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# WORKING PAPER

# International commodity prices and the persistence of civil conflict

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# International commodity prices and the persistence of civil conflict*

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**Abstract**

We develop a general equilibrium model to analyse the impact of the international commodity prices on civil conflict. We focus on the specific labour market context of 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 matter just as much: a drop in those prices increases the attractiveness of other 'economic' activities such as rebellion/warfare and can, therefore, trigger civil conflict. Furthermore, we show 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 below which conflict is not lucrative.

## 1 Introduction

The resurgence of civil conflicts after the Cold War has spurred a plethora of scientific 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 shows that more research on the causes of civil war is absolutely 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

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factors that relates to both underdevelopment and weak states is the dependence on (certain) natural 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 need 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 (e.g. oil or kimberlite diamond-mining), especially where property rights are ill-defined, or illegal markets (e.g. drugs production or 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 are 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 (e.g. coffee or cocoa) which are predominantly produced by a large number of small farmers in rural areas, almost exclusively in developing countries.

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 in our opinion characterise a considerable share of today's war-torn sub-Saharan African areas. On the one hand, the model incorporates coercive oligopolies, 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 mineral resource abundant areas. The profits that accrue to those who control the resource abundant territories allure other potential 'firms'. This entrance will last as long as the profits from operating the mines in the conquered areas exceed the costs of running a rebel organisation. In this sense, we endogenise the number of warring groups: the viable number of rebel groups follows from the equilibrium zero profit condition. Moreover, competition between the competing firms is not settled by the market (prices) for mineral rich areas but by the relative investments in arms and armed forces.

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

Like in the seminal paper by Grossman [1991], we stress the arbitrage between the returns from fighting and the returns from conventional economic activity: besides the mineral sector we incorporate an agrarian sector that produces tropical agricultural commodities. The context we consider, therefore, is very specific: a 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 in New York or in London,[3] the price setting is exogenous to the local market but determines the profits and, hence, the attractiveness of the different sectors. We study how changes in the world market prices of mineral resources and tropical 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. Thus, by exploring the causal link between adverse external price shocks and civil war, we attempt to fill one of the gaps in the current literature (Sambanis [2002, p. 230]).

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 potential number of warring 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 are viewed as agents that advance an entire ethnoregional group's interests, by which his model inherently carries the 'grievance factor' within it. 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 (and possibly appropriates) the rebel group's profit.

The paper has two major contributions, from which several policy recommendations derive. First, we show that international commodity prices matter for Third World civil

[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 looks at 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 most important futures and options markets for several internationally traded agricultural commodities: cocoa, coffee, cotton, orange juice and sugar. The London Metal Exchange is the most important non-ferrous metals futures and options market.

conflict. On the one hand, the accelerated world economic development, which mainly occurred in the western world, intensified the search for natural resources. The fact that those resources happen to be abundant especially in certain underdeveloped areas in Africa implies that the costs and benefits from this modernisation[4] process accrue to different parts of the world: while the western world enjoys (strong) economic development, southern countries bear the costs of the struggle for the required mineral resources. We show that the sustained economic development in First World countries may well have increased political tension in underdeveloped and mineral-rich Third World countries: the increasing demand for primary commodities makes resource-rich but poor countries very vulnerable to the struggle for those resources. In other words, sub-Saharan Africa may suffer (part of) the cost of the sustained economic advancement of the high income countries. On the other hand, we show that tropical agricultural commodity prices matter just as much: a drop in those 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 the struggle for its spoils. We thus provide a theoretical mechanism through which exogenous variables such as weather shocks and climatic hazards, but also international price shocks,[5] can have an impact on civil conflict. We show that both rising mineral prices and falling tropical agricultural commodity prices may be important determinants of rebellion and that, essentially, it is their relation that matters.

Second, we show that the *occurrence* of civil war may carry within itself a non-reversible component. If an increase of mineral prices or a decrease of tropical agricultural commodity prices (or a combination of the two) triggers civil conflict, a mere return of the prices to their pre-conflict level may not be sufficient to end the conflict. The mechanism behind this result is that a civil conflict, due to its destructive nature, lowers agricultural productivity and reduces wages in agriculture. The resulting lower equilibrium market wage increases the mining profits and, thus, lowers the threshold mineral price below which, or increases the tropical agricultural commodity price above which, only a single rebel group is viable.

The following policy recommendations derive from these results. First, since relative international commodity prices matter for conflict, taxing mineral resources and supporting the prices of tropical agricultural commodities may be effective instruments to end or prevent civil conflict. Moreover, our results may explain the failure of certain peace agreements (Regan [2002]; Fearon [2004]): irrespective of what policy makers or warlords agree, as long as the economic trade-off for labourers is in favour of mining or joining

[4]By looking at the effect of external price shocks on the sub-Saharan labour market, our model contains an element of modernisation theory (Newman [1991]).

