3. Natural resources and social conflict: an explanation of sub-Saharan countries' stagnation*

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3.1. INTRODUCTION

Sub-Saharan countries have shown substantial stagnation in their per capita GDP in the last 30 years (see Durlauf et al., 2005). Collier and Gunning (1999) argue that sub-Saharan countries have particular characteristics with respect to other developing countries, such as widespread corruption, strong social fractionalization and a large number of civil wars. They also claim that the divergence between the development paths of sub-Saharan countries and those of other developing countries started at the beginning of the 1970s. The colonial past has undoubtedly played a contributory role in the weakness of social and political institutions of sub-Saharan countries. However, other aspects appear to characterize these countries, such as low investment rates, low levels of human capital and (relative) abundance of natural resources (see Collier and Gunning, 1999). As regards the endowment of natural resources, Auty (2001) discusses how countries whose output is concentrated in primary sectors show low growth rates (see also Sachs and Warner, 2001; Mehlum et al., 2006; and Humphreys et al., 2007). The literature has proposed many complementary explanations of the phenomenon, denoted as the curse of natural resources, among which: i) strong exports of natural resources change the terms of trade, crowding out the traded-manufacturing activities (Sachs and Warner, 2001); ii) the rents from natural resources distort the allocation of investments (for example less incentive to invest in education, see Gylfason, 2001); and iii) the rents from natural resources encourage strong rent-seeking activities and/or social conflict in countries with weak institutions (see Olsson, 2007 and Mehlum et al., 2006).

In this chapter we argue that the stagnation of sub-Saharan economies is mainly explained by their high level of social conflict. Here, in particular, social conflict is caused by the joint effect of abundance of natural resources, low level of per capita GDP, social fractionalization, and weak political and social institutions.

A theoretical model is built on Olsson (2007) and Mehlum et al. (2003). It aims to identify the conditions under which countries can be trapped in a permanent underdevelopment regime. In the economy there are two sectors; in the natural resources sector output depends only on the stock of natural resources, while in the productive sector output depends on labour and on the stock of capital. The economy is populated by two groups of individuals (that is society is polarized into two homogeneous ethnic/religious groups). Formally, government owns the property rights on natural resources, but it can only partially appropriate rents from them (that is institutions are weak). The two groups compete for the appropriation of the residual rents. Grossman and Kim (1996) argue that the social conflict (predation in their terms) is particularly fierce when the level of rents does not crucially depend on social conflict. Rents from natural resources are therefore assumed to be independent of social conflict and output in the industrial sector cannot be predated. Government invests a share of the collected resources to increase the average endowment of capital of economy. The other possible source of capital accumulation is the non-consumed output of the industrial sector.

The competition for the appropriation of residual rents between the two groups is modelled as a one-shot game, where both groups simultaneously choose how to allocate their time between the productive sector and fighting for the appropriation of income from natural resources. Technology in the productive sector is linear in capital; therefore, given a sufficiently high level of investment rate, the economy without conflict would grow in the long run. But the waste of resources caused by social conflict can generate a poverty trap, that is countries with a low initial level of capital can be trapped in a low-income equilibrium.

We find that the long-run behaviour of the economy crucially depends on the quality of institutions: fewer appropriable rents means less incentive to compete for them, as in Olsson (2007) and Mehlum et al. (2003). But, differing from the latter, the level of actual stock of per capita capital is also a crucial factor: capital determines the *outside option* of the competition for rents (see Collier et al., 2005, for a similar point). The *curse of natural resources* is therefore the result of the joint effect of weak institutions and of a low level of per capita income (capital). A counterintuitive example explains the importance of considering institutions and level of per capita income jointly: an increase in resources harvested by government, which are then entirely consumed by the same government, thereby reducing the rents to be shared between the two groups, could help the country to escape from the poverty trap. However, in the empirical analysis this could also signal weak institutions. The model, moreover, points out that a high population growth rate and low private and public investment rates may also increase the probability of being trapped in a stagnant regime.

