International commodity prices and civil conflict*

Preliminary version

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Abstract

We develop a general equilibrium model to analyse the impact of (fluctuations of) the internationally set prices of mineral resources and tropical agricultural commodities on civil conflict. We focus on the specific labour market context in underdeveloped rural sub-Saharan African areas where highly valuable and easily appropriable natural resources constitute the only alternative economic assets to tropical agricultural commodities. We show that not only the price of mineral resources matters, prices of tropical agricultural commodities weigh just as much: a drop in agricultural prices increases the attractiveness of other 'economic' activities such as rebellion/warfare and can, therefore, trigger civil conflict. Furthermore, we demonstrate that the *occurrence* of civil war may carry a non-reversible component within it: due to its destructive nature on agricultural productivity, civil war lowers market wages, thus increasing the mining profits and lowering the threshold mineral prices (increasing the threshold crop prices) below (above) which conflict is not lucrative.

1 Introduction

The resurgence of civil conflicts after the Cold War has spurred a plethora of scientific – political and economic – and policy inspired literature (Collier et al. [2003]). In an attempt to organise and guide the vast literature, Sambanis [2002] provides a fundamental and exhaustive review of the major theoretical and empirical contributions in the field so far. If one thing, his review article clearly indicates that more research on the root causes of, and potential mechanisms that lead to, civil war is no less than necessary.

Among the many and diverse analyses of the potential risk factors for civil war outbreak, there appears to be some (theoretical) agreement on the importance of economic development and state strength (Sambanis [2002]; Lacina [2004]). One of the often cited factors that relates to both underdevelopment and weak states is the dependence on (certain) natural

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resources. It is, indeed, hard to disregard that a considerable share of today's conflicts occurs in areas where highly valuable and easily appropriable natural resources account for a considerable share of generated income.

The two predominant academic views that link natural resources to civil war tend to disagree on the linking mechanism. Among others, Fearon [2005] stresses the role of grievances: ethnic, religious or political groups rebel against, for example, oppression or inequality and find in natural resources the means to finance rebellion. Collier and Hoeffler [2004] and the likes, on the other hand, attribute a greater role to greed, the struggle for scarce resources. However relevant the true nature of the linking mechanism may be, the fact remains that rebel groups require resources to be viable: waging war requires armed forces and weaponry. Moreover, since warfare in itself does not create economic surplus (at best, whatever one group gains, the other loses) it must extract resources from other sectors in the economy. Obviously, sectors with excess profits, such as non-contestable markets (mining of diamond, coltan, oil ... where property rights are ill-defined) or illegal markets (drugs production, looting,...) are natural candidates for such extraction.

Mineral resources, however, have played a very different role in different areas of the world (Mehlum et al. [2006]): the discovery of valuable resources in the north-eastern provinces of the DR Congo had a dramatically different effect on the country's development than a similar discovery had in Australia or Canada.'[1] They can, therefore, not account for the full story. Another feature that many contemporaneous conflicts share, is that they're predominantly fought in sub-Saharan Africa (SIPRI [1998, 1999]), and more specifically in underdeveloped rural areas with very few economic alternatives to cultivating so-called 'tropical agricultural commodities': internationally traded (and consumed) agricultural commodities which are predominantly produced by a large number of small farmers in rural areas, almost exclusively in developing countries (coffee, cocoa, etc.).

This unenviable, but distinct position of sub-Saharan Africa surely justifies a context-specific theoretical analysis. Therefore, like e.g. Azam [2002] and Miguel et al. [2004], we present a local analysis and focus on those parameters that, we believe, characterise a considerable share of today's war-torn sub-Saharan African areas. On the one hand, we incorporate the above-mentioned coercive monopolies, a mining sector with imperfectly defined property rights. We develop a general equilibrium model where – as in Collier [2000] – we model rebel-groups as enterprises that compete for the monopolistic right to exploit mineral resources. The monopolistic profits that accrue to those who control the resource abundant territories allure other potential 'firms'. This entrance will endure as long as the expected conquered share of the monopolistic profits exceeds the costs of running a rebel organisation. In this sense, we endogenise the number of warring factions: the number of competing groups follows from the equilibrium zero profit condition. Moreover, competition between the competing 'firms' is not settled by the market (prices) but by the relative investments in arms and armed forces.