[5]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.

rebel organisations, there will always be an incentive for some new warlord or shrewd rebel commander to exploit this labour supply. Therefore, it may not always be sensible to broker a peace agreement. Furthermore, it is shown that weapon embargoes may backfire: although they can reduce the duration of an ongoing war, pre-emptive weapon embargoes may actually trigger civil conflict. Finally, and maybe most importantly, by sustaining economic diversification, local authorities and the international community can reduce Third World countries' vulnerability to fluctuating world market prices for tropical agricultural commodities and, thus, their proneness to civil conflict.

The paper is organised as follows: Section 2 presents the assumptions and develops the model. Sections 3 and 4 elaborate on the impact of the international prices of mineral resources and tropical agricultural commodities on, respectively, the onset and the persistence of civil conflicts. Section 5 analyses the effectiveness of weapon embargoes to prevent or end civil conflict, Section 6 extends the model to include other sectors and Section 7 concludes.

# 2 A benchmark model

We consider a predominantly rural area with a lack of, or ill-defined, political and property rights. We analyse the specific context where economic activity and the corresponding value added are concentrated in two sectors: small scale agriculture of an internationally traded commodity (e.g. coffee or cocoa) and artisanal mining (e.g. alluvial diamonds or coltan).

We consider an economy with $N$ agents, where each agent supplies one unit of labour inelastically and extracts utility from his wage, $w$. In order to preclude corner solutions, we assume that labour supply is large enough to secure production in both the mining sector and the agricultural sector.

## 2.1 The agricultural sector

We assume an agricultural sector with $M_a$ units of agricultural land. Each agricultural firm has a constant returns to scale production function $f_a(l_a, L_a) = l_a^{\alpha} L_a^{1-\alpha}$ with $\alpha \in ]0,1[$, where $l_a$ is the amount of labour input and $L_a$ the amount of agricultural land a firm uses. The price for agricultural output, $p_a$, is exogenously determined on international markets. If $w$ is the wage per unit of labour and $s_a$ the price per unit of agricultural land, then we can write the profit for an agricultural firm as:

$$\begin{aligned} \pi_a &= p_a f(l_a, L_a) - w l_a - s_a L_a \\ &= L_a \left( p_a f(l_a/L_a, 1) - w l_a/L_a - s_a \right), \end{aligned} \tag{1}$$

where equation (1) follows from the constant returns to scale production function. Each agricultural firm will optimise its profit per unit of land. The first order condition of equation (1) with respect to $l_a/L_a$ determines the optimal amount of labour per unit of

land, $(l_a/L_a)^*$ as a function of $w$ and $p_a$:[6]

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

Define $\pi_a^*$ as the corresponding optimal profit in the agricultural sector:

$$\pi_a^* = L_a \left[ p_a f\left( \left(\frac{l_a}{L_a}\right)^*, 1 \right) - w \left(\frac{l_a}{L_a}\right)^* - s_a \right]. \tag{3}$$

Assuming perfect competition in the agricultural sector and, therefore, zero profits in equilibrium, equation (3) allows us to derive the optimal price of land, $s_a^*$, as a function of $w$ and $p_a$:

$$s_a^* = f\left( \left(\frac{l_a}{L_a}\right)^*, 1 \right) - w \left(\frac{l_a}{L_a}\right)^*. \tag{4}$$

With a fixed endowment of agricultural land, $M_a$, the total amount of labour employed in the agricultural sector will be equal to $M_a(l_a/L_a)^*$.

## 2.2 The mining and rebel sector

We focus on geographically concentrated mineral resources and we assume that there are $M_m$ units of mineral abundant land to extract, say, $M_m$ is the amount of mining sites. Mining firms are assumed to be controlled by rebel organisations who skim off the excess profits in this sector. Somewhat jumping ahead, we assume that each mining firm is owned by a single rebel group and we model the 'contest' for the exploitation rights of a mine as 'civil war' between $n$ rebel groups ($n$ is endogenously determined and will be modelled in Section 2.4). It is helpful to think of this competition as an alternative economic activity besides mining and farming: the rebel sector.

Output of a mining firm, $i$, is given by the constant returns to scale production function $f_m(l_i, t_i) = l_i^\beta (M_i t_i)^{1-\beta}$ with $\beta \in ]0,1[$, where $l_i$ is the amount of labour and $t_i$ the fraction of the resource abundant land that is owned by rebel group $i$. The output price of mineral resources, $p_m$, is determined on the international market and, therefore, exogenous.

Output of the rebel sector is the fraction of mineral resource rich land, $t_i$, that a rebel group $i$ controls and exploits. Input for the rebellion sector consists of an army, $a_i$, and weaponry, $g_i$. We assume that the price of weapons, $p_g$, 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.[7] 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: $w$.

[6] Note that variables with an asterisk represent optimal values.