From an empirical point of view, Auty (2001) contains many historical examples of collapses of economies caused by social conflict for the appropriation of rents. Civil wars can be considered the fiercest type of social conflict: there exists a general consensus on the definition of civil war, while other types of social conflict, such as riots and coups, are more difficult to measure. Many scholars, therefore, focus on the determinants of civil wars to study social conflict within a country. Empirical analysis by Collier and Hoeffler (2004) and Collier et al. (2006) of the onset of a civil war and its long-run effects support our theoretical results. Collier et al.'s (2005) finding that sub-Saharan countries have the highest probability of civil war onset gives further empirical support to our approach. To test the relationship between the abundance of natural resources and civil war onset, Sambanis (2003) presents many case studies of countries, including many sub-Saharan countries. Finally, Olsson (2006 and 2007) documents how diamond production has directly triggered civil war in many sub-Saharan countries.

In spirit the model follows the game-theoretical approach to social conflict exposed in Hirshleifer (2001). The approach adopted by Dixit (2004) is close to ours; in the limiting case of non-existence of government the issue analysed in this chapter is equivalent to the definition of property rights on natural resources in an economy without any legal system. Gonzales (2007) analyses a growth model with social conflict but in equilibrium the economy is not growing and therefore the opportunity cost of social conflict is constant; moreover his focus is on the welfare implication of social conflict. Benhabib and Rustichini (1996) deal with the issue but in a very different framework. Finally, models with occupational choice by Acemoglu (1995), Murphy et al. (1993) and Mehlum et al. (2003) are close to this model in their focus on the incentives to individuals to become producers or predators and how their choice affects the development of an economy.

3.2. EMPIRICAL EVIDENCE ON GROWTH, NATURAL RESOURCES AND SOCIAL CONFLICT

With the negative effect of social conflict on the development of countries taken for granted, the motivations for this chapter are two empirical regularities showed by cross-country analyses: i) the negative relationship between growth and abundance of natural resources and ii) the positive relationship between the latter and social conflict, in particular with the onset of civil war. Two such regularities suggest a natural explanation of the stagnant growth regime of sub-Saharan countries in the last 30 years.

3.2.1. Cross-country Evidence

We consider a sample of 108 countries, among which there are 30 sub-Saharan countries.[1] Table 3.1 reports the averages of the following variables: average growth rate of per capita GDP in 1975–2004, *AV.GR*; the log of per capita GDP in 1975, *LOG.GDP.1975*; average share of non-manufactured exports of total exports in the period 1975–2004, *NM.EXP*;[2] the average investment rate in 1975–2004, *SAV.RATE*; average growth of population in 1975–2004, *GR.POP*; average enrolment in secondary education in 1975–2004, *EN.SEC* for sub-Saharan countries and for the rest of the sample.

The table shows that sub-Saharan countries' per capita GDP stagnated in the period (0 per cent on average); by contrast, the average growth rate of per capita GDP of all the other countries is equal to 1.9 per cent. Moreover, sub-Saharan countries on average have lower initial levels of per capita GDP, higher population growth rates, lower saving rates and lower education levels. Finally, the share of non-manufactured exports of total exports, which should capture the importance of natural resources in the country's economy, is higher in sub-Saharan countries, as well as the share of countries with a civil war in the period (10 out of 30 versus 19 out of 78).

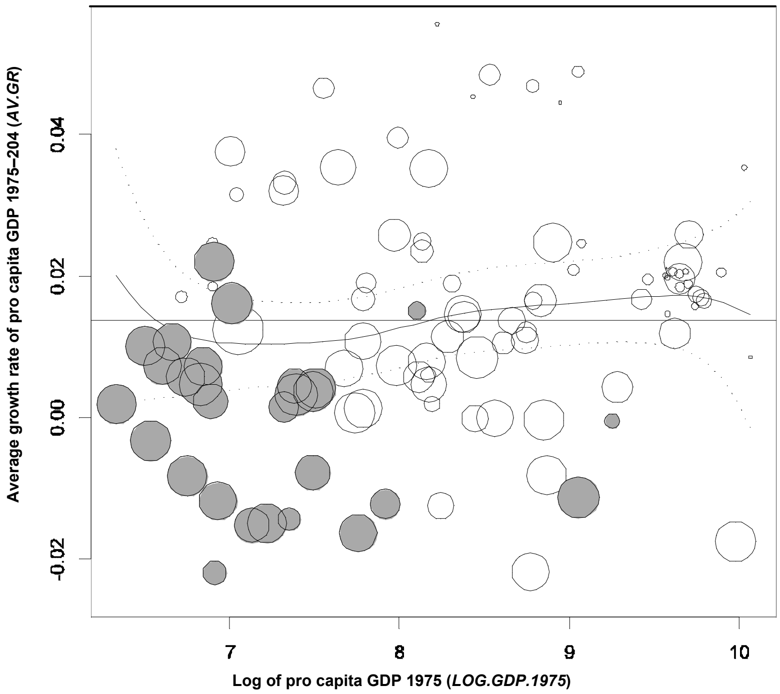
Table 3.1. Descriptive statistics of the variables in the sample (sub-Saharan countries versus all other countries)

