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Natural resources and civil conflicts: Policy analysis under general equilibrium

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In this paper, a two-period general equilibrium model on the relationship between natural resources and civil conflict has been developed. Unlike existing literature, both resource extraction and wage rate are considered as endogenous during the conflict. The main purpose of the paper is to examine policy options for international community to limit the conflict intensity. It has been found out that a current international sanction will reduce civil conflict if the wage rate is fixed. However, when the wage rate is endogenous, the effect of current sanction is uncertain. Productivity improvement in agricultural sector may also subside the conflict. The study results also suggest that a bilateral piece-meal reduction in war efforts is the most effective policy for conflict reduction.

Key words: Natural resources, civil conflicts, general equilibrium, sanctions.

INTRODUCTION

Conflicts, especially civil conflicts, are not only common, but also pervasive. According to the World Development Report (2011), currently one-and-a-half billion people in the world live in areas affected by fragility, conflict, or large-scale, organized criminal violence. These conflicts have devastating socio-economic effects on the conflict-affected countries. For example, no low-income conflict-affected country has yet to achieve a single United Nations Millennium Development Goal (UN MDG).

Many studies have found out that natural resource abundance is one of the prime causes of civil conflict. The main reason is that natural resource rents are lucrative prizes for the winner of the conflict. However, sometimes warring parties also use natural resources as a source of funding during the conflict. Revenues from natural resource exports allow warring groups to hire soldiers and finance other costs of war (World Bank, 2003; Ross, 2004; Lujala et al., 2005, UN, 2005, Humphreys and Weinstein, 2008).

In the past two decades, seven African countries have endured brutal civil conflicts fueled by diamonds: Sierra Leone, Liberia, Angola, the Republic of Congo, Ivory Coast, the Central African Republic, and the Democratic Republic of Congo. Other examples include: gemstones have been linked to civil wars in Afghanistan, Myanmar (Burma), and Cambodia; drugs like opium and coca have fueled civil wars in Afghanistan, Myanmar, Colombia, and Peru; timber has played a vital role in the civil wars in

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Cambodia, Liberia, and the Republic of Congo; several oil producing states have experienced civil wars, including Angola, Colombia, Morocco, Nigeria, and Sudan (Le Billon, 2000; World Bank, 2003; Ross, 2004; Fearon, 2005; Humphreys, 2005; Janus, 2012).

The literature on the relationship between natural resources and civil wars was pioneered by Coller and Hoeflier (1998) and since then many scholars have studied this issue empirically (Fearon and Latin, 2003; Fearon, 2004 and 2005; Collier and Hoeflier, 2004; Montalvo and Reynal-Querol, 2005; Collier et al., 2009; Estenban et al., 2011; Le Billon, 2013; Koubi et al., 2014; Morelli and Rohner, 2015; Asal et al., 2016; Gawande et al., 2017). However, there are only few theoretical literatures on the linkage between natural resources and civil conflict.[1]

In this paper, we develop a new theoretical model of civil conflict. As opposed to most of the existing theoretical literature that treat natural resources as exogenous conflict prize, we consider natural resource extraction as endogenous during the conflict.[2] Majority of the existing models also consider civil war between two ethnic groups (one group might be ruler, other group is rebel), who have own labor-force and they use those labors either in war or in productive activities. These models often treat the groups as a unitary actor, ignoring the problem of collective action. But, there should be some incentives for the members of a group to participate in the war. Such incentives might include wages, opportunities to loot, promises of future reward, or physical protection from harm (Blattman and Miguel, 2010).[3]

To solve the problem of collective action, we consider war between two warlords, each of whom form a group by hiring labor from competitive labor market.[4] The market wage rate is a proxy for reward to join in the group. Warlords employ labor for two purposes: extraction of natural resources initially controlled by the them, and conflict to capture more resources. Thus, resource extraction is *endogenous* in the study model, under consideration.

The existing models consider a *partial equilibrium framework* in analyzing civil conflict. They consider that all agents in an economy engage in war; they do not consider the possibility that there may be some peaceful agents or sectors in the economy that are separate from the war sector. In the model, we consider a separate agriculture sector, which is not related to the war sector.[5] Agriculture sector also hires labor from competitive labor market. Thus, we consider *a general equilibrium framework* as opposed to partial equilibrium framework of the existing literature.

Civil conflict literature so far ignored the role labor market in conflict[6]. But in reality, most of the conflict involve large number of labor force, which may be transferred from productive sectors of the economy and affect the wage rate. Thus, wage rate may not be fixed during the war, rather may be endogenously determined in the labor market. In the model, wage rate is endogenously determined by war sector and agricultural sector.

We consider that two warlords fight for some labor-intensive resources.[7] The examples of labor-intensive resources are gemstones, drugs, timber, coffee, forests, fisheries etc. Most of these resources are renewable, geographically spread and require large amount of labor to extract.[8] We also consider a two-period model. In the first period two groups extract resources and fight with each other. If a group wins the war, in the second period it gets the remaining resource stock. Each warlord uses the resource revenue to finance the costs of extraction and costs of war. Depending on the levels of revenue and costs, the budget constraint of each warlord might be binding or non-binding. However, we consider that civil wars are expensive, and thus budget constraint of each warlord is binding.

By using the study model, we examine policy options for international community to limit the civil conflicts. The first policy we consider is sanctions on natural resource exports from conflict zone, which is known as 'blood diamond' policy. The model predicts that a sanction on resource exports will surely limit the conflict if wage rate is fixed (that is, unemployment in the economy). Note, Janus (2012) also finds the same result. However, we found that if wage rate is endogenous (that is, under full employment) and there are limited opportunities of employment in alternative sectors such as in agricultural sector, the conflict may increase due to sanction. Thus, unlike Janus (2012), we show that sanctions might be counter-productive.

A second policy option is productivity improvement in the agricultural sector (or other formal sectors). An increase in productivity will increase the labor demand in agricultural sector, which in turn can increase wage rate and can limit the conflict. Another policy would be to cut the access to the physical resource stock for the warring groups. But, it is very difficult for international community

[1]See, for example, Torvick (2002), Olsson and Fors (2004), Maxwell and Reuveny (2005), Holder (2006), Olsson (2007), Janus (2012).

[2]Janus (2012) first adopted this approach.

[3]Weinstein (2007) also shows that in Mozambique, Sierra Leone, and Peru rebel fighters were remunerated with looting of civilian property and drug sales.

[4]Grossman (1991, 1999) and Gates (2002) also consider this type of micro-economic approach of rebellion in which private gain motivates decisions.

[5]In fact this can represent any sector other than the war sector, like manufacturing sector.

[6]Hasan and Lahri (2015) consider the role of labor market in case of inter-state conflict.

[7]By labor-intensive resource we mean the resources that can be extracted by labor-intensive method.

[8]In Liberia and Sierra Leone, different types resources (e.g. rubber, timber, diamonds, and iron ore) and their geographical spread have lead to development of warlords and highly fragmented conflicts between a weak government and numerous armed groups controlling resources (Addison et al., 2002). A few studies show that even if gemstones and drugs are not linked to the onset of a conflict, these resources tend to lengthen the pre-existing conflict. Availability of these easily marketable resources also makes it harder to implement peace accord among warring parties (Ross, 2004).

to apply this policy, and it may decrease post-conflict welfare. Thus, if international community can negotiate with the warring groups and can convince them that both will be benefited by reducing the conflict efforts, conflict may diminish.

