta(p_2'^2 - p_2{}^2)}{w} - \frac{(p_2 + \theta(p_2' - p_2))p_1}{w}$$

If at initial equilibrium $p_1 = p_2$, then

$$D = (p_2 + \theta(p_2' - p_2))\left(\frac{2wy - 3p_1}{w}\right) + \frac{\theta(p_2' - p_2)(p_2' + p_2)}{w} - \frac{\theta(p_2' - p_2)p_1}{w}$$

$$= (p_2 + \theta(p_2' - p_2))\left(\frac{2wy - 3p_1}{w}\right) + \frac{\theta(p_2' - p_2)p_2'}{w}$$

$$= \frac{p_2}{w}(2wy - 3p_1) + \frac{\theta(p_2' - p_2)}{w}(2wy - 3p_1 + p_2')$$

Then the equlibrium war efforts of each coutry is:

$$\tilde{l}_c = \frac{1}{4w^2}[p(2wy - 3p_1) + \theta(p_2' - p_2)(2wy - 3p_1 + p_2')$$