Like in the seminal paper by Grossman [1991], we stress the arbitrage between the returns from fighting (for the right to exploit the mining sector) and the returns from conventional economic activity. Besides the mineral sector, we incorporate an agrarian sector that produces tropical agricultural commodities. Therefore, we consider a very specific context: a

[1] Our model provides *an* explanation why this might be so.

poorly diversified economy where mining is the only conventional employment alternative to producing a tropical agricultural commodity,[2] and where besides mining or farming, labourers can choose to join a rebel group. The relative attractiveness of one sector to another then depends on the world market prices: be it the London Metal Exchange (minerals) or the New York Board of Trade (primary agricultural commodities),[3] the price setting is exogenous to the local market but determines the profits and hence the attractiveness of the different sectors.

Before discussing our main findings, it is worthwhile to briefly elaborate on a paper by Azam [2002] that is closely related to ours in spirit. Although the paper has a different focus than ours – it looks at the determinants of the levels of fighting and looting – Azam too starts from a sub-Saharan African context. He considers two ethnoregional groups that optimise their respective allocation of labour over production (farming), fighting and looting and each warlord or group's leader optimises his own group's utility. The three major aspects in which our analysis differs from his allow us to pinpoint the core specifications of our model. First, in order to allow for mineral resources to play a role, we add a productive (mining) rather than a predatory (looting) sector to the economy. Second, contrary to Azam (and the majority of contributions to this literature), we endogenise the equilibrium number of warring factions, conflicting groups. In our model, conflict between two groups is not predetermined by the core assumptions: whether conflict erupts and how many groups participate in it, depends on the equilibrium conditions of the model. Finally, by incorporating their entire ethnoregional group's utility, in Azam [2002] warlords can be viewed as the ethnoregional group's social planner. In contrast, we allow for a 'greedy' rebel leader: although rebel groups may (or may not) evolve around ethnic lines, the rebel leader only optimises his own payoff.

The model allows us to study how changes in technology and the world market prices of weapons, mineral resources and agricultural commodities have an impact on the investment in armed forces and weapons and on the viable number of rebel groups in a certain area. It is, therefore, well suited to study the onset and ending of conflict and the persistence of it (Hegre [2004]).

By looking at the effect of external price shocks on the sub-Saharan labour market, we incorporate an element of the modernisation theory into our model (Newman [1991]). The accelerated world economic development, which especially took place in the western world, intensified the search for natural resources. The fact that these resources happen to be abundant especially in certain underdeveloped areas in Africa implies that the costs and benefits from this modernisation process accrue to different parts of the world: while the western world enjoys/ed (strong) economic development, southern countries bear the

[2]Our focus on such a 'restricted' labour market is inspired by the fact that many of the least developed countries (most often war-torn too) rely heavily, that is for more than half their total export earnings, on three or fewer (in most cases just one) of such (a) tropical agricultural commodities (FAO [2004]). Our analyses is, therefore, complementary to Addison [2005], who investigates the importance of agriculture for development in more general terms, i.e., he also takes those agricultural commodities for which developing countries have to compete with developed countries (like cotton, sugar, corn...) into account.

[3]The New York Board of Trade provides the world's premier futures and options markets for several internationally traded agricultural commodities: cocoa, coffee, cotton, orange juice and sugar [`http://www.nybot.com/`]. The London Metal Exchange is the world's premier non-ferrous metals futures and options market [`http://www.lme.com/`].

costs of the struggle for the required mineral resources. First, we argue that the sustained economic development in the 'First World' countries may well have increased political tension in underdeveloped and mineral-rich 'Third World' countries. In other words, sub-Saharan Africa may have borne/suffered the cost of the sustained economic advancement of the high income countries: the increasing demand for primary commodities made the resource-rich but poor countries very vulnerable to the struggle for those resources.

Furthermore, we find that not only the price of mineral resources matters. Agricultural commodity prices matter just as much: a drop in these prices increases the attractiveness of other economic assets such as minerals. High relative prices of coffee, cocoa or palm oil would, therefore, offer sub-Saharan African labourers a valuable alternative to mining and, more importantly, to contesting the right to exploit the mining sector (which we call 'rebellion'). We thus provide a theoretical mechanism through which exogenous variables such as weather shocks and climatic hazards, but also international price shocks, can have an impact on civil conflict. By using variation in rainfall as an instrumental variable for income growth, Miguel et al. [2004, p. 727] find that "GDP growth is significantly negatively related to the incidence of civil conflict in sub-Saharan Africa" and that this relationship is "very strong." In an extensive empirical study of politically-motivated violence in Colombia between 1988 and 2004, Dube and Vargas [2007] show that a "higher value of [coffee] in international markets eases social unrest, while a lower value exacerbates politically-motivated violence." Furthermore, it is probably not a mere coincidence that the civil war in Côte d'Ivoire (Woods [2003]) and the genocide in Rwanda (Kamola [2007]) erupted shortly after a sharp decline in the world prices of, respectively, cocoa and coffee. Adverse weather or international price shocks in a primary agricultural commodity-dependent area, therefore, induce a similar impact on a labourer's labour-market trade-off as an increase in the price of mineral resources: mining (and the struggle for it) becomes relatively more attractive than farming. In other words, increasing mineral prices and falling agricultural commodity prices are two sides of the same coin and they are the main determinants of rebellion in our model.