However, in extreme situation international community may apply this policy. Finally, the model shows that the most effective policy for conflict resolution would be bilateral piecemeal reduction in war efforts. Regardless of whether wage rate is fixed or endogenous, a mutual reduction in war efforts by the warring groups increases their welfare.

The model

We consider two risk-neutral warlords, who own and control some natural resource stocks, and fight with each other to capture more resources.[9] Both warlords hire labor from a competitive labor market for two purposes: extraction of resources and fighting. We consider two periods: in the first period two groups extract resources and fight with each other; and if a group wins the war, in the second period it gets the remaining resource stock. Resource revenues are used by the warlords to finance the costs of extraction and costs of war. We also consider that there is a part of the economy that is not affected directly by the conflict. In particular, there is a landlord in the economy, and she produces agricultural goods by hiring labor from the same labor market considered earlier. Thus, we consider a general equilibrium framework.

Let warlord *i*, *i* = 1,2, possesses an initial resource stock y_i, and hires l_{ri} amount of labor for extraction and l_{ci} amount of labor for fighting a war. The resource extraction function is for simplicity given by:

$$r_i = 2l_{ri}^{1/2}.$$

This function implies that extraction is diminishing with the amount of labor. Warlord *i's* winning probability in war is given by the conventional ratio-form contest success function:

$$q_i = l_{ci}/(l_{ci}+l_{cj}),\ j \neq i.$$ [10]

This function implies that for given amount of conflict labor of group *j*, the winning probability of warlord *i* increases with its' conflict labor and vice versa. The landlord, who produces agricultural goods, hires l_a amount of labor from the labor market. The agricultural production function is given by:

$$A = 2l_a^{1/2}V^{1/2},$$

where *V* is a fixed amount of land available to the landlord. Labors move freely between sectors, and as a result wage rate is the same in all sectors. The net expected return of warlord *i* in two periods is given by:

$$R_i = p_1 r_i - (wl_{ri} + wl_{ci}) + q_i p_2 (y_i + y_j - r_i - r_j)$$

$$= p_1(2l_{ri}^{1/2}) - (wl_{ri} + wl_{ci}) + \frac{l_{ci}}{l_{ci}+l_{cj}} p_2(y_i + y_j - 2l_{ri}^{1/2} - 2l_{rj}^{1/2}), i = 1,2;\ j \neq i, \quad (1)$$

where p_1 is the current international market price of resource, *w* is the wage rate, and $p_1 r_i - (wl_{ri} + wl_{ci})$ is the net revenue in period 1. The expected world market price of resources in period 2 is p_2, and $(y_i + y_j - r_i - r_j)$ is the resource stock that warlord *i* get at the beginning of the 2nd period if it wins the conflict. For simplicity, we also assume no discounting for period 2. Since q_i is the probability of winning for group *i* in the conflict, the expected revenue of the group in the 2nd period is $q_i p_2 (y_i + y_j - r_i - r_j)$. The warlord *i* maximizes expected return subject to the budget constraint. Since we assume that resource revenues are used to finance the costs of war, the budget constraint for each warlord can be written as:

$$p_1 r_i \geq (wl_{ri} + wl_{ci}),\ i = 1, 2.$$

The landlord also maximizes profit and the profit function is given by:

$$R_a = p_a(2l_a^{1/2}V^{1/2}) - wl_a, \quad (2)$$

where p_a is the market price of agricultural goods. Suppose the economy has a fixed supply of labor, denoted by *L*. The demand for labor comes from three sectors: resource extraction, conflict, and agricultural sectors. Thus, the labor market equilibrium condition is as follows:

$$l_{r1} + l_{r2} + l_{c1} + l_{c2} + l_a = L \quad (3)$$

Equations (1) to (3) describe our model. Now we will find the equilibrium conditions of the agents in our model. Consider that two warlords play a simultaneous move game. That is, each warlord *i* maximize the following Lagrangian function taking the extraction labor and conflict labor of other warlord as given:

[9]We implicitly assume that there is no formal government in the economy who can secure property rights. Due to the absence of governance and enforcement, ownership and control of resources is settled by open conflict or, equivalently by the threat of conflict.

[10]Many authors use this type of contest success function, e.g., Tullock (1980), Hirshleifer (1991), Skaperdas (1996), Ploeg & Rohner (2012).

$$\max L_i = p_1(2l_{ri}^{1/2}) - (wl_{ri} + wl_{ci}) + \frac{l_{ci}}{l_{ci}+l_{cj}} p_2(y_i + y_j - 2l_{ri}^{1/2} - 2l_{rj}^{1/2})$$
$$+ \gamma_i [p_1(2l_{ri}^{1/2}) - (wl_{ri} + wl_{ci})], i = 1,2; j \neq i, \quad (4)$$

where γ_i is the Lagrangian multiplier. The constraint above specifies that extraction and conflict are funded by selling extracted resources. We can consider two possible cases regarding budget constraint: budget constraint is binding, and budget constraint is non-binding. In practice, wars are costly and they require lot of resources to finance. Thus, in most cases, the budget constraint of the wars would be binding. In the model, the budget constraint is more likely to be binding when (1) the resource stock is higher, (2) the current resource price is lower, (3) the future resource price is higher, and (4) agricultural productivity is higher.[11] Assuming binding budget constraint, from (4) we derive the optimality conditions or first order conditions for l_{ri}, l_{ci}, and γ_i (i = 1,2) respectively as follows:[12]

$$p_1(1+\gamma_i) l_{ri}^{-1/2} = w(1+\gamma_i) + \frac{l_{ci}}{l_{ci}+l_{cj}} p_2 l_{ri}^{-1/2} \quad (5)$$

$$\frac{l_{cj}}{(l_{ci}+l_{cj})^2} p_2(y_i + y_j - 2l_{ri}^{1/2} - 2l_{rj}^{1/2}) = w(1+\gamma_i) \quad (6)$$

$$p_1(2l_{ri}^{1/2}) = (wl_{ri} + wl_{ci}) \quad (7)$$

Equation (5) implies that marginal benefit of extraction labor (in the left hand side) must equal marginal cost of extraction labor (in the right hand side). Marginal benefit of extraction equals the value of marginal product of extraction labor, while marginal cost equals wage cost of labor plus opportunity cost of extracting now instead of conserving it for the future. The opportunity cost of extraction is equal to the probability of winning the conflict times with the value of marginal product of labor in period 2. Equation (6) equates the marginal benefit of labor in conflict, which is the change in the likelihood of winning times the prize of winning the conflict, to the marginal cost of labor in conflict. Note, if budget constraint is binding, the value of resource in period 1 will exceed market price p_1 and will be equal to $p_1(1+\gamma_i)$, where γ_i is the shadow value of increased extraction as it loosens the constraint.

Similarly, cost of labor exceeds the market wage rate w and it is equal to $w(1+\gamma_i)$. Equation (7) shows the binding budget constraint that total labor costs of extraction and conflict cannot exceed the total revenue from extraction. For simplicity of the analysis, we assume that two warlords are *symmetric* (i.e., $y_1 = y_2$). Then the first order conditions for each warlord become:

$$p_1(1+\gamma) l_r^{-1/2} = w(1+\gamma) + \frac{1}{2} p_2 l_r^{-1/2} \quad (8)$$

$$\frac{1}{2l_c} p_2(y - 2l_r^{1/2}) = w(1+\gamma) \quad (9)$$

$$p_1(2l_r^{1/2}) = (wl_r + wl_c) \quad (10)$$

Using equations (8) to (10) we get following two equations:

$$4p_1 l_r^{1/2} - 3wl_r + wyl_r^{1/2} = p_1 y \quad (11)$$

$$l_c = \frac{2p_1 l_r^{1/2}}{w} - l_r \quad (12)$$

In this case, we don't have explicit solution for l_r and l_c. However, we have implicit solutions in terms of parameters as follows: $l_r(p_1, w, y)$ and $l_c(p_1, w, y)$.