	Sub-Saharan Countries	Other Countries
Number of countries	30	78
AV.GR	0%	1.9%
LOG.GDP.1975	1919	7825
AV.RATE	10.7	21.2
GR.POP	2.7%	1.4%
EN.SEC	27.8	81.8
NM.EXP	79.9	51.8
CIVIL.WAR	10	19

Source: WDI (2006)

To show that a stagnant growth regime characterizes almost all the sub-Saharan countries in the period, Figure 3.1 reports the average growth rate of per capita GDP for the period 1975–2004 against its initial level.

In Figure 3.1 each circle represents a country. The circle radius is proportional to *NM.EXP* and dark grey circles represent sub-Saharan countries. The horizontal line represents the average growth rate of the



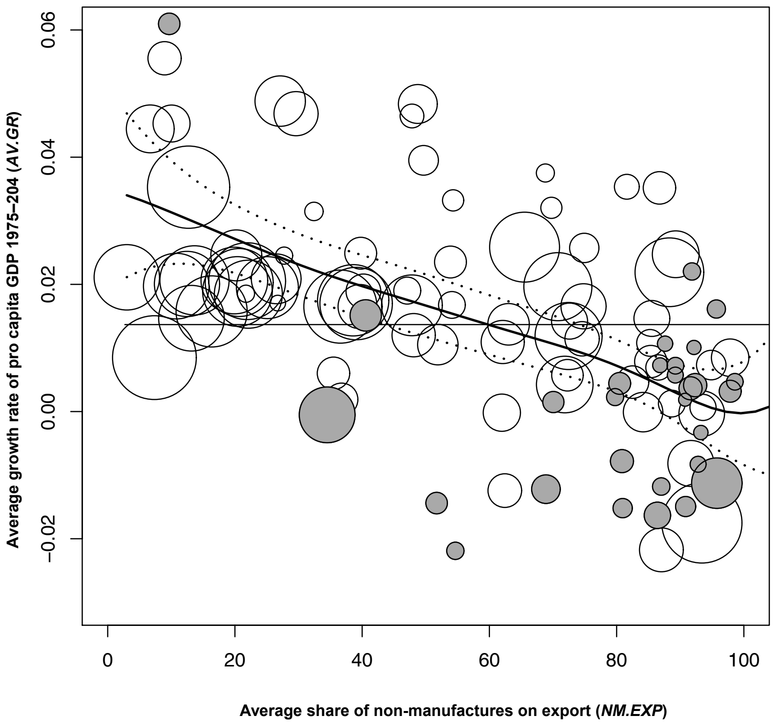
Note: The circle radius is proportional to the share of non-manufactured exports on total exports (*NM.EXP*). Dark grey circles represent sub-Saharan countries. The horizontal line represents the average growth rate of the sample.

Source: WDI (2006).

Figure 3.1. Average growth rate of per capita GDP for the period 1975–2004 against the level of per capita GDP in 1975.

sample equal to 1.4 per cent. The figure reports a non-parametric estimate and its confidence bands of the relationship between the average growth rate and the log of initial per capita GDP.[3] The estimate shows that there is no convergence among the per capita GDP of countries (confidence bands include the average growth rate of sample for all the range of the log of per capita GDP), and that, overall, sub-Saharan countries had particularly low growth rates and substantial higher shares of non-manufactures on exports.