The paper also provides an alternative explanation for the failure of some 'peace agreements' (Regan [2002]; Fearon [2004]). If the relative attractiveness of the economic alternatives (relative international prices) are unfavourable to hosting a peace agreement, it might not be useful to seal one. In other words, irrespective of what policy makers or warlords agree, as long as the economic trade-off for labourers is in favour of mining or joining rebel organisations, there will always be an incentive for some new warlord or shrewd rebel commander to exploit this labour supply.

Finally and maybe most importantly, we demonstrate that the *occurrence* of civil war may carry within itself a non-reversible component. If an increase in mineral prices, a decrease in agricultural commodity prices or a combination of the two, triggers civil conflict, a mere return of those prices to their pre-conflict level may not be sufficient to end the warfare. The mechanism behind this result is that a civil strife, due to its destructive nature, lowers the wages in the mining sector. This increases the mining profits and lowers the threshold mineral price (increases the threshold agricultural commodity prices) below which only a single rebel group is viable.

Thus, by exploring the causal link between adverse external price shocks and civil war in what could be viewed as a typical sub-Saharan context, we attempt to fill one of the

gaps in the current literature (Sambanis [2002, p. 230]). The paper is organised as follows: Section 2 presents the core assumptions and develops the theoretical model. Sections 3 and 4 elaborate on the impact of the international price setting of mineral resources and agricultural commodities on the onset and the persistence of civil conflicts, respectively. We conclude in Section 5.

2 A benchmark model

We assume an economy with N agents, where each agent offers inelastically one unit of labour and derives utility from his wage w. Note that, in order to preclude corner solutions, we assume that labour supply (N) is large enough to exclude the case where all labourers either work in the mining sector or join a rebellion army.

We consider a predominantly rural area with a lack of, or at least ill-defined, political rights (Elbadawi and Sambanis [2000, p. 250]). We analyse the specific context where economic activity and the corresponding value added are concentrated in two sectors: an agricultural sector and a mining sector. In particular, we focus on small scale agriculture (coffee/cocoa/palm oil) and small scale (artisanal) mining of alluvial diamonds, coltan, gold etc.

2.1 The agricultural sector

We assume that the agricultural sector has a decreasing returns to scale production function $f(l_a) = l_a^{\alpha}/\alpha$ (with $0 < \alpha < 1$) where l_a is the amount of labour input. The price for agricultural commodities (p_a) is exogenously determined on international markets. If we consider a fixed cost (F_a) of starting up agricultural activity, profits in the agricultural sector are determined by:

$$\pi_a = p_a f(l_a) - w l_a - F_a. \tag{1}$$

The FOC determines the optimal value of employment in the agricultural sector (l_a^*) with respect to wages in the sector (w):

$$p_a \frac{\partial f(l_a)}{\partial l_a} = w \leftrightarrow l_a^*(w) = \left[\frac{p_a}{w}\right]^{\frac{1}{1-\alpha}}. \tag{2}$$

Define π_a^* as the corresponding optimal profit in the agricultural sector:

$$\pi_a^* = \left[\frac{1-\alpha}{\alpha}\right], \frac{p_a^{\frac{1}{1-\alpha}}}{w^{\frac{\alpha}{1-\alpha}}} - F_a. \tag{3}$$

2.2 The mining sector

We focus on geographically concentrated mineral resources and consider a mining sector that allows for at most one firm. With perfect competition on the labour market, wages in the mining sector equal wages in the agricultural sector: w. Output of the mining sector is a continuous, increasing and concave function (decreasing returns to scale) of labour

employment in the mining sector: $f(l_m) = l_m^\beta/\beta$ (with $0 < \beta < 1$). The output price of mineral resources (p_m) is exogenous, i.e. determined on the international market.