In this economy, the landlord also maximizes her revenue by hiring labor from labor market. From (2) we get first order condition for profit maximization of the landlord as follows:

$$p_a l_a^{-1/2} V^{1/2} = w \quad (13)$$

Equation (13) implies that in equilibrium marginal benefit of agricultural labor (equal to the value of marginal product of labor) must be equal to marginal cost of labor (equal to wage rate). From (13) we get the optimal value of l_a as:

$$l_a = \frac{p_a^2 V}{w^2} > 0.$$

If there is *full employment* in the economy, then wage rate is endogenous. The wage rate is determined by the labor market equilibrium condition. With two symmetric warring groups the labor market equilibrium condition is as follows:

$$2l_r + 2l_c + l_a = L \quad (14)$$

Equation (14) determines the wage rate for the labor in this economy.

[11] budget constraint will be non-binding in the opposite cases.

[12] Variation in y_i, i = 1,2, across warlords means generally that we cannot rule out the possibility that one of the two agents will extract all resources in the first period so that $r_i = y_i$. However, to focus on the issue of concern, we assume an interior optimum. Note, for an interior equilibrium to exist any asymmetry between two warlords in initial resource stock y_i needs to be small.

Comparative statics: Policy analysis

International community frequently imposes sanctions on resource exports to reduce civil conflict related to natural resources. For example, sanctions have targeted countries experiencing civil war, such as Liberia, Rwanda, Sudan, Lebanon, Cambodia, and Yugoslavia (Escribà-Folch, 2010). Diamond embargo was imposed on warring groups of Ivory Coast, Sierra Leone, Liberia, and Angola to end conflicts related to diamond (Wallensteen et al., 2006). A sanction on resource exports reduces the export price that is received by the sanctioned country. Thus, we will examine how war efforts of the warring groups change with the change in resource price. We also examine how war efforts change with the change in agricultural price or productivity, and with the exogenous change in resource stock. We shall do these comparative static exercises separately for two cases: 1) when there is unemployment in the economy (the wage rate is fixed), and 2) when there is full employment in the economy (the wage rate is endogenous). In each case, first we examine how optimal choices of l_r, l_c, and l_a changes with exogenous changes in parameters (p_1, p_2, p_a, y), and then we discuss policy implications of the findings.

Unemployment

In many conflict-prone developing countries, unemployment is a common phenomenon. When there is unemployment in the economy, wage rate (*w*) is fixed. Then the conflict sector and non-conflict sector are not connected with each other. That is, our model can be called *partial equilibrium* one. Now we shall analyze what happens to equilibrium choices of l_r and l_c, when the parameters, p_1, p_2, and *y* change exogenously. Totally differentiating (11) and (12) we get:

$$\Lambda dl_r = (y - 4l_r^{1/2})dp_1 + (0)dp_2 + (p_1 - wl_r^{1/2})dy \quad (15)$$

$$dl_c = \left(\frac{2l_r^{1/2}}{w} + \frac{p_1 l_r^{-1/2} - w}{w}.\frac{\partial l_r}{\partial p_1}\right)dp_1 + (0)dp_2 + \left(\frac{p_1 l_r^{-1/2} - w}{w}.\frac{\partial l_r}{\partial y}\right)dy, \quad (16)$$

where

$\Lambda = 2p_1 l_r^{-1/2} - 3w + \frac{1}{2}wyl_r^{-1/2} > 0$ for stability of the Nash equilibrium.

From (15) and (16) we get:

$$\frac{\partial l_r}{\partial p_1} = \frac{y - 4l_r^{1/2}}{\Lambda} > 0, \ \frac{\partial l_c}{\partial p_1} = \frac{2l_r^{1/2}}{w} + \frac{p_1 l_r^{-1/2} - w}{w}.\frac{\partial l_r}{\partial p_1} > 0, \quad (17)$$

$$\frac{\partial l_r}{\partial p_2} = \frac{\partial l_c}{\partial p_2} = 0, \quad (18)$$

$$\frac{\partial l_r}{\partial y} = \frac{p_1 - wl_r^{1/2}}{\Lambda} > 0, \ \frac{\partial l_c}{\partial y} = \frac{p_1 l_r^{-1/2} - w}{w}.\frac{\partial l_r}{\partial y} > 0, \quad (19)$$

Where:

$p_1 l_r^{-1/2} - w = p_2 l_r^{-1/2}/2(1+\gamma) > 0$ from first order condition of each warlord's (see (8)) equilibrium, $p_1 - wl_r^{1/2} = l_r^{1/2}(p_1 l_r^{-1/2} - w) > 0$, and $y - 4l_r^{1/2} = wl_r^{1/2}/(p_1 l_r^{-1/2} - w) > 0$ (see appendix A.1). Equations (17) to (19) provided the following proposition:

Proposition 1: *When there is unemployment in the economy so that wage rate is fixed, (a) a temporary rise in resource price increases both extraction and conflict; (b) an increase in expected future price of resource does not affect extraction and conflict; (c) a rise in physical resource stock increases both extraction and conflict.*

A temporary rise in resource price in the current period leads to hiring more labor for extraction. This is logical because a rise in resource price increases the marginal benefit of labor in extraction. As the budget constraint is binding, conflict labor also increases in this case. With more resource revenue (as both price and extraction increases) warlords can employ more labor in conflict. However, the increase in extraction also tends to reduce the conflict labor as prize of conflict falls. The positive effects dominate negative effect, resulting in a net increase in conflict. The proposition1 suggests that when there is unemployment in the economy, a temporary current sanction that reduces the export price of resource decreases war intensity. Note, the study finding confirms Janus (2012) finding that under binding budget constraint current sanction is effective. Since budget constraint is binding in the current period, the future price does not affect extraction and conflict in our model. Thus, under binding constraint a sanction threat that reduces the future price of resource will not be effective in reducing conflict. An increase in physical resource stock increases extraction. Conflict also increases as prize of conflict increases. Thus, when there is unemployment in the economy, a reduction of resource stock can reduce the conflict. But, it is very difficult for international community to apply this policy, it will also decrease post-conflict welfare. However, in extreme situation international community may apply this policy.

Full employment

Now if we consider full employment in the economy, wage rate will be endogenous. Any exogenous policy changes will affect wage rate through labor market. In this case, the labor market equilibrium condition is as follows:

$$2l_r(p_1, w, y) + 2l_c(p_1, w, y) + l_a(p_a, w, V) = L \qquad (20)$$

Totally differentiating equation (20) we get:

$$\left(\frac{\partial l_r}{\partial w} + \frac{\partial l_c}{\partial w} + \frac{1}{2}\frac{\partial l_a}{\partial w}\right)dw = -\left(\frac{\partial l_r}{\partial p_1} + \frac{\partial l_c}{\partial p_1}\right)dp_1 - \left(\frac{\partial l_r}{\partial y} + \frac{\partial l_c}{\partial y}\right)dy - \frac{1}{2}\frac{\partial l_a}{\partial V}dV - \frac{1}{2}\frac{\partial l_a}{\partial p_a}dp_a \qquad (21)$$

where

$$\frac{\partial l_r}{\partial w} + \frac{\partial l_c}{\partial w} + \frac{1}{2}\frac{\partial l_a}{\partial w} = \frac{p_1 w l_r^{1/2} - 4p_1^2 - w l_a \Lambda}{w^2 \Lambda} = \frac{\Omega}{w^2 \Lambda}.$$