To investigate the relationship between the latter two variables, Figure 3.2 reports the relationship between the average growth rate of per capita GDP versus the share of non-manufactured exports on total exports. The radius of the circle is proportional to the log of initial per capita GDP. Figure 3.2 suggests that the abundance of natural resources could have a negative effect



Note: The circle radius is proportional to the log of per capita GDP in 1975. Dark grey circles represent sub-Saharan countries. The horizontal line represents the average growth rate of the sample.

Source: WDI (2006).

Figure 3.2. Average growth rate of per capita GDP against the share of non-manufactured exports on total exports (NX.EXP).

on growth rate. Moreover, the negative effect appears particularly severe for countries with a low initial income, that is sub-Saharan countries.

The variables reported in Table 3.1 show a high correlation among themselves and, therefore, sound causal relationships are hardly detectable (that is standard linear regressions are biased by endogeneity). Nonetheless, only for exploratory purposes, Table 3.2 reports the estimate of two models for our sample of 108 countries: Model 1 is the usual cross-country growth regression but including the export of primary goods $NM.EXP$; Model 2 is the best model (in terms of the highest $\overline{R}^2$) when some interaction terms are introduced.

Table 3.2. The best estimate of a standard growth model with the addition of the share of non-manufactured exports on total exports and interaction terms among variables.

Dependent variable: AV.GR	Model 1	Model 2
(Intercept)	0.0457***	0.0146
INI.GDP	–0.0136***	–0.0125***
SAV.RATE	0.0013***	0.0020***
POP.GR	–0.2871	
EN.SEC	0.0273***	0.0279**
NM.EXP	–0.0001*	0.0003*
POP.GR:NM.EXP		–0.0055*
SAV.RATE:NM.EXP		–0.0000**
	0.69	0.71
Number of countries	108	108

Notes: Significant codes: 0‘***’ 0.001‘**’ 0.01‘*’.

Table 3.2 shows the remarkable result that in Model 2 the coefficient of $NM.EXP$ becomes positive once we control for the interactions among variables (that is natural resources are good for growth). $NM.EXP$ has, on the contrary, a negative impact when it interacts with the investment rate $SAV.RATE$ and the growth rate of population $GR.POP$; the latter sign signals that social conflict could be at work, while the negative sign of the interaction term of $NM.EXP$ with $SAV.RATE$ suggests that abundance of natural resources can crowd out manufactures investment by changing the terms of trade.

The lack of data does not allow us to control for the quality of institutions. For a limited number of countries (that is 26), and only for the period 2001–2005, the World Bank provides three indices based on enterprise surveys in which the managers surveyed ranked the respect of property rights ($PROPERTY.RIGHTS$), corruption ($CORRUPTION$) and crime ($CRIME$) as a major business constraint in a given country (in particular, the indices represent the per cent of managers surveyed which say that property rights are respected and corruption and crime are a problem for business activity in the country). Table 3.3 reports such indices.

Sub-Saharan countries seem to have low-quality institutions. The result is, however, not conclusive partly due to the small number of countries and, overall, because the quality of institutions is probably endogenous (that is the evidence reported in Table 3.3 could be the results of the stagnant growth regime of sub-Saharan countries).

Table 3.3. Descriptive statistics of the quality of institutions for 2001–2005 for a restricted number of countries.

	Sub-Saharan countries	Other countries
Number of countries	5	21
PROPERTY.RIGHTS	36.3%	44.3%
CORRUPTION	45%	40.6%
CRIME	36.9%	29.25%

Source: WDI (2006).

As regards civil wars, the fiercest type of social conflict, Collier et al. (2005) consider a sample of 161 countries in the period 1960–1999; they identify 78 cases of civil wars regarding 50 countries, among which are 18 sub-Saharan countries. Their analysis shows that the amount of rents from natural resources has significant explanatory power in predicting civil war onsets. Collier and Hoeffler (2002), however, show that the higher probability of civil war onsets in the sub-Saharan countries disappears after controlling for the initial level of per capita GDP, the importance of the primary sector and social fractionalization. All these three aspects are consistent with the theoretical model presented in Section 3.3.