With F_m representing the fixed costs of operating a mine (shovels, sieves, small pumps, etc.), profits for the mining firm are given by:

$$\pi_m = p_m f(l_m) - w l_m - F_m. \tag{4}$$

Optimising these profits with respect to employment in the mining sector (l_m) allows us to compute the optimal amount of labour,

$$p_m \frac{\partial f(l_m)}{\partial l_m} = w \leftrightarrow l_m^*(w) = \left[\frac{p_m}{w}\right]^{\frac{1}{1-\beta}}, \tag{5}$$

from which we get the optimal profit in the mining sector:

$$\pi_m^* = \left[\frac{1-\beta}{\beta}\right] \frac{p_m^{\frac{1}{1-\beta}}}{w^{\frac{\beta}{1-\beta}}} - F_m. \tag{6}$$

Note that profits in the mining sector are increasing in the (internationally determined) mineral prices ($\partial\pi_m^*/\partial p_m = f(l_m^*)$) and decreasing in the market wages ($\partial\pi_m^*/\partial w = -l_m^*$). Furthermore, excess profits ($\pi_m^* > 0$) will attract other groups to contend the ownership of the mining sector,[4] while if π_m^* is negative, the mining sector is not profitable and there will be no mining activity. We will restrict the analysis to the more interesting case where $\pi_m^* > 0$.

2.3 The 'rebel sector'

Competition for the acquisition of mineral exploitation rights is modelled as civil strife: a conflict between n rebellion groups. It is helpful to think of this competition as an alternative economic activity besides mining and farming: the 'rebel sector.'

Output of the rebel sector is the fraction of time (P_i) that a rebel group (i) controls and exploits the mining sector. An alternative interpretation may be that P_i defines the probability that group i controls the mining sector for the entire period, the victory probability. Input for the rebellion sector consists of labour (an army force l_i) and armoury (g_i). We assume that the price of weapons/guns (p_g) is determined on the international market while rebel wages are determined on the labour market. We assume that rebel groups recruit solely on the local labour market.[5] Thus, individuals can choose between mining, farming or enrolling in a rebel army. Equilibrium on the labour market requires that individuals are indifferent to working in either sector. In equilibrium, therefore, wages are the same across all sectors: w. The victory probability (P_i) of rebel group i is determined by its relative

[4]Note that the profitability of operating the mining sector is independent of who exploits it: π_m^* is taken as fixed and given by every player that might be interested in exploiting the mine.

[5]If a rebel group hires mercenaries, we assume that these soldiers have to be paid in advance and that we can, therefore, incorporate their wages in the costs of armoury.

'competitiveness', its war power relative to the competing rebel groups. The technology function $h(l_i, g_i) = l_i^{\gamma} g_i^{\delta}$ determines P_i:

$$P_i(\{l_j, g_j\}_{j \leq n}) = \frac{h(l_i, g_i)}{\sum_{j=1}^{n} h(l_j, g_j)}. \tag{7}$$

The function h is continuous, increasing and concave in both l_i and g_i, and P_i is similar to the Contest Success Function which was introduced by Hirshleifer [1995]. The sum of γ and δ then represents what Hirshleifer calls the 'decisiveness parameter': the degree to which increased investments in soldiers and weapons are translated in a higher victory probability.

The profits of rebellion for a rebel group are then given by:

$$\pi_i = P_i \pi_m^* - w l_i - p_g g_i - F_r, \tag{8}$$

where F_r are the fixed costs involved in setting up a rebel-group, recruitment costs for instance.[6] While taking the actions of other potential groups as given, each rebel group maximises its profits with respect to l_i and g_i:

$$\frac{\partial \pi_i}{\partial l_i} = 0 \quad \leftrightarrow \quad \frac{\partial P_i}{\partial l_i} \pi_m^* - w = 0, \tag{9}$$

$$\frac{\partial \pi_i}{\partial g_i} = 0 \quad \leftrightarrow \quad \frac{\partial P_i}{\partial g_i} \pi_m^* - p_g = 0. \tag{10}$$

Equations (9) and (10) allow us to derive the two implicit equations which determine the optimal values of l_i and g_i:

$$l_i^*(w) = \frac{\pi_m^*}{w} \gamma P_i \left(1 - P_i\right), \tag{11}$$

$$g_i^*(w) = \frac{\pi_m^*}{p_g} \delta P_i \left(1 - P_i\right). \tag{12}$$

We analyse the symmetric case where each rebel group has the same objective function and the optimal values of l_i and g_i are unique. For each rebel group i, j, therefore holds that $l_i = l_j = l_r$ and $g_i = g_j = g_r$. Then, $P_i = \frac{1}{n}$ and we can compute the equilibrium number of 'competing' groups by substituting (l_r^*) and (g_r^*) into equation (8). Introducing $\lambda = \delta + \gamma$, profits for a rebel group are given by:

$$\pi_r^* = \frac{1}{n} \pi_m^* \left[1 - \lambda(1 - \frac{1}{n})\right] - F_r. \tag{13}$$

The condition for rebel groups to enter the civil strife 'sector' is that these profits are positive, i.e.:

$$\pi_r^* \geq 0 \quad \leftrightarrow \quad -F_r + \frac{1}{n} \pi_m^* (1 - \lambda) + \left[\frac{1}{n}\right]^2 \pi_m^* (\lambda) \geq 0. \tag{14}$$

[6] Collier and Hoeffler [2000] discuss these costs at large in a draft version, where they assume that recruitment costs are higher if a rebel group can not recruit along ethnic or religious lines.