[7] 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 weaponry.

A rebel group 'produces' war power. Let $h(a_i, g_i) = a_i^\gamma g_i^\delta$ be a rebel group's production function, where $\gamma, \delta > 0$. The fraction of mining land that is controlled by rebel group $i$, $t_i$, is determined by its relative 'competitiveness', its war power relative to the competing rebel groups, which we represent by the following competitiveness function:

$$t_i(\{a_j, g_j\}_{j \leq n}) = \frac{h(a_i, g_i)}{\sum_{j=1}^{n} h(a_j, g_j)}. \tag{5}$$

Equation (5) is similar to Hirshleifer's [1995] Contest Success Function. The parameters $\gamma$ and $\delta$ are the elasticities of the function $h$ with respect to $a_i$ and $g_i$. The sum of $\gamma$ and $\delta$ represents what Hirshleifer [1995] calls the 'decisiveness parameter': the degree to which increased investments in soldiers and weapons are translated in a higher victory probability. In Section 2.5, we will further elaborate on the meaning and impact of these elasticities.

Then, assuming that there is a fixed cost $F$ of operating and controlling a mine (shovels, sieves, small pumps, etc. on the one hand, and, for instance, recruitment costs on the other), the profits for rebel group $i$ are given by:

$$\pi_i = p_m f_m(l_i, M_m t_i) - w l_i - w a_i - p_g g_i - F.$$

To maximise their profits, rebel groups take potential other groups' actions as given, which generates the following first order conditions with respect to $l_i$, $a_i$ and $g_i$:

$$w = p_m \frac{\partial f_m(l_i, M_m t_i)}{\partial l_i}, \tag{6}$$

$$w = p_m \frac{\partial f_m(l_i, M_m t_i)}{\partial t_i} \frac{\partial t_i}{\partial a_i}, \tag{7}$$

$$p_g = p_m \frac{\partial f_m(l_i, M_m t_i)}{\partial t_i} \frac{\partial t_i}{\partial g_i}. \tag{8}$$

Equations (6), (7) and (8) allow us to derive the three (implicit) equations which determine the optimal quantities: $l_i^*$, $a_i^*$ and $g_i^*$ (and $t_i^*$) as functions of the endogenous variables $w$, $l_j$, $a_j$, $g_j$ for $j \neq i$ and the exogenous variables $M_m$, $p_m$ and $p_g$:[8]

$$l_i^* = \left[\frac{p_m \beta}{w}\right]^{\frac{1}{1-\beta}} M_m t_i^*, \tag{9}$$

$$a_i^* = \frac{p_m}{w}(1-\beta) f_m(l_i^*, M_m t_i^*)(1 - t_i^*)\gamma, \tag{10}$$

$$g_i^* = \frac{p_m}{p_g}(1-\beta) f_m(l_i^*, M_m t_i^*)(1 - t_i^*)\delta. \tag{11}$$

We consider the symmetric case where each rebel group has the same objective function and the same optimal values of $l_i^*$, $a_i^*$ and $g_i^*$. In that case, $t_i^* = \frac{1}{n}$, and for each rebel group

[8] It can be shown that the second order conditions for a maximum are also satisfied.

$i$ and $j$, it holds that $l_j^* = l_i^*$, $a_j^* = a_i^*$ and $g_j^* = g_i^*$. The equilibrium profit for a rebel group – given the total number of competing rebel groups – can then be written as:

$$\pi_i^* = p_m f_m \left( l_i^*, M_m \frac{1}{n} \right) - w l_i^* - w a_i^* - p_g g_i^*. \tag{12}$$

By substituting conditions (9), (10) and (11) into equation (12), this yields:

$$\pi_i^* = M_m \frac{1}{n} p_m^{\frac{1}{1-\beta}} \left[ \frac{\beta}{w} \right]^{\frac{\beta}{1-\beta}} (1-\beta) \left[ 1 - (\gamma + \delta) \left( 1 - \frac{1}{n} \right) \right] - F. \tag{13}$$

Note that $\pi_i^*$ depends on $w$, $n$, $p_m$ and $M_m$, but not directly on $p_g$.

## 2.3 Clearing the labour market

To pinpoint the equilibrium values of $l_a^*$, $l_i^*$, $a_i^*$ and $g_i^*$, we still need to determine the equilibrium wage $w^*$. Equilibrium on the labour market imposes the following condition:

$$N = M_a \left( \frac{l_a}{L_a} \right)^* + n \left( a_i^* + l_i^* \right). \tag{14}$$

The value of $w$ for which equation (14) holds, determines the equilibrium wage $w^*$ as a function of $n$ and the exogenous variables $p_a$, $p_m$, $M_a$, $M_m$, $N$ and $p_g$. If we substitute equation (2), (9) and (10) in condition (14), we obtain:

$$N = M_a \left[ \frac{p_a \alpha}{w^*} \right]^{\frac{1}{1-\alpha}} + M_m \left[ \frac{p_m \beta}{w^*} \right]^{\frac{1}{1-\beta}} \left[ 1 + \frac{1-\beta}{\beta} \gamma \left( 1 - \frac{1}{n} \right) \right]. \tag{15}$$