Note, for stability of equilibrium of the labor market, the coefficient of *dw* must be negative. Thus, $\Omega / w^2 \Lambda < 0 \Rightarrow \Omega = p_1 w l_r^{1/2} - 4p^2 - w l_a \Lambda < 0$. From (21) we derive the changes in *w* with respect to changes in p_1, y, and p_a as follows (Appendix A.2):

$$\frac{dw}{\partial p_1} = \frac{w^2(4l_r^{1/2} - y) + w(2wl_r^{1/2} - p_1 l_r^{-1/2} y)}{\Omega} > 0,$$

$$\frac{dw}{\partial p_a} = -\frac{p_a \Lambda}{\Omega} > 0,$$

$$\frac{dw}{\partial y} = -\frac{w^2(p_1 - wl_r^{1/2}) + wl_r^{-1/2}(p_1 - wl_r^{1/2})^2}{\Omega} > 0. \qquad (22)$$

where

$2wl_r^{1/2} - p_1 y l_r^{-1/2} < 0$, because $p_1 l_r^{-1/2} > w$ and $y > 2l_r^{1/2}$, as we have seen earlier.

In this case, a temporary rise in resource price increases the demands for both extraction and conflict labors which causes a rise in wage rate. An increase in agricultural productivity increases the wage rate by increasing the demand for agricultural labor. An increase in physical resource stock increases wage rate by increasing the demand for both extraction and conflict labors. Now we can do the comparative statics again in *general equilibrium framework*. Differentiating (20) with respect to p_1 and using (17) and (22) we get (see detail derivation in appendix A2):

$$\frac{dl_r}{dp_1} = \frac{\partial l_r}{\partial p_1} + \frac{\partial l_r}{\partial w}.\frac{dw}{dp_1} =$$
$$\frac{w(y - 4l_r^{1/2})}{\Omega}\left[\frac{2p_1(y - 4l_r^{1/2})}{\Lambda} - \frac{p_a{}^2 V}{w^2}\right], \qquad (23)$$

$$\frac{dl_c}{dp_1} = \frac{\partial l_c}{\partial p_1} + \frac{\partial l_c}{\partial w}.\frac{dw}{dp_1} =$$
$$\frac{p_1 y l_r^{-1/2} - 2wl_r^{1/2}}{\Omega}\left[\frac{2p_1(y - 4l_r^{1/2})}{\Lambda} - \frac{p_a{}^2 V}{w^2}\right], \qquad (24)$$

$$\frac{dl_a}{dp_1} = \frac{\partial l_a}{\partial p_1} + \frac{\partial l_a}{\partial w}.\frac{dw}{dp_1} = -\frac{p_a{}^2 V}{w^2}.\frac{dw}{dp_1} \qquad (25)$$

Note, $dl_r / dp_1 > 0$ and $dl_c / dp_1 > 0$, if and only if *V* is sufficiently large. Equations (23) to (25) provided the following proposition.

Proposition 2: *If there is full employment in the economy so that wage rate is endogenous, a temporary rise in resource price increases both extraction and conflict only if agricultural sector is sufficiently large, and decreases agricultural production.*

We know that a temporary increase in resource price increases demands for both extraction and conflict labors, if other things remain constant. However, an increase in resource price also increases wage rate, which tends to reduce the demands for both extraction and conflict labors. Which effect will dominate depends on the size of the agricultural sector. If agricultural sector is relatively small (that is, *V* is small) so that employment in agricultural sector is low, then a rise in resource price does cause a big increase in wage rate (as less labor available who can shift from agriculture sector to extraction and conflict sectors).

A big rise in wage leads to a big fall in the demand for extraction and conflict labor. Thus, net effects on the demands for extraction and conflict labors might be negative if wage rate rises enough. On the other hand, if agricultural sector is relatively large, change in wage rate will be small, then an increase in resource price may lead to increase in both extraction and conflict labors. A temporary increase in resource price decreases employment in agricultural sector by increasing the wage rate.

The proposition 2 implies that even if the budget constraint is binding, a current sanction may not reduce the conflict intensity if the wage rate is endogenous (that is, if there is full employment in the economy). The effects of sanction depend on the alternative employment opportunities, which in turn depend on the size the formal sector (agriculture sector in our model). If the formal sector is small so that employment opportunity is low, a sanction that reduces resource price may in fact increase the conflict. A reduction in resource price due to sanction reduces the demand for both extraction and conflict labors initially, as a result wage rate falls. If alternative employment opportunity is low, the fall in wage will be high. If the fall in wage rate is sufficiently high, the warlords will hire more labor for conflict that may exceed the initial reduction in demand for conflict labor. Thus, sanction on resource exports may be counter-productive under binding budget constraint. This finding contradicts Janus (2012) finding that under binding budget constraint a current sanction definitely reduces war intensity. Differentiating (20) with respect to *y* and using (19) and (22) we get (Appendix A2):

$$\frac{dl_r}{dy} = \frac{\partial l_r}{\partial y} + \frac{\partial l_r}{\partial w}.\frac{dw}{dy} =$$

$$\frac{w(p_1 - wl_r^{1/2})}{\Omega}\left[\frac{p_1 l_r^{-1/2}(wl_r - p_1 y)}{w\Lambda} - \frac{p_a{}^2 V}{w^2}\right] > 0, \quad (26)$$

$$\frac{dl_c}{dy} = \frac{\partial l_c}{\partial y} + \frac{\partial l_c}{\partial w}.\frac{dw}{dy} =$$

$$\frac{l_r^{-1/2}(p_1 - wl_r^{1/2})^2}{\Omega}\left[\frac{p_1(wl_r - p_1 y)}{\Lambda(p_1 - wl_r^{1/2})} - \frac{p_a{}^2 V}{w^2}\right], \quad (27)$$

$$\frac{\partial l_a}{\partial y} = \frac{\partial l_a}{\partial y} + \frac{\partial l_a}{\partial w}.\frac{dw}{dy} = -\frac{2p_a{}^2 V}{w^3}.\frac{dw}{dy} < 0 \quad (28)$$

where $p_1 y - wl_r = (p_1 y l_r^{-1/2} - wl_r^{1/2})l_r^{1/2} > 0$, as we have shown that $p_1 y l_r^{-1/2} - wl_r^{1/2} > 0$. Note, $dl_c / dy > 0$ if and only if *V* is sufficiently large. Equations (26) to (28) provided the following proposition.

Proposition 3: *When there is full employment in the economy so that wage rate is endogenous, a rise in physical resource stock increases extraction, increases conflict only if agricultural sector is sufficiently large, and decreases agricultural production.*

A rise in physical resource stock increases extraction directly, but decreases through rise in wage rate associated with it. In this case, direct effects dominate indirect effect resulting in a net increase in extraction. A rise in physical resource stock tends to increase the demand for conflict labor directly, while it tends to reduce the demand for conflict labor via increase in wage rate (as demands for both extraction and conflict labors rise). The magnitude of wage increase depends on the relative size of the agricultural sector. The larger the agricultural sector, the more number of labor employed in that sector. Then labors can be easily transferred from agriculture to war sector and the increment of wage will be low. In this case direct effect dominates indirect effects and there will be net increase in conflict labor. However, if agricultural sector is relatively small, then employment level in this sector will be low. In this case, wage increase will be high due to increased demand from war sector. If increase in wage is sufficiently high, the indirect effect may outweigh the direct effect which results a net decrease in conflict labor. An increase in resource stock decreases the employment in agricultural sector by increasing wage rate.