The zero-profit condition for the rebel sector ($\pi_r^* = 0$) generates one strictly positive (real) root:

$$\frac{1}{n'} = -\frac{1-\lambda}{2(\lambda)} + \sqrt{\left[\frac{1-\lambda}{2(\lambda)}\right]^2 + \frac{F_r}{\pi_m^*}\frac{1}{\lambda}}. \tag{15}$$

The equilibrium/viable number of rebel groups is the greatest integer n^* smaller than n' which satisfies equation (15). Hence, it will probably be the case that rebel organisations make strictly positive profits. We assume that these excess profits accrue to the rebel leader, who is taken to be a member of the rebel army: the rebel leader receives a wage w, increased with these excess profits. As consumption prices are exogenously determined in our model, the (potentially) resulting excess consumption of this rebel leader will have no equilibrium consequences.

From equation (13) we can derive the condition for at least n rebel groups to compete, in terms of p_m and w. Assume that $\lambda \leq \frac{n}{n-1}$, then remark that

$$\frac{1}{n}\pi_m^*\left[1-\lambda(1-\frac{1}{n})\right] - F_r \geq 0 \leftrightarrow w \leq \frac{p_m^{\frac{1}{\beta}}}{\left[\frac{\beta}{1-\beta}\left(\frac{nF_r}{1-\lambda(1-\frac{1}{n})} + F_m\right)\right]^{\frac{1-\beta}{\beta}}} \tag{16}$$

will be satisfied for either high values of p_m or low values of w.

2.4 Clearing on the labour market

We assume production in both the agricultural and the mining sectors, i.e., both l_a and l_m are strictly positive. We can now impose an equilibrium condition: the equilibrium wage results from clearing on the labour market.

Free entry in the agricultural sector implies that as long as $\pi_a^* > 0$, firms will enter the sector (which increases wages), while as long as $\pi_a^* < 0$, firms leave the sector (which decreases wages). Therefore, in equilibrium, it is required that $\pi_a^* = 0$. The market clearing wage is then determined by:

$$w^* = \left[\frac{1-\alpha}{\alpha F_a}\right]^{\frac{1-\alpha}{\alpha}} p_a^{\frac{1}{\alpha}}. \tag{17}$$

Remark that the equilibrium market wage (w^*) is increasing in the prices for agricultural commodities (p_a).

3 The outbreak of civil war

Straightforward comparative static analysis unveils the potential impact on poor but resource-rich rural sub-Saharan African areas of price fluctuations on the respective international markets.

First, note that the mining sector needs to be sufficiently profitable for more than one rebel group (i.e. $n \geq 2$) in order to generate what we call a civil war. Formally, civil war requires that condition (14) is satisfied for $n \geq 2$. Since the left-hand side of inequality (14)

is decreasing in n, if a certain π_m^* satisfies inequality (14) for $n > 2$, it satisfies the inequality for $n = 2$ as well. Obviously, if the mining sector is profitable for more than two rebel groups, it should be profitable for two groups too. In the remaining calculus, therefore, we will assume $n = 2$. A civil war then requires that:

$$\pi_m^*(2 - \lambda) - 4F_r \geq 0.$$

A necessary condition for this inequality to hold is that $\lambda < 2$, in which case it is useful to rewrite condition (14) as:

$$\pi_m^* \geq \frac{4F_r}{2 - \lambda}. \tag{18}$$

The subsequent sections elaborate on how some pertinent exogenous variables may influence this condition and, therefore, the potential onset/offset of civil conflict.

International mineral prices

An increase in the international prices of mineral resources (p_m) will have a positive effect on π_m^*. Therefore, an increase in p_m may trigger a civil war.

The intuition behind this result is straightforward: on the one hand an increase in p_m increases the costs of running a rebel organisation ($w^* l_r + p_g g_r = \frac{1}{4}\lambda\pi_m^*$) while on the other hand it increases the profitability of mining and, therefore, a rebel organisation's potential income ($\frac{\pi_m^*}{2}$). Since we assume that $\lambda < 2$, the increased potential income is higher than the increased costs.