First, note that equation (15) does not depend directly on $p_g$. Furthermore, it is readily seen that in order to preserve the equilibrium on the labour market, an increase in $M_a$, $p_a$, $M_m$ or $p_m$ will require an increase in $w^*$. An increase in $N$, on the other hand, will require a decrease of the equilibrium wage, $w^*$. Finally, and maybe most importantly in the context of this paper, note that if the amount of mineral resource rich land ($M_m$) is very small compared to the amount of agricultural land ($M_a$), the equilibrium market wage is mainly determined by $p_a$. Hence, while a change in $p_a$ will require a large adjustment of the equilibrium wage, a change in $p_m$, $M_a$ or $M_m$ will only require minor adjustments in order to preserve the equilibrium on the labour market.

## 2.4 Equilibrium number of rebel groups

Substituting the equilibrium wage into equation (13), we can derive a rebel group's equilibrium profit as a function of $n$, and the exogenous variables $p_m$, $M_m$, $p_a$, $M_a$ and $N$:

$$\pi_i^* = M_m \frac{1}{n} p_m^{\frac{1}{1-\beta}} \left[ \frac{\beta}{w^*} \right]^{\frac{\beta}{1-\beta}} (1-\beta) \left[ 1 - (\gamma + \delta) \left( 1 - \frac{1}{n} \right) \right] - F. \tag{16}$$

Equation (16) is strictly decreasing in $n$ (see also Appendix A.1) for $n \in [1, \infty[$). Then, if we assume that positive profits for rebel organisations will attract other potential rebel groups, i.e. that $n$ will increase as long as:

$$\pi_i^*(n) \geq 0, \tag{17}$$

it follows that the equilibrium/viable number of rebel groups, $n^*$, can be determined as the greatest integer $n$ that still satisfies equation (17), and that this value is unique.[9]

Note that the equilibrium number of rebel groups, $n^*$, is an integer. It is, therefore, likely 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. Since consumption prices are exogenously determined in our model, the (potentially) resulting excess consumption of this rebel leader will not have equilibrium consequences.

## 2.5 The outbreak of civil war

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

Formally, civil war requires that condition (17) is satisfied for some $n \geq 2$. Since, as shown in Section 2.4, profits $\pi_i^*$ are decreasing in $n$, there will be civil war if and only if $\pi_i^* \geq 0$ for $n = 2$. Civil war, therefore, requires that:

$$\pi_i^*(2) = \underbrace{\frac{M_m}{2}\left[\frac{p_m\beta^\beta}{(w^*)^\beta}\right]^{\frac{1}{1-\beta}}(1-\beta) - F}_{I} \underbrace{- \frac{M_m}{2}\left[\frac{p_m\beta^\beta}{(w^*)^\beta}\right]^{\frac{1}{1-\beta}}\frac{(1-\beta)(\gamma+\delta)}{2}}_{II} \geq 0, \tag{18}$$

where $w^*$ is determined by:

$$N = M_a\left[\frac{p_a\alpha}{w^*}\right]^{\frac{1}{1-\alpha}} + M_m\left[\frac{p_m\beta}{w^*}\right]^{\frac{1}{1-\beta}}\left[1 + \frac{1-\beta}{\beta}\gamma\frac{1}{2}\right]. \tag{19}$$

We split equation (18), and call Part I a rebel group's *(hypothetical) operational revenue*, i.e. profits a rebel group obtains without incorporating the costs of fighting:

$$\frac{M_m}{2}\left[\frac{p_m\beta^\beta}{(w^*)^\beta}\right]^{\frac{1}{1-\beta}}(1-\beta) - F \;=\; M_m p_m f_m(l_i^*, 1/2) - w^* l_i^* - F, \tag{20}$$

and Part II its *(hypothetical) operational cost*:

$$\frac{M_m}{2}\left[\frac{p_m\beta^\beta}{(w^*)^\beta}\right]^{\frac{1}{1-\beta}}\frac{(1-\beta)(\gamma+\delta)}{2} \;=\; w^* a_i^* + p_g g_i^*. \tag{21}$$

[9] We assume that if $\pi_i^*(1) < 0$, then $n^* = 0$.

Observe that when $\gamma + \delta \geq 2$, $\pi_i^*(2)$ is always negative and the equilibrium number of rebel organisations will always be less than 2. Therefore, we will focus on the more interesting case where $\gamma + \delta < 2$, where conflict is not excluded by technological constraints.