3.2.2. Case Studies of Sub-Saharan Countries

The empirical evidence discussed above provides macro evidence for the relationships between growth, natural resources and social conflict for a large cross-section of countries. Case studies regarding some sub-Saharan countries provide complementary information to evaluate whether such macro relationships are effectively *casual* relationships. As noted by Olsson (2006), sub-Saharan countries have a large diamond production, and in such countries, with the exception of Botswana and South Africa, diamond production appears to fuel endemic social conflict. Indeed, civil wars in Angola, Sierra Leone, Liberia and the Democratic Republic of Congo appear the result of the fighting for the appropriation of their diamond production. For other sub-Saharan countries, like the Central African Republic, Cote d'Ivoire, Guinea, Uganda and the Republic of Congo, with no production of diamonds but bordering diamond-producing countries, diamonds have been a source of intense illegal activity (for example corruption, smuggling, and so on). All these sub-Saharan countries appear to have been in a stagnant growth regime in the last 30 years.

Sambanis (2003) reviews 22 case studies of civil war onset or war avoidance, including the following 10 sub-Saharan countries: Burundi, the Democratic Republic of Congo, Kenya, Cote d'Ivoire, Mali, Mozambique, Nigeria, Senegal, Sierra Leone and Sudan. Civil war in Burundi seems only partially linked to natural resources, social fractionalization being the main factor, while civil war in Mozambique was mainly financed by the diaspora in Rhodesia. By contrast, civil wars in the Democratic Republic of Congo seem to be caused by the abundance of natural resources (many different types of minerals); the same in Kenya (rich agricultural production), Mali (gold and diamonds), Nigeria (oil), Senegal (cannabis and timber), Sierra Leone (diamonds) and Sudan (oil). Interestingly, in Cote d'Ivoire, which is a resource-abundant country, strong redistributive policies (good institutions) was used to mitigate conflict risk.

3.3. THE MODEL

Suppose that the economy is composed of two groups of individuals, *Citizens* and *Rebels*. At period t the cardinality of the groups of *Citizen*s (C) and *Rebel*s (R) are equal to N^C and N^R, and $N=N^C+N^R$ is the total population (in the following, time index is omitted if this is not source of confusion). In the economy there exists a flow of income from natural resources F. A share equal to $1-\gamma\geq 0$ is appropriate by Government and the remaining part γ is appropriate by the two groups. Parameter γ should measure the quality of institutions, that is higher γ means less efficient institutions.

In each period every rebel has to decide how to allocate his/her time between the productive sector, $l^R\geq 0$, and fighting for the appropriation of income from natural resources, $p\geq 0$. Total endowment of time is normalized to 1, that is $l^R+p=1$. The time employed in the productive sector has a reward proportional to the per capita capital of the economy $k_t=K_t/N_t$; in particular a rebel gets $Al^R k_t$ from the productive sector. By the same token, every citizen has to decide how to employ their time between the productive sector, $l^C\geq 0$, and fighting for the appropriation of income from natural resources, $d\geq 0$. with the total endowment of time again normalized to 1, that is $l^C+d=1$. Symmetrically, a citizen gets $Al^C k_t$ from the productive sector.

The intensity of *social conflict* is measured by the share of population engaged in the fight for the appropriation of income from natural resources, that is $\beta^R p+\beta^C d$, where $\beta^R=N^R/N$ is the share of *Rebels* on total population and $\beta^C=N^C/N$ is the share of *Citizens* on total population ($\beta^R+\beta^C=1$). We assume that β^C and β^R are constant over time.

Within each group appropriate income is equally shared among the members of the group, so that each member of the same group adopts the same decision on personal time allocation. Given p and d, $N^R p/(N^R p+N^C d)$

and $N^C d/(N^R p+N^E d)$ are the shares of respectively accruing to *Rebels* and *Citizens*.