Proposition 3 implies that if the budget constraint is binding, but wage rate is endogenous, a reduction in physical resource stock may not decrease the war intensity. If formal sector is relatively small so that employment opportunity is low, a reduction in resource stock (by international action) may exacerbate conflict. Differentiating (20) with respect to p_a and using (22) we get (Appendix A.2):

$$\frac{dl_r}{dp_a} = \frac{\partial l_r}{\partial p_a} + \frac{\partial l_r}{\partial w}.\frac{dw}{dp_a} = \frac{\partial l_r}{\partial w}.\frac{dw}{dp_a} < 0, \quad (29)$$

$$\frac{dl_c}{dp_a} = \frac{\partial l_c}{\partial p_a} + \frac{\partial l_c}{\partial w}.\frac{dw}{dp_a} = \frac{\partial l_c}{\partial w}.\frac{dw}{dp_a} < 0, \quad (30)$$

$$\frac{dl_a}{dp_a} = \frac{\partial l_{ar}}{\partial p_a} + \frac{\partial l_a}{\partial w}.\frac{dw}{dp_a} = \frac{2l_a p_1(wl_r^{1/2} - 4p_1)}{p_a\Omega} > 0, \quad (31)$$

where:

$$wl_r^{1/2} - 4p_1 < wl_r^{1/2} - p_1 < 0.$$

Equations (29) to (31) provided the following proposition.

Proposition 4: *When there is full employment in the economy so that wage rate is endogenous, a rise in agricultural productivity or price decreases both extraction and conflict, and increase agricultural production.*

An increase in agricultural productivity or price increases the demand for agricultural labor directly. As a result, wage rate increases. A rise in wage rate reduces both the extraction and conflict. Increase in wage rate reduces the demand for agricultural labor also, but direct effect dominates indirect effect, resulting net increase in agricultural labor. This proposition 4 suggests that if the budget constraint is binding, an increase in agricultural productivity definitely reduces the conflict intensity. This implies that if alternative opportunities of employment and income increase in the economy, less people will engage in war activities.

Piecemeal reduction in war efforts

Now we will examine, starting from war equilibrium if both groups agree to reduce the war efforts mutually, whether their expected return increase or decrease. An increase in expected return implies an increase in welfare and vice versa. Now, we will not assume that two groups are symmetric.[13] When the budget constraint is binding, with optimal values of l_{ri} and, l_{ci}, i = 1,2, the maximum expected return of group 1 is:

$$R_1 = \frac{l_{c1}}{l_{c1}+l_{c2}} p_2(y_1+y_2-2l_{r1}^{1/2}-2l_{r2}^{1/2}), \tag{32}$$

and that of group 2 is:

$$R_2 = \frac{l_{c2}}{l_{c1}+l_{c2}} p_2(y_1+y_2-2l_{r1}^{1/2}-2l_{r2}^{1/2}). \tag{33}$$

Now if warlords negotiate with each other and agree to reduce war efforts mutually, we want to see what happens to their welfare. Again, we consider two scenarios: unemployment and full employment. When there is unemployment in the economy, wage rate is fixed. Then, totally differentiating (32) and using the first order conditions, we get (see Appendix A3):

$$dR_1 = -2(1+\gamma_2)wdl_{c2} \tag{34}$$

Similarly, totally differentiating (33) and using the first order conditions, we get:

$$dR_2 = -2(1+\gamma_1)wdl_{c1} \tag{35}$$

Equations (34) and (35) imply that if the budget constraint is non-binding and wage rate is fixed, a bilateral reduction of war efforts (that is, $dl_{ci} < 0$) increases the expected return of both warring groups. In this case, gain in return of each war group comes from two sources. Firstly, reduction in war efforts of group *j* decreases it's winning probability, and thus increases the return of group *i* (which is equal to $(1+\gamma_j)wdl_{cj}$). Secondly, extraction of group *j* also decreases due to decrease in war efforts as budget constraint is binding, which increases the return of group *i* further (by $(1+\gamma_j)(p_1 l_{rj}^{-1/2} - w)dl_{rj} = (1+\gamma_j)wdl_{cj}$). When there is full employment in the economy, wage rate is endogenous. Then, totally differentiating (32) and using first order conditions, we get:

$$dR_1 = -2(1+\gamma_1)(l_{r1}+l_{c1})dw - 2(1+\gamma_2)wdl_{c2} \tag{36}$$

[13]Even if two groups are non-symmetric, at Nash equilibrium, $l_{r1} = l_{r2}$ and $l_{c1} = l_{c2}$ in this case.

Similarly, totally differentiating (33) and using first order conditions, we get:

$$dR_2 = -2(1+\gamma_2)(l_{r2}+l_{c2})dw - 2(1+\gamma_1)wdl_{c1} \tag{37}$$

From labor market equilibrium condition we get (Appendix A3):

$$\Gamma dw = -wp_1 l_{r1}^{-1/2}(dl_{c1}+dl_{c2}), \tag{38}$$

Where:

$\Gamma = 2[w(l_{r1}+l_{c1}) - l_a(p_1 l_{r1}^{-1/2} - w)] < 0$ for stability of excess demand function for labor.

Equation (38) implies that wage rate decreases when warlords decrease their war efforts (that is, $dl_{c1} < 0$, $dl_{c2} < 0$). In this case, equations (36) and (37) imply that a bilateral reduction of war efforts definitely increase the returns of both warring groups. When wage rate is endogenous, a bilateral reduction in war efforts increases return of each group by two channels. First, reduction in number of soldiers and associated reduction of extraction by group *j* increases the return of group *i* (by $2(1+\gamma_j)wdl_{cj}$). Second, reductions of conflict labor and extraction labor reduce the wage rate and thus reduce the costs of both extraction and conflict. We derive following proposition from this section.

Proposition 5: *When the budget constraint is binding, a bilateral piecemeal reduction in war efforts unambiguously increases the welfare of each warring party both in the presence and absence of unemployment.*

Proposition (5) implies that a mutual reduction of war efforts unambiguously increase the welfare of the warring groups. Thus, if international community can negotiate with the warring groups and can convince them that both will be benefited by reducing the conflict, then conflict may be reduced. It suggests that diplomatic negotiation can be an effective tool for conflict resolution in the presence of information gap and commitment problem.

Conclusion

This paper aims to examine the policy options for international community to reduce the intensity of civil conflicts related to natural resources. For that purpose, we develop a general equilibrium model of civil conflict where two warlords fight with each other to capture resources, and there exists a separate agricultural sector which is not directly related to the war sector. In the study model, resource extraction is endogenous during the conflict, which is true for many real conflicts. Both warlords and agricultural sector compete for same labor force, making wage rate endogenous under full employment.

The findings of the paper have important policy implications for conflict resolution. The first policy we consider is sanction on exports of natural resources from conflict zone, which is known as 'blood diamond' policy. The study results suggest that under binding budget constraints of the warlords, a temporary current sanction will reduce the conflict intensity, if wage rate of the economy is fixed. Note, Janus (2012) also found the same result. However, we found out that if wage rate is endogenous and there are limited opportunities of employment in alternative sectors such as agricultural sector, the conflict intensity may increase due to current sanction. Thus, unlike Janus (2012), we show that sanctions might be counter-productive.