**Assumption 1.** *Conflict is not excluded by war power-producing technologies:* $\gamma + \delta < 2$.

The subsequent sections elaborate on how some pertinent exogenous variables may influence condition (18) and, therefore, the potential onset/offset of civil conflict.

# 3 International commodity prices

We first analyse the potential impact of fluctuations in the international prices of mineral resources and tropical agricultural commodities on civil conflict.

## 3.1 Mineral resources

An increase in the international prices of mineral resources ($p_m$) will increase $\pi_i^*(2)$ (cf. Appendix A.2) and may, therefore, trigger a civil war.

The intuition behind this result is straightforward. An increase in $p_m$ increases both the operational costs of running a rebel organisation (equation (21)) and – by directly increasing the operational revenue of mining – a rebel organisation's potential income (equation (20)). However, by Assumption 1, we know that the first effect is smaller than the second.

**Policy Implication 1.** *Taxing mineral resources may be an effective tool to prevent or end 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 from that country to reduce the relative attractiveness of its mining industry. It should, however, be acknowledged that, especially with easily accessible and lootable resources, tax evasion is undoubtedly a legitimate concern.

## 3.2 Tropical agricultural commodities

From equation (15) we know that a decrease in the tropical agricultural commodity prices $p_a$ decreases the equilibrium wage $w^*$ which, in turn, increases the potential profits for the rebel organisation, $\pi_i^*(2)$ (cf. Appendix A.3). A decrease in $p_a$ increases the operational revenue of mining and the operational cost of a rebel organisation. However, due to Assumption 1 we know that the total increase in potential income is higher than the total increase in potential costs.

**Policy Implication 2.** *High(er) prices for tropical agricultural commodities can be an effective tool to prevent or end 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. It should be of interest for international policy makers that, as the current model shows, the prices for tropical agricultural commodities can serve the same goal. If, for example, the prices of mineral resources increase due to the increased demand, the price of tropical agricultural commodities remains a valuable tool to prevent the outbreak of civil conflicts. 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, as an instrument to reduce a rural area's proneness to conflict, measures to support international prices for tropical agricultural commodities provide an alternative to taxing mineral resources.

**Policy Implication 3.** *Favourable international commodity prices are conducive to peace.*

# 4 The persistence of civil war

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[10] (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 instance $v \in [0, \infty[$, civil war destroys a fraction $1 - \sigma(v)$ 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 $\sigma$ has similar implications as an increase of the agricultural price $p_a$. Therefore, by equation (15), an increase in $\sigma$ induces an increase in the equilibrium wage $w^*$. Let $\dot{\sigma}(v) = \lim_{\substack{h \rightarrow 0 \\ h>0}} \frac{\sigma(v+h)-\sigma(v)}{h}$ and assume that there exists a 'lower bound' $\sigma_l \in ]0, 1[$ such that:

$$\begin{cases} \dot{\sigma}(v) > 0 \text{ if and only if } n^* \leq 1 \text{ and } \sigma(v) < 1, \\ \dot{\sigma}(v) < 0 \text{ if and only if } n^* > 1 \text{ and } \sigma(v) > \sigma_l, \\ \dot{\sigma}(v) = 0 \text{ if and only if } n^* \leq 1 \text{ and } \sigma(v) = 1 \text{ or } n^* > 1 \text{ and } \sigma(v) = \sigma_l. \end{cases} \tag{22}$$

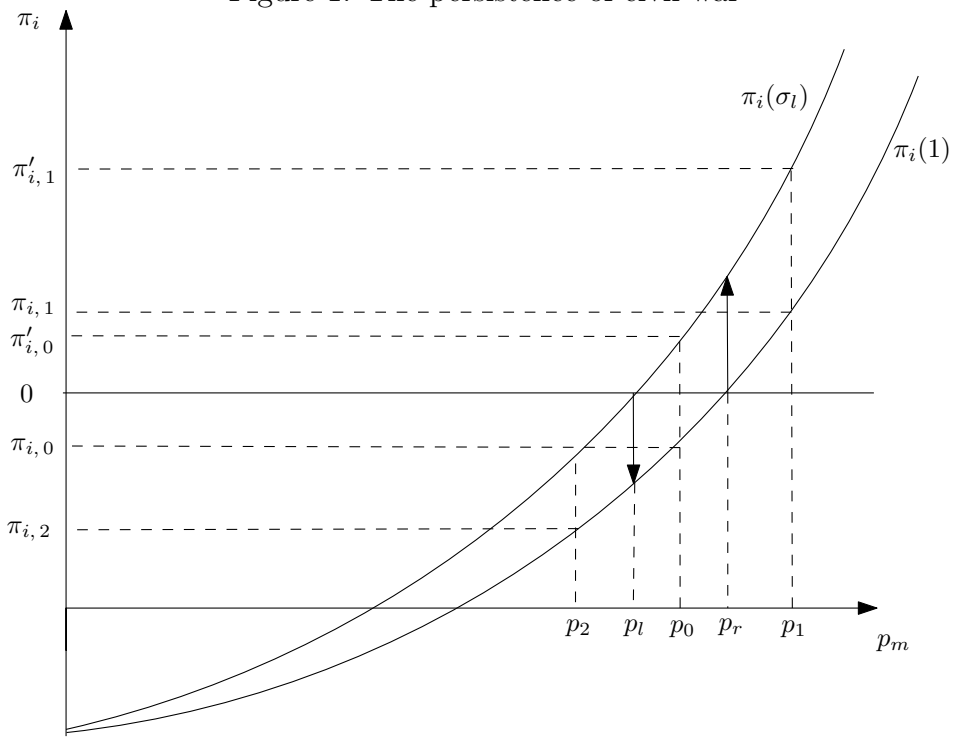
This means that $\sigma(v)$ decreases over time as long as there is a civil war (until the lower bound is reached) and increases during periods of peace. Therefore, the longer the civil war lasts, the smaller the fraction of potential output that is actually realised becomes.