The utility of the representative rebel is given by:

$$U^R = A(1-p_t)\ k_t + \left(\frac{N^R p_t}{N^R p_t + N^C d_t}\right)\frac{\gamma F}{N^R} = A(1-p_t)\ k_t + \left(\frac{p_t}{\beta^R p_t + \beta^C d_t}\right)\gamma f, \quad (3.1)$$

where $f = F/N$ is the per capita income from natural resources, while the utility of the representative citizen is given by:

$$U^C = A(1-d_t)\ k_t + \left(\frac{d_t}{\beta^R p_t + \beta^C d_t}\right)\gamma f. \quad (3.2)$$

We assume that f is constant over time. The aggregate stock of capital in the economy is the result of private saving from the productive sector and of public saving; in particular:

$$K_{t+1} = (1-\delta)\ K_t + sA(1-p_t)\ k_t N^R + sA(1-p_t)\ k_t N^C + s^G(1-\gamma)\ F, \quad (3.3)$$

where $\delta > 0$ is the depreciation rate of capital, $s \geq 0$ is the private marginal saving rate from output of private sector and $s^G \geq 0$ is the public marginal saving rate. All income from natural resources is consumed. Equation (3.3) can be expressed in terms of per capita capital, that is:

$$k_{t+1} = \frac{(1-\delta)\ k_t + sA(1-p_t)\ k_t \beta^R + sA(1-d_t)\ k_t \beta^C + s^G(1-\gamma)\ f}{1+n}, \quad (3.4)$$

where $n = N_{t+1}/N_t - 1 \geq 0$ is the constant growth rate of the population. Income from the productive sector cannot be predated, that is it cannot be a source of dispute between the two groups (see Grossman and Kim, 1996).

The framework can be extended to consider different groups; the extension would not provide any additional insight with respect to the issue analysed here, but as increases the time devoted to fighting would tend to decrease as its marginal effect on the share of appropriate income from natural resources tends to decrease.[4]

3.4. OPTIMAL STRATEGIES

In every period *Citizens* and *Rebels* choose their time allocation by playing a one-shot game. Proposition 1 states the Nash equilibrium of the game.

Proposition 1 *Assume that* $\beta^R \leq 1/2$; *then in the Nash equilibrium of the one-shot game between* Citizens *and* Rebels*:*

$$p^* = d^* = 1 \qquad \text{when } k_t \in \left[0,\, \bar{k}^d\right];$$

$$p^* = 1,\ d^* = \left(\tfrac{1}{1-\beta^R}\right)\sqrt{\tfrac{\beta^R \gamma f}{A k_t}} - \tfrac{\beta^R}{1-\beta^R} \qquad \text{when } k_t \in \left[\bar{k}^d,\, \bar{k}^p\right]$$

$$p^* = \tfrac{\gamma f}{4\beta^R A k_t},\ d^* = \tfrac{\gamma f}{4\left(1-\beta^R\right) A k_t} \qquad \text{when } k_t \in \left[\bar{k}^p,\, +\infty\right),$$

where $\bar{k}^d = \gamma f \beta^R / A$ *and* $\bar{k}^p = \gamma f \big/ \left(4\beta^R A\right)$ *with* $\bar{k}^d \le \bar{k}^p$.

Proof See Appendix B.

Proposition 1 shows that the intensity of social conflict depends on the ratio between f and k_t: for low level of $k_t \left(k_t \le \bar{k}^d\right)$ all population is engaged in the fight for the appropriation of natural resources, that is there is a fierce civil war; for a higher but always low level of $k_t \left(k_t \in \left[\bar{k}^d, \bar{k}^p\right]\right)$ only *Rebels* are fully engaged in the fight, while a part of *Citizens* are employed in the productive sector; finally for sufficiently high level of capital $(k_t > \bar{k}^p)$ some *Rebels* also stop fighting and shift to productive sector. Therefore, *ceteris paribus*, social conflict, measured by $\beta^R p_t^* + \beta^C d_t^*$, monotonically decreases with the level of per capita capital k_t. The result is expected, given that the opportunity cost of fighting is proportional to k_t. If $\beta^R > 1/2$ in the intermediate range of capital all *Citizens* would defend, while only some *Rebels* would be engaged in the fight.

It is straightforward to prove that if $k_t > \bar{k}^d$ social conflict decreases with (the opportunity cost of fighting) and increases with (the reward for fighting). Finally, if $k_t \in \left[\bar{k}^d, \bar{k}^p\right]$ social conflict increases with $\beta^R p$ (the size of the minority in the country). All these findings agree with the empirical evidence on the causes and intensity of civil wars discussed in Collier and Hoeffler (2004) and in Collier et al. (2006).

The social optimal allocation of time $p^* = d^* = 0$ cannot be reached because there is no self-enforcing agreement on the sharing of income from natural resources in the one-shot game.