Policy Implication 1. *A tax on mineral resources may be an effective tool to prevent civil conflict in poor but resource-rich countries.*

Low mineral resource prices reduce the risk of a civil war in rural areas with few economic alternatives. Since prices are set on international markets, the international community may agree to impose a tax on the sales of mineral resources. Such a tax would reduce the price p_m to $p_m(1-t)$. By the implicit function theorem we can derive the marginal effect of such a tax (for constant w) on the profits: $\partial\pi_m^*/\partial t = -pf(l_m^*)$. It should, however, be acknowledged that especially with easily accessible and lootable resources, tax evasion is probably, if avoidable, a legitimate concern.

International agricultural commodity prices

From equation (17) we know that a decrease in the agricultural commodity prices (p_a) leads to a decrease in the wage w. In a similar way as the increase in the international prices of mineral resources, a decrease in the agricultural commodity prices has a double impact on the profits of the rebel groups. While increasing the profits of mining (π_m^*) and, therefore, a rebel organisation's potential income ($\frac{\pi_m^*}{2}$), it also increases the optimal size of a rebel organisation, and hence also its cost ($w^* l_r + p_g g_r = \frac{1}{4}\lambda\pi_m^*$). Again, with $\lambda < 2$, the total increase in potential income is higher than the total increase in potential costs.

Note that due to the constant scale elasticity-assumption, w^* only affects the rebel group's trade-off through its impact on π_m^*, not through its impact on the army wages.

Policy Implication 2. *High(er) prices for agricultural commodities can be an effective tool to prevent conflict in poor but resource-rich countries.*

In order to reduce its proneness to conflict, a country would favour low profits in the mining sector. The current model shows that not only low international prices for mineral resources, but high international prices for agricultural commodities too, can serve that goal. Which tool serves best will depend on the various production technologies in the economy and, probably even more so, on the implementing institution. In any case, we hope to show that besides taxing mineral resources, the international community can also try to manipulate the international prices for agricultural commodities in order to mitigate a rural area's proneness to conflict.

A weapon embargo

In a strict sense, a weapon embargo implies that no rebel group can purchase weapons: each rebel group therefore takes the amount $g = 0$ as given and optimises its expected profit with respect to l. Condition (14) then changes to:

$$\frac{1}{2}\pi_m^* - \left[\frac{1}{4}\gamma\pi_m^* + F_r\right] \geq 0. \tag{19}$$

Maybe rather surprisingly, with constant scale-elasticity, which implies that $\gamma < \lambda$, instead of preventing it, a watertight weapon embargo may well lead to civil strife. The intuition is that an effective embargo lowers the optimal size of a rebel group while it does not affect the expected revenue. Therefore, it increases the expected profits of rebellion. Without constant scale-elasticity, the effect is undetermined.

Besides this direct effect, it should be stressed that the availability of weapons also has an indirect effect on civil war. As will be shown in section 4, regardless of the specification of the scale-elasticity, the availability of weapons may lead to larger persistence effects once civil war breaks out.

Note, however, that considering the history of weapon embargoes, water-tightness may not be the most realistic assumption (Tierney [2005]). Especially in poor third world countries, where wars are primarily fought with small arms, the legal prohibition of the arms-trade is more likely to merely restrain the access to weapons and, thereby, to increase their price (p_g). Surprisingly again, with constant scale-elasticity, the price of weapons has no influence on the constraint that determines the outbreak of civil war. The current model therefore argues that, at best, an embargo is irrelevant.

Policy Implication 3. *A weapon embargo is not effective in preventing or ending civil conflict.*

4 The persistence of civil wars

So far, the analysis was static. A civil war, however, has a devastating impact on the stocks of physical and human capital in the economy. Capital flight, the destruction of

infrastructure and casualties of war, especially in the economically productive age range, reduce the economic potential of war-torn areas dramatically (Imai and Weinstein [2000]).

In order to incorporate this negative impact of civil war into our model, we allow for shifting productivity in the agricultural sector[7] (Fulginiti et al. [2004]). During civil war we assume less capital intensive agricultural commodity production in less accessible areas (because of, e.g., hazardous transportation) with less productive labourers (children, elderly).

Assume that at time $t \in [0, \infty[$ civil war destroys a fraction $1 - \sigma(t)$ of the agricultural production, with $\sigma(.) : [0, \infty[\rightarrow [0, 1]$. The function $\sigma(.)$ represents the fraction of an economy's potential agricultural production that is actually produced. A rise in σ has similar implications as an increase of the agricultural price p_a. Therefore, by equation (16), an increase in σ induces an increase in the equilibrium wage w^*. Let $\dot{\sigma}(t) = \frac{\partial \sigma(t)}{\partial t}$ and assume that there exists a 'lower bound' $\sigma_l \in]0, 1[$ such that:

$$\begin{cases} \dot{\sigma}(t) > 0 \text{ if and only if } n \leq 1 \text{ and } \sigma(t) < 1, \\ \dot{\sigma}(t) < 0 \text{ if and only if } n > 1 \text{ and } \sigma \geq \sigma_l, \\ \dot{\sigma}(t) = 0 \text{ if and only if } n \leq 1 \text{ and } \sigma(t) = 1 \text{ or } n > 1 \text{ and } \sigma(t) = \sigma_l. \end{cases} \tag{20}$$

This means that $\sigma(t)$ decreases over time as long as there is a civil war (until the lower bound is reached) and increases during periods of peace. Therefore, the longer the civil war lasts, the smaller becomes the fraction of potential output that is actually realised.