The dynamics of these productivity shifts are illustrated in Figure 1, which displays the hypothetical profits of a rebel group when the number of rebel groups is equal to 2,

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

i.e. equation (18), as a function of the price of mineral resources ($p_m$). $\pi_i(\sigma_l)$ and $\pi_i(1)$ show the profits of mining for the border-levels of agricultural productivity, during war and peace respectively.

Figure 1: The persistence of civil war




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 ($\pi_{i,0} < 0$) 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 ($\pi_{i,1} \geq 0$). The higher mineral prices increase the mining profits from $\pi_{i,0}$ to $\pi_{i,1}$ and lead to the entrance of a second rebel group. The emerging conflict causes destruction of agricultural output: the profit function gradually moves from $\pi_i(1)$ to $\pi_i(\sigma_l)$. The resulting lower mining wages then increase the profits of mining from $\pi_{i,1}$ to $\pi'_{i,1}$.

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 ($\pi'_{i,0} \geq 0$) 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 'stickiness': a price increase that leads to an outbreak of civil war will not be recovered

by a mere reversing of the price increase. Moreover, the longer the war wages, the larger the decrease in mineral prices or the increase in tropical agricultural commodity prices will have to be in order to end the war.

**Policy Implication 4.** *The longer a war wages, the less effective international commodity prices become as an instrument to foster conditions favourable to peace.*

# 5 A weapon embargo

A weapon embargo restricts the accessibility of weapons and is likely to alter the technology of conflict. It is, therefore, an obvious and popular (DellaVigna and La Ferrara [2008]) policy instrument to deter conflict. We distinguish between an embargo's direct effect – on the rebel group's investment decision – and its indirect effect – on the level and size of destruction a war entails.

## 5.1 A rebel group's investment decision

### 5.1.1 Restricted access to weapons

In a strict sense, a watertight weapon embargo implies that rebel groups can not purchase weapons anymore: each rebel group therefore takes the amount $g_i = \bar{g} \leq g_i^*$ as given and optimises its expected profit with respect to $l_i$ and $a_i$. Condition (18) then changes to:

$$\pi_i^*(2) = p_a f_m(l_i^*, 1/2)(1 - \beta - 1/2(1-\beta)\gamma) - p_g \bar{g} - F. \tag{23}$$

Equation (23) will be larger than equation (18) if and only if $p_g g_i^* \geq p_g \bar{g}$, which we assume. Hence, maybe rather surprisingly, with constant scale-elasticity, instead of preventing it, a watertight weapon embargo may well lead to civil conflict: by lowering the operational costs without affecting the operational revenue, an effective embargo increases the expected profits of rebellion. Without constant scale-elasticity, the effect is undetermined.

Considering the history of weapon embargoes, however, watertightness may not be the most realistic assumption (Tierney [2005]; DellaVigna and La Ferrara [2008]). 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 (see equation (18)).

**Policy Implication 5.** *Restricting the access to weapons is ineffective to deter civil conflict.*

### 5.1.2 Restricted war technology

A weapon embargo presumably also affects the technology of war and conflict ($\gamma + \delta$): by restricting the access to certain types of weapons, an embargo may constrain rebel groups to resort to different fighting technologies.

To see how changing war technologies may affect civil war, it is important to understand the distinction between what Hirshleifer [1995] calls defensive and offensive technologies. With offensive technologies, $\gamma + \delta$ is large, marginally more arms investments are converted in considerable war power differences and, therefore, in a considerably larger share of the mining sector. In contrast, with defensive technologies, $\gamma + \delta$ is small, differences in arms investments have a limited effect on relative war power. With the latter, therefore, rebel groups have no incentive to be large and hypothetical operational costs ($w^* a_i^* + p_g g_i^*$) will be low. This, in turn, increases the viable number of rebel groups: with defensive technologies even low hypothetical operational profits can be sufficient to trigger civil conflict. Therefore, since it is likely to impose lower – more defensive – war technologies, a weapon embargo can be expected to trigger, rather than prevent, civil conflict.