A second policy option is productivity improvement in the agricultural sector (or any other sector like manufacturing sector). An increase in productivity will increase the labor demand in agricultural sector, which in turn can increase wage rate and can limit the conflict. Another policy would be to decrease the physical resource stock. But, it is very difficult for international community to apply this policy, and it may decrease post-conflict welfare. However, in extreme situation international community may apply this policy. Finally, we found out that the most effective policy for conflict resolution would be bilateral piecemeal reduction in war efforts. The role of international community is thus to convince the warring groups to negotiate with each other. This result supports the conventional wisdom that diplomatic solution is the best to resolve any conflict.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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APPENDIX

A1

From (11) we get:

$$p_1 y - 4p_1 l_r^{1/2} = wyl_r^{1/2} - 3wl_r \Rightarrow p_1(y - 4l_r^{1/2}) = wl_r^{1/2}(y - 4l_r^{1/2}) + wl_r \Rightarrow (p_1 - wl_r^{1/2})(y - 4l_r^{1/2})$$
$$= wl_r \Rightarrow (y - 4l_r^{1/2}) = wl_r /(p_1 - wl_r^{1/2}) = wl_r^{1/2} /(p_1 l_r^{-1/2} - w) > 0.$$

A.2

Derivation of $\partial l_r / \partial w$, $\partial l_c / \partial w$, ***and*** $\partial l_a / \partial w$

$$\frac{\partial l_r}{\partial w} = \frac{3l_r - yl_r^{1/2}}{\Lambda} = -\frac{p_1(y - 4l_r^{1/2})}{w\Lambda} \quad \text{(A-1)}$$

$$\frac{\partial l_c}{\partial w} = \frac{p_1 l_r^{-1/2} - w}{w} . \frac{\partial l_r}{\partial w} - \frac{2p_1 l_r^{1/2}}{w^2} = \frac{p_1 l_r^{-1/2} - w}{w} . \frac{3l_r - yl_r^{1/2}}{\Lambda} - \frac{2p_1 l_r^{1/2}}{w^2}$$

$$= \frac{w(p_1 l_r^{-1/2} - w)(3l_r - yl_r^{1/2}) - 2p_1 l_r^{1/2}(2p_1 l_r^{-1/2} - 3w + \frac{1}{2}wyl_r^{-1/2})}{w^2\Lambda}$$

$$= \frac{9wp_1 l_r^{1/2} + w^2 yl_r^{1/2} - 2p_1 wy - 3w^2 l_r - 4p_1^2}{w^2\Lambda}$$

$$= \frac{w(4p_1 l_r^{1/2} + w^2 yl_r^{1/2} - 3wl_r) + 5p_1 wl_r^{1/2} - 2p_1 wy - 4p_1^2}{w^2\Lambda}$$

$$= \frac{p_1 wy + 5p_1 wl_r^{1/2} - 2p_1 wy - 4p_1^2}{w^2\Lambda} = \frac{5p_1 wl_r^{1/2} - p_1 wy - 4p_1^2}{w^2\Lambda}$$

$$= \frac{4p_1 l_r^{1/2}(w - p_1 l_r^{-1/2}) + p_1 w(l_r^{1/2} - y)}{w^2\Lambda} \quad \text{(A2)}$$

$$\frac{\partial l_a}{\partial w} = -\frac{2p_a^2 V}{w^3} \quad \text{(A3)}$$

Derivation of the changes in w ***with respect to changes in*** p_1, p_2 ***and*** y

$$\frac{dw}{dp_1} = -\frac{\frac{\partial l_r}{\partial p_1} + \frac{\partial l_c}{\partial p_1}}{\frac{\partial l_r}{\partial w} + \frac{\partial l_c}{\partial w} + \frac{1}{2}\frac{\partial l_a}{\partial w}} = -\frac{(y - 4l_r^{1/2})/\Lambda + (p_1 yl_r^{-1/2} - 2wl_r^{1/2})/w\Lambda}{-p_1(y - 4l_r^{1/2})/w\Lambda + [4p_1 l_r^{1/2}(w - p_1 l_r^{-1/2}) + p_1 w(l_r^{1/2} - y)]/w^2\Lambda - l_a / w}$$

$$= -\frac{(wy + p_1 yl_r^{-1/2} - 6wl_r^{1/2})/w\Lambda}{(p_1 wl_r^{1/2} - 4p_1^2 - wl_a\Lambda)/w^2\Lambda} = \frac{w(6wl_r^{1/2} - wy - p_1 yl_r^{-1/2})}{p_1 wl_r^{1/2} - 4p_1^2 - wl_a\Lambda}$$

$$= \frac{w^2(4l_r^{1/2} - y) + w(2wl_r^{1/2} - p_1 l_r^{-1/2} y)}{\Omega} \quad \text{(A4)}$$

$$\frac{dw}{dy} = -\frac{\frac{\partial l_r}{\partial y} + \frac{\partial l_c}{\partial y}}{\frac{\partial l_r}{\partial w} + \frac{\partial l_c}{\partial w} + \frac{1}{2}\frac{\partial l_a}{\partial w}} = -\frac{(p_1 - wl_r^{1/2})/\Lambda + [l_r^{-1/2}(p_1 - wl_r^{1/2})^2]/w\Lambda}{-p_1(y - 4l_r^{1/2})/w\Lambda + [4p_1 l_r^{1/2}(w - p_1 l_r^{-1/2}) + p_1 w(l_r^{1/2} - y)]/w^2\Lambda - l_a/w}$$

$$= -\frac{w^2(p_1 - wl_r^{1/2}) + wl_r^{-1/2}(p_1 - wl_r^{1/2})^2}{p_1 w l_r^{1/2} - 4p_1^2 - wl_a\Lambda}$$

$$= -\frac{w^2(p_1 - wl_r^{1/2}) + wl_r^{-1/2}(p_1 - wl_r^{1/2})^2}{\Omega} \quad \text{(A5)}$$

$$\frac{dw}{dp_a} = -\frac{\frac{1}{2}\frac{\partial l_a}{\partial p_a}}{\frac{\partial l_r}{\partial w} + \frac{\partial l_c}{\partial w} + \frac{1}{2}\frac{\partial l_a}{\partial w}} = -\frac{1/2(2p_a V/w^2)}{-p_1(y - 4l_r^{1/2})/w\Lambda + [4p_1 l_r^{1/2}(w - p_1 l_r^{-1/2}) + p_1 w(l_r^{1/2} - y)]/w^2\Lambda - l_a/w}$$

$$= -\frac{p_a\Lambda}{p_1 w l_r^{1/2} - 4p_1^2 - wl_a\Lambda}$$

$$= -\frac{p_a V}{\Omega} \quad \text{(A6)}$$

Differentiating (20) with respect to p_1 ***and*** y

$$\frac{dl_r}{dp_1} = \frac{\partial l_r}{\partial p_1} + \frac{\partial l_r}{\partial w}.\frac{dw}{dp_1} = \frac{y - 4l_r^{1/2}}{\Lambda} + \frac{p_1(4l_r^{1/2} - y)}{w\Lambda}.\frac{w^2(4l_r^{1/2} - y) + w(2wl_r^{1/2} - p_1 l_r^{-1/2} y)}{\Omega}$$

$$= \frac{y - 4l_r^{1/2}}{\Lambda} + \frac{p_1 w(y - 4l_r^{1/2})^2 + p_1(4l_r^{1/2} - y)(2wl_r^{1/2} - p_1 l_r^{-1/2} y)}{\Lambda\Omega}$$

$$= \frac{y - 4l_r^{1/2}}{\Lambda\Omega}[\Omega + p_1 w(y - 4l_r^{1/2}) - p_1(2wl_r^{1/2} - p_1 l_r^{-1/2} y)]$$