The dynamics of these productivity shifts are illustrated in figure (1), which displays the profits of mining (π_m^*) as a function of the price of mineral resources (p_m). $\pi_m(\sigma_l)$ and $\pi_m(1)$ show the profits of mining for the border-levels of agricultural productivity, during war and peace respectively.

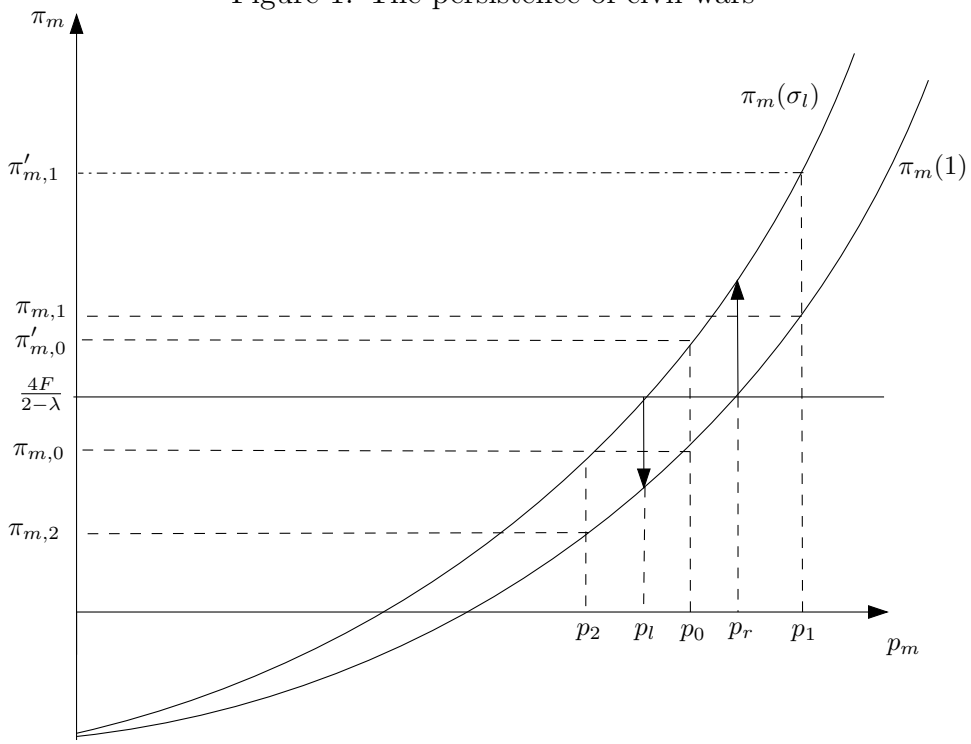
Assume an increase in the price of mineral resources on the international market from p_0 to p_1, a price which is higher than the threshold-price p_r at which rebellion shifts to be viable for more than one group. Assume, therefore, a peaceful economy where mining generates insufficient added value to support two or more rebel groups ($\pi_{m_0} < \frac{4F_r}{2-\lambda}$) that, by the (mis?)fortunes of a price increase for mineral resources on the international market, turns into a conflict economy where two or more groups would find an interest in exploiting the mine ($\pi_{m_1} \geq \frac{4F_r}{2-\lambda}$). The higher mineral prices increase the mining profits from π_{m_0} to π_{m_1} and lead to the entrance of a second rebel group. The emerging conflict causes destruction of agricultural output: the profit function shifts from $\pi_m(1)$ to $\pi_m(\sigma_l)$. The resulting lower mining wages then increase the profits of mining from π_{m_1} to π'_{m_1}.

It is readily seen from figure (1) that reversing the process will require a much greater decrease in mineral prices than a mere return to the pre-war level: a decrease in mineral prices from p_1 to p_0 keeps the mining profits above the threshold ($\pi'_{m_0} \geq \frac{4F_r}{2-\lambda}$) and therefore does not initiate a return to the pre-war level of agricultural productivity. For peace to return, prices of minerals would have to drop below p_l, the price level at which mining does not generate enough value added to entice more than one rebel group to exploit it.