**Policy Implication 6.** *A weapon embargo that leads to a more defensive war technology may induce civil conflict.*

## 5.2 The level and size of destruction

It is highly probable that the level of $\sigma$ and the size of $\dot{\sigma}$ depend on the size of $a_i^*, g_i^*$ and on the fighting technology $\gamma + \delta$: when armies and weapon arsenals are large, and if the technology is offensive ($\gamma + \delta$ is large), we may expect a more destructive and devastating conflict and, thus, larger persistence effects of civil war.

Therefore, to the extent that a weapon embargo reduces the quantity of weapons and lowers the war technology that is available to the warring groups, it may limit the persistence of civil conflict.

**Policy Implication 7.** *A weapon embargo that leads to a more defensive war technology may mitigate the persistence of civil conflict.*

The impact of a weapon embargo, therefore, crucially depends on its timing: a preemptive embargo, by lowering the operational costs of rebellion, may actually trigger a conflict, while a reactive embargo, by limiting the destruction caused by a conflict, is likely to reduce its duration.[11]

# 6 Economic diversification

So far, we have considered two (productive) sectors, agriculture and mining, and have shown that the equilibrium wage $w^*$ largely depends on the international price of the agri-

[11] The net effect will be determined by a trade-off between the increase in $\sigma$ due to the embargo and the upward shift in $\pi_i^*(2)$ due to a more defensive technology.

culture commodity, $p_a$. Here, we show how the model can easily be extended to incorporate multiple sectors.

Consider a sector $k$, which we call the manufacturing sector. A manufacturing firm uses an amount of labour, $l_k$, and an amount of 'manufacturing capital'[12] equal to $c_k$. We assume that the total amount of manufacturing capital available in the economy, $M_k$, is fixed, and that its price, $s_k$, is determined endogenously. Manufacturing production is determined by a constant returns to scale production function:

$$f_k(l_k, c_k) = l_k^{\eta} c_k^{1-\eta}.$$

We assume that the price of a manufacturing good, $p_k$, is determined on international markets. Therefore, profits per firm are given by:

$$\pi_k = p_k f_k(l_k, c_k) - w l_k - s_k c_k = c_k \left[ f_k\left(\frac{l_k}{c_k}, 1\right) - w\frac{l_k}{c_k} - s_c \right].$$

The first-order condition with respect to $l_k/c_k$ determines the optimal amount of labour per unit of manufacturing capital $(l_k/c_k)^*$ as a function of $w$ and $p_k$:

$$\left(\frac{l_k}{c_k}\right)^* = \left(\frac{p_k \eta}{w}\right)^{\frac{1}{1-\eta}}.$$

The zero profit condition determines the equilibrium price of capital $s_c^*$. Total labour demand by the manufacturing sector is $M_k(l_k/c_k)^*$ and the equilibrium wage, $w^*$, is determined by the equilibrium condition on the labour market:

$$N = M_a(l_a/L_a)^* + M_k(l_k/c_k)^* + n^*\left(a_i^* + l_i^*\right). \tag{24}$$

It is easy to see that when $p_a$ decreases, the resulting decrease in $w^*$ – necessary to make the equilibrium condition binding – will be less than in our basic model. Therefore, introducing an extra sector lowers the equilibrium wage's sensitivity to a change in agricultural prices. Generalising equation (24), by including multiple sectors $j = 1, \ldots, m$:

$$N = \sum_{j=1}^{m} M_j(l_j/z_j)^* + n^*(a_i^* + l_i^*),$$

where $z_j$ is an industry-specific production factor. We demonstrate that – in this specific setting – more economic diversity lowers the equilibrium wage's sensitivity to fluctuations of a single price, $p_j$.

Considering the high volatility of – especially tropical – agricultural commodity prices and the much more stable prices for manufacturing goods, diversifying away from tropical agricultural commodity prices and further industrialisation are likely to reduce the conflict proneness of many, especially sub-Saharan African, rural areas.

[12]Think of manufacturing capital as the essential infrastructure, e.g. factory buildings, machinery etc., that is fixed in the short term.

# 7 Conclusion

We have used conventional economic analysis, a simple 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. This analysis allows us to draw some remarkable conclusions and formulate policy recommendations.

First, the well-documented link between mineral resources and civil conflict is corroborated by our model: international market prices for mineral resources affect the opportunity costs of joining a rebel movement and, therefore, the labour market choice in many rural areas with limited alternatives on the labour market. Therefore, an increase in the prices of mineral resources can trigger civil conflict. Moreover, we show that the tropical agricultural commodity prices have an inverse, but analogous, impact on 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 and, thus, reduce a country's proneness to conflict. International commodity prices may, in other words, provide the international community with an instrument to foster peace in the Third World.