$$= \frac{y - 4l_r^{1/2}}{\Lambda\Omega}[p_1 w l_r^{1/2} - 4p_1^2 - wl_a\Lambda + p_1 wy - 6p_1 w l_r^{1/2} - p_1^2 l_r^{-1/2} y]$$

$$= \frac{y - 4l_r^{1/2}}{\Lambda\Omega}[p_1 wy - 4p_1^2 - wl_a\Lambda - 5p_1 w l_r^{1/2} - p_1 l_r^{-1/2}(4p_1 w l_r^{1/2} - 3wl_r - wyl_r^{1/2})]$$

$$= \frac{y - 4l_r^{1/2}}{\Lambda\Omega}[2p_1 wy - wl_a\Lambda - 8p_1 w l_r^{1/2}]$$

$$= \frac{w(y-4l_r^{1/2})}{\Lambda\Omega}[2p_1(y-4l_r^{1/2})-l_a\Lambda]$$

$$= \frac{w(y-4l_r^{1/2})}{\Omega}[\frac{2p_1(y-4l_r^{1/2})}{\Lambda}-l_a] \quad \text{(A7)}$$

$$\frac{dl_r}{dy} = \frac{\partial l_r}{\partial y} + \frac{\partial l_r}{\partial w}.\frac{dw}{dy} = \frac{p_1 - wl_r^{1/2}}{\Lambda} + \frac{3l_r - yl_r^{1/2}}{\Lambda}.-\frac{w^2(p_1 - wl_r^{1/2}) + wl_r^{-1/2}(p_1 - wl_r^{1/2})^2}{\Omega}$$

$$= \frac{p_1 - wl_r^{1/2}}{\Lambda\Omega}[\Omega - w^2(3l_r - yl_r^{1/2}) - wl_r^{-1/2} - (p_1 - wl_r^{1/2})(3l_r - yl_r^{1/2})]$$

$$= \frac{p_1 - wl_r^{1/2}}{\Lambda\Omega}[p_1wl_r^{1/2} - 4p_1^2 - wl_a\Lambda + w(3l_r - yl_r^{1/2})(-p_1l_r^{-1/2})]$$

$$= \frac{p_1 - wl_r^{1/2}}{\Lambda\Omega}[p_1wl_r^{1/2} - 4p_1^2 - wl_a\Lambda + (4p_1l_r^{1/2} - p_1y)p_1l_r^{-1/2}]$$

$$= \frac{p_1 - wl_r^{1/2}}{\Lambda\Omega}[p_1l_r^{-1/2}(wl_r - p_1y) - wl_a\Lambda]$$

$$= \frac{w(p_1 - wl_r^{1/2})}{\Omega}[\frac{p_1l_r^{-1/2}(wl_r - p_1y)}{w\Lambda} - l_a] \quad \text{(A8)}$$

$$\frac{dl_c}{dp_1} = \frac{\partial l_c}{\partial p_1} + \frac{\partial l_c}{\partial w}.\frac{dw}{dp_1} = \frac{p_1yl_r^{-1/2} - 2wl_r^{1/2}}{w\Lambda} + \frac{4p_1l_r^{1/2}(w - p_1l_r^{-1/2}) + p_1w(l_r^{1/2} - y)}{w^2\Lambda}.$$

$$\frac{w^2(4l_r^{1/2} - y) + w(2wl_r^{1/2} - p_1l_r^{-1/2}y)}{\Omega}$$

$$= \frac{1}{w^2\Lambda\Omega}[(p_1yl_r^{-1/2} - 2wl_r^{1/2})\Omega + p_1w^3(4l_r^{1/2} - y)^2 + w^2(4l_r^{1/2} - y)(p_1wl_r^{1/2} - 4p_1^2)$$

$$+ p_1w^2(4l_r^{1/2} - y)(2wl_r^{1/2} - p_1l_r^{-1/2}y) + w(p_1wl_r^{1/2} - 4p_1^2)(2wl_r^{1/2} - p_1l_r^{-1/2}y)]$$

$$= \frac{(y-4l_r^{1/2})}{w^2\Lambda\Omega}[p_1w^3(y - 4l_r^{1/2}) - w^2(p_1wl_r^{1/2} - 4p_1^2) - p_1w^2(2wl_r^{1/2} - p_1l_r^{-1/2}y)]$$

$$+ \frac{1}{w^2\Lambda\Omega}[(p_1yl_r^{-1/2} - 2wl_r^{1/2})(p_1wl_r^{1/2} - 4p_1^2 - wl_a\Lambda) + w(p_1wl_r^{1/2} - 4p_1^2)(2wl_r^{1/2} - p_1yl_r^{-1/2})]$$

$$= \frac{(y-4l_r^{1/2})}{\Lambda\Omega}(p_1wy - 7p_1wl_r^{1/2} + p_1^2l_r^{-1/2}y + 4p_1^2) + \frac{1}{w^2\Lambda\Omega}[-w^2l_a\Lambda(p_1yl_r^{-1/2} - 2wl_r^{1/2})]$$

$$= \frac{p_1(y-4l_r^{1/2})}{\Lambda\Omega}(wy - 7wl_r^{1/2} + p_1l_r^{-1/2}y + 4p_1) - \frac{l_a}{\Omega}(p_1yl_r^{-1/2} - 2wl_r^{1/2})$$

$$= \frac{p_1(y-4l_r^{1/2})}{\Lambda\Omega}(p_1 l_r^{-1/2} y + 3wl_r^{1/2} - 7wl_r^{1/2} + p_1 l_r^{-1/2} y) - \frac{l_a}{\Omega}(p_1 y l_r^{-1/2} - 2wl_r^{1/2})$$

$$= \frac{2p_1(y-4l_r^{1/2})}{\Lambda\Omega}(p_1 l_r^{-1/2} y - 2wl_r^{1/2}) - \frac{l_a}{\Omega}(p_1 y l_r^{-1/2} - 2wl_r^{1/2})$$

$$= \frac{(p_1 l_r^{-1/2} y - 2wl_r^{1/2})}{\Lambda\Omega}[2p_1(y-4l_r^{1/2}) - l_a\Lambda]$$

$$= \frac{(p_1 l_r^{-1/2} y - 2wl_r^{1/2})}{\Omega}[\frac{2p_1(y-4l_r^{1/2})}{\Lambda} - l_a] \qquad \text{(A9)}$$

$$\frac{dl_c}{dy} = \frac{\partial l_c}{\partial y} + \frac{\partial l_c}{\partial w}.\frac{dw}{dy} = \frac{l_r^{-1/2}(p_1 - wl_r^{1/2})^2}{w\Lambda} + \frac{4p_1 l_r^{1/2}(w - p_1 l_r^{-1/2}) + p_1 w(l_r^{1/2} - y)}{w^2\Lambda}$$

$$(-)\frac{w^2(p_1 - wl_r^{1/2}) + wl_r^{-1/2}(p_1 - wl_r^{1/2})^2}{\Omega}$$

$$= \frac{l_r^{-1/2}(p_1 - wl_r^{1/2})^2}{w\Lambda} - \frac{(p_1 wl_r^{1/2} - 4p_1^{\,2}) + p_1 w(4l_r^{1/2} - y)}{w^2\Lambda}.\frac{w^2(p_1 - wl_r^{1/2}) + wl_r^{-1/2}(p_1 - wl_r^{1/2})^2}{\Omega}$$