These simple dynamics demonstrate how the outbreak of civil war may be subject to 'stickyness': a price increase that leads to an outbreak of civil war will not be recovered by a

[7]Since we consider small scale, artisanal mining (cf. section 2), productivity in the mining sector is assumed not to suffer from civil war.

Figure 1: The persistence of civil wars



mere reversing of the price increase. Moreover, equation (20) shows that the longer the war wages, the larger the decrease in mineral prices or the increase in agricultural commodity prices will have to be in order to end the war.

It should, furthermore, be of interest for international policy makers that, not only a reduction in the mineral prices, but also an increase in the agricultural commodity prices (through its impact on the wages) can help ending an ongoing war. If the prices of mineral resources increase due to the increased demand, the price of agricultural commodities remains a valuable tool to prevent the outbreak of civil conflicts.

Note, finally, that it is conceivable that the level of σ depends on the size of l_r^* and g_r^*. Especially if the size of the weapon arsenal is high, we may expect a more devastating conflict and more destruction. Although in our model the price of weapons has no influence on the condition that determines the threshold for outbreak of the civil war, it may, however, have a large negative impact on the persistence of it.

5 Conclusion

In this paper we have used conventional economic analysis, a general equilibrium model, to analyse the potential influence of the world market prices for mineral resources and tropical agricultural commodities on civil conflict in poor sub-Saharan African countries. The analysis allows us to draw four main conclusions.

First, the well-documented link between natural resources and (the onset of) civil strife is firmly corroborated by our model: international market prices for natural resources affect

the opportunity costs of joining a rebel movement and, therefore, the labour market choice in many rural areas with limited labour alternatives. Remark, furthermore, that we show that not only a discovery of natural resources, a so-called windfall, but an increase in the prices too can be the spark that triggers civil conflict.

Moreover, we show that the tropical agricultural commodity prices have an inverse, but analogous impact on the on- and offset of civil conflict. High or increasing tropical agricultural commodity prices reduce the attractiveness of economic activities such as, for instance, mining or rebellion: they turn farming into a valuable labour alternative for rural labourers. Therefore, we show that not only low international prices for mineral resources, but high international prices for agricultural commodities too, can reduce a country's proneness to conflict.

Third, the critical role of natural resources (agricultural commodities included) and their internationally set prices our model uncovers, indirectly also provides an alternative explanation for the failure of some/many peace agreements. Due to the limited labour market alternatives in many of the conflict-prone areas, a peace agreement between two or more rebel leaders, warlords etc., will not be sustainable if prices of mineral resources are (relatively) too high or agricultural commodity prices too low to make farming a valuable alternative labour choice to rebellion and predation on the mining sector. In that case, the labour market will provide new potential rebel leaders an incentive to step in, or the old rebel leaders an incentive to breach the peace agreement they signed.

Finally, we show that through its destructive impact on agricultural productivity, civil war carries a sense of irreversibility in it. For instance, a decrease in the prices of tropical agricultural commodities or an increase in the mineral prices that, through an increase in the profits of mining, triggers civil war, decreases agricultural productivity and, therefore, equilibrium market wages. These lower wages increase the profits of mining even more and increase the attractiveness of contesting the right to exploit the mine. Therefore, the necessary decrease in mineral prices will be larger than the initial increase in those prices that triggered the conflict.

Summarising, we believe that the model presented in this paper provides an unmistakable policy implication: diversification of the economic activity is a crucial first step conflict-prone areas should take, both in order to reduce their dependence on (fluctuations of) the international market and in order to provide labour forces with a less harmful economic alternative to farming. It should be clear, however, that this recommendation carries beyond vulnerable countries alone: the international community, too, can contribute to such diversification. First, and probably most easily, international donor countries and agencies can stimulate investments in certain types of industrial activity. More fundamentally, however, first world agricultural policy (in particular the agricultural export subsidisation and tariff escalation) could be altered in favour of a less distorted world market. We hope to have established the potential of high(er) prices for tropical agricultural commodities as a complementary or even alternative policy channel through which conflict in predominantly agricultural and mineral resources dependent areas can be ended or even avoided. It should then be obvious that first world export subsidies for non-tropical agricultural commodities, which distort the tropical agricultural sector in favour of a limited number of tropical commodities and thereby (due to the increased supply) induce lower prices for these commodities, and so-called 'tariff

escalation' (higher import duties for processed products than for raw commodities), which inhibits the development of a processing sector, may impose an underestimated cost on poor but resource-rich and (tropical) agricultural commodity dependent countries.

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