Consequently, our model provides an explanation for the failure of peace agreements. Unfavourable international commodity prices may make peace agreements unsustainable when the labour market alternatives are limited: when the prices of mineral resources are relatively too high to make farming a valuable alternative to predation on the mining sector, 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. Hence, for peace agreement negotiations to be worthwhile, the labour market should provide potential rebels and looters with alternative economic activities.

Furthermore, we show that, through its destructive impact on agricultural productivity, civil war perpetuates itself. For instance, a decrease in the prices of tropical agricultural commodities that 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 increase in tropical agricultural commodity prices will be larger than the initial decrease in those prices that triggered the conflict.

Maybe rather surprisingly, then, it is shown that a pre-emptive weapon embargo may actually trigger a conflict: by lowering the operational costs of rebellion, it increases its potential profits. Since, on the other hand, a weapon embargo may also reduce the duration of an ongoing conflict, the timing of its implementation is likely to affect the effectiveness of a weapon embargo.

Finally, the model establishes diversification of the economic activity as a critical instrument for deterring conflict: by reducing its dependence on (fluctuations of) the international market, and by providing its labourers with productive economic alternatives when small scale farming turns unprofitable, it reduces an area's conflict proneness. It should be clear, however, that the consequent 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 (the aid side) can bolster production – both agricultural and industrial – for the local market and should be wary of exacerbating Third World countries' dependence on tropical agricultural commodities. More fundamentally, however, First World agricultural policy (the trade side) could be altered in favour of a less distorted world market. It is widely acknowledged that First World export subsidies for non-tropical agricultural commodities distort agriculture in tropical areas in favour of a limited number of tropical commodities, and that so-called 'tariff escalation' (higher import duties for processed products than for raw commodities) inhibits the development of a processing sector. Therefore, by potentially nurturing civil conflict, First World agricultural policy may well impose a highly underestimated cost on resource-rich but tropical agricultural commodity dependent countries.

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# A Derivation of the comparative static results

## A.1 $\pi_i^*$ is decreasing in $n$

Differentiate equation (16) w.r.t. $n$:

$$\frac{d\pi_i^*}{dn} = \frac{\partial \pi_i^*}{\partial n} + \frac{\partial \pi_i^*}{\partial w^*}\frac{dw^*}{dn}.$$

Denote the rhs of equation (15) by $A$, and differentiate this equation w.r.t. $n$:

$$0 = \frac{\partial A}{\partial w^*}\frac{dw^*}{dn} + \frac{\partial A}{\partial n}.$$

After substitution, we have that:

$$\frac{d\pi_i^*}{dn} = \frac{\partial \pi_i^*}{\partial n} + \frac{\partial \pi_i^*}{\partial w^*}\frac{-\frac{\partial A}{\partial n}}{\frac{\partial A}{\partial w^*}}.$$

Straightforward computation shows that his expression is negative for $n \geq 1$.

## A.2 $\pi_i^*(2)$ is increasing in $p_m$

Differentiate equation (18) with respect to $p_m$:

$$\frac{d\pi_i^*(2)}{dp_m} = \frac{\partial \pi_i^*(2)}{\partial p_m} + \frac{\partial \pi_i^*(2)}{\partial w^*}\frac{dw^*}{dp_m}.$$

Denote the rhs of equation (19) by $A$, and differentiate this equation w.r.t. $p_m$:

$$0 = \frac{\partial A}{\partial w^*}\frac{dw^*}{dp_m} + \frac{\partial A}{\partial p_m}.$$

After substitution, we have that:

$$\frac{d\pi_i^*(2)}{dp_m} = \frac{\partial \pi_i^*(2)}{\partial p_m} + \frac{\partial \pi_i^*(2)}{\partial w^*}\frac{-\frac{\partial A}{\partial p_m}}{\frac{\partial A}{\partial w^*}}.$$

Straightforward computation shows that this expression is positive.

## A.3 $\pi_i^*(2)$ is decreasing in $p_a$

Differentiate equation (18) with respect to $p_a$:

$$\frac{d\pi_i^*(2)}{dp_a} = \frac{\partial \pi_i^*(2)}{\partial w^*} \frac{dw^*}{dp_a}.$$

Denote the rhs of equation (19) by $A$, and differentiate this equation w.r.t. $p_a$:

$$0 = \frac{\partial A}{\partial w^*} \frac{dw^*}{dp_a} + \frac{\partial A}{\partial p_a}.$$

After substitution, we have that:

$$\frac{d\pi_i^*(2)}{dp_a} = \frac{\partial \pi_i^*(2)}{\partial w^*} \frac{-\dfrac{\partial A}{\partial p_a}}{\dfrac{\partial A}{\partial w^*}}.$$

Straightforward computation shows that this expression is negative.