$$= \frac{(p_1 - wl_r^{1/2})}{w\Lambda\Omega}[l_r^{-1/2}(p_1 - wl_r^{1/2})\Omega - p_1 w^2(4l_r^{1/2} - y) - w(p_1 wl_r^{1/2} - 4p_1^{\,2}) - p_1 w(4l_r^{1/2} - y)$$

$$l_r^{-1/2}(p_1 - wl_r^{1/2}) - (p_1 wl_r^{1/2} - 4p_1^{\,2})l_r^{-1/2}(p_1 - wl_r^{1/2})]$$

$$= \frac{(p_1 - wl_r^{1/2})}{w\Lambda\Omega}[l_r^{-1/2}(p_1 - wl_r^{1/2})(p_1 wl_r^{1/2} - 4p_1^{\,2} - wl_a\Lambda) - p_1 w^2(4l_r^{1/2} - y) - w(p_1 wl_r^{1/2} - 4p_1^{\,2})$$

$$- p_1 w(4l_r^{1/2} - y)l_r^{-1/2}(p_1 - wl_r^{1/2}) - (p_1 wl_r^{1/2} - 4p_1^{\,2})l_r^{-1/2}(p_1 - wl_r^{1/2})]$$

$$= \frac{(p_1 - wl_r^{1/2})}{w\Lambda\Omega}[-wl_r^{-1/2}(p_1 - wl_r^{1/2})l_a\Lambda - p_1 w^2(4l_r^{1/2} - y) - w(p_1 wl_r^{1/2} - 4p_1^{\,2})$$

$$- p_1 w(4l_r^{1/2} - y)l_r^{-1/2}(p_1 - wl_r^{1/2})]$$

$$= \frac{(p_1 - wl_r^{1/2})}{\Lambda\Omega}[-l_r^{-1/2}(p_1 - wl_r^{1/2})l_a\Lambda + p_1 w(4l_r^{1/2} - y)p_1 l_r^{-1/2} - p_1 wl_r^{1/2} + 4p_1^{\,2}]$$

$$= \frac{(p_1 - wl_r^{1/2})}{\Lambda\Omega}[-l_r^{-1/2}(p_1 - wl_r^{1/2})l_a\Lambda + p_1 l_r^{-1/2}(p_1 y - wl_r)] = \frac{l_r^{-1/2}(p_1 - wl_r^{1/2})}{\Omega}[\frac{p_1(p_1 y - wl_r)}{\Lambda} - (p_1 - wl_r^{1/2})l_a]$$

$$= \frac{l_r^{-1/2}(p_1 - wl_r^{1/2})^2}{\Omega}[\frac{p_1(p_1 y - wl_r)}{\Lambda(p_1 - wl_r^{1/2})} - l_a] \qquad \text{(A10)}$$

Differentiating l_a with respect to p_a

$$\frac{dl_a}{dp_a} = \frac{\partial l_a}{\partial p_a} + \frac{\partial l_a}{\partial w}.\frac{dw}{dp_a}$$

$$= \frac{2l_a}{p_a} + (-)\frac{2l_a}{w}.(-)\frac{w^2 l_a\Lambda}{p_a\Omega}$$

$$= \frac{2l_a}{p_a\Omega}[\Omega + wl_a\Lambda]$$
$$= \frac{2l_a}{p_a\Omega}[(p_1 wl_r^{1/2} - 4p_1^2 - wl_a\Lambda) + wl_a\Lambda]$$
$$= \frac{2p_1 l_a}{p_a\Omega}(wl_r^{1/2} - 4p_1) \quad \text{(A11)}$$

A3

When w is fixed:

Totally differentiating (32) we get:

$$dR_1 = \frac{l_{c1}}{(l_{c1}+l_{c2})} p_2(-l_{r1}^{-1/2}dl_{r1} - l_{r2}^{-1/2}dl_{r2}) + \frac{l_{c2}}{(l_{c1}+l_{c2})^2} p_2(y_1 + y_2 - 2l_{r1}^{1/2} - 2l_{r2}^{1/2})dl_{c1}$$
$$- \frac{l_{c1}}{(l_{c1}+l_{c2})^2} p_2(y_1 + y_2 - 2l_{r1}^{1/2} - 2l_{r2}^{1/2})dl_{c2} \quad \text{(A12)}$$

Applying first order conditions of warlord 1 in to (A-12) we get:

$$dR_1 = -(1+\gamma_1)(p_1 l_{r1}^{-1/2} - w)dl_{r1} - (1+\gamma_2)(p_1 l_{r2}^{-1/2} - w)dl_{r2} + (1+\gamma_1)wdl_{c1} - (1+\gamma_2)wdl_{c2} \quad \text{(A13)}$$

Totally differentiating two budget constraints we get:

$$(p_1 l_{r1}^{-1/2} - w)dl_{r1} = wdl_{c1}, (p_1 l_{r2}^{-1/2} - w)dl_{r2} = wdl_{c2} \quad \text{(A14)}$$

Then, substituting (A14) in to (A13) we get:

$$dR_1 = -(1+\gamma_1)wdl_{c1} - (1+\gamma_2)wdl_{c2} + (1+\gamma_1)wdl_{c1} - (1+\gamma_2)wdl_{c2} = -2(1+\gamma_2)wdl_{c2} \quad \text{(A15)}$$

When w is endogenous

Totally differentiating two budget constraints we get:

$$(p_1 l_{r1}^{-1/2} - w)dl_{r1} = (l_{r1} + l_{c1})dw + wdl_{c1},\ (p_1 l_{r2}^{-1/2} - w)dl_{r2} = (l_{r2} + l_{c2})dw + wdl_{c2} \quad \text{(A16)}$$

Then, substituting (A-16) in to (A-13) we get:

$$dR_1 = -(1+\gamma_1)[(l_{r1} + l_{c1})dw + wdl_{c1}] - (1+\gamma_2)[(l_{r2} + l_{c2})dw + wdl_{c2}] + (1+\gamma_1)wdl_{c1} - (1+\gamma_2)wdl$$
$$= -2(1+\gamma_1)(l_{r1} + l_{c1})dw - (1+\gamma_2)wdl_{c2} \quad \text{(A17)}$$

Totally differentiating labor market equilibrium condition we get

$$dl_{r1} + dl_{r2} + dl_{c1} + dl_{c2} + dl_a = 0 \quad \text{(A18)}$$

Substituting (A-16) and value of dl_a in to (A-18) we get

$$(dl_{c1}+dl_{c2})+\frac{2(l_{r1}+l_{c1})}{p_1 l_{r1}{}^{-1/2}-w}dw+\frac{w}{p_1 l_{r1}{}^{-1/2}-w}(dl_{c1}+dl_{c2})-\frac{2l_a}{w}dw=0$$

$$\left[\frac{2(l_{r1}+l_{c1})}{p_1 l_{r1}{}^{-1/2}-w}-\frac{2l_a}{w}\right]dw=\frac{p_1 l_{r1}{}^{-1/2}}{p_1 l_{r1}{}^{-1/2}-w}(dl_{c1}+dl_{c2})$$

$$2[w(l_{r1}+l_{c1})-l_a(p_1 l_{r1}{}^{-1/2}-w)]dw=-wp_1 l_{r1}{}^{-1/2}(dl_{c1}+dl_{c2})$$

$$\Gamma dw=-wp_1 l_{r1}{}^{-1/2}(dl_{c1}+dl_{c2}) \qquad \text{(A19)}$$

where $\Gamma = 2[(wl_{r1}+l_{c1})-l_a(p_1 l_{r1}{}^{-1/2}-w)]<0$ for stability of excess demand function for labor.