3.5. LONG-RUN EQUILIBRIUM

Equation (3.4) and Proposition 1 give the dynamics of per capita capital:

$$k_{t+1} = \begin{cases} \left(\frac{1}{1+n}\right)\left[(1-\delta)k_t + s^G(1-\gamma)f\right] & \text{when } k_t \in \left[0, \bar{k}^d\right]; \\ \left(\frac{1}{1+n}\right)\left[(1-\delta+sA)k_t - s\sqrt{\beta^R \gamma f A k_t} + s^G(1-\gamma)f\right] & \text{when } k_t \in \left[\bar{k}^d, \bar{k}^p\right] \\ \left(\frac{1}{1+n}\right)\left[(1-\delta+sA)k_t - s\gamma f/2 + s^G(1-\gamma)f\right] & \text{when } k_t \in \left[\bar{k}^p, +\infty\right), \end{cases} \tag{3.5}$$

Proposition 2 states under which configuration of parameters the economy displays multiple (two) equilibria.

Proposition 2 *Assume that* $\beta^R \leq 1/2$ *and*

$$sA \in \left(\delta+n, \frac{\delta+n}{1-2\beta^R} - \frac{s^G 4\beta^R A(1-\gamma)}{\gamma(1-2\beta^R)}\right]. \tag{3.6}$$

Then there exist two equilibria k^{E_S} *and* k^{E_U}, *the first stable and the second unstable, where:*

$$k^{E_U} = \frac{f\left[s\gamma - 2s^G(1-\gamma)\right]}{2(sA-\delta-n)} \tag{3.7}$$

and $k^{E_S} < \bar{k}^p < k^{E_U}$.

Proof See Appendix C.

Figure 3.3 reports a graphical illustration of Proposition 2.

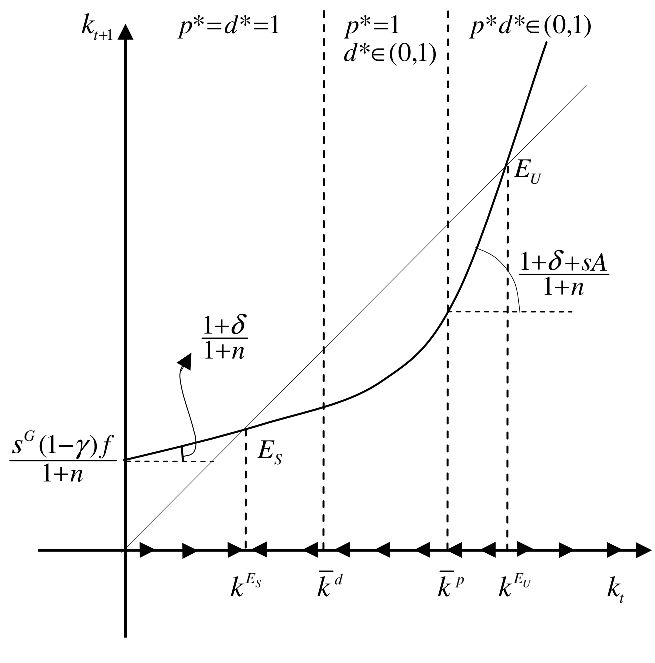


Figure 3.3. Economy with two equilibria

Figure 3.3 shows that an economy displays two different dynamics according to its initial level of capital; an economy with a low initial level of per capita capital, that is $k_0 < k^{E_U}$, will be converging toward equilibrium E_S, while an economy with a sufficiently high initial level of per capita capital, that is $k_0 > k^{E_U}$, will grow forever. The model therefore exhibits poverty trap.

Proposition 3 characterizes the long-run dynamics of economy.

Proposition 3 *Assume that* $\beta^R \le 1/2$ *and Condition (3.6) holds. If* $k_0 < k^{E_U}$ *then the per capita capital of economy will be converging towards* k^{E_S}, *while if* $k_0 > k^{E_U}$ *then* $\lim_{t\to\infty} g_k = k_{t+1}/k_t - 1 = sA - \delta - n$.

Proof See Appendix D.

Figure 3.4 shows the growth path of the economy, g_k, under condition (3.6) in Proposition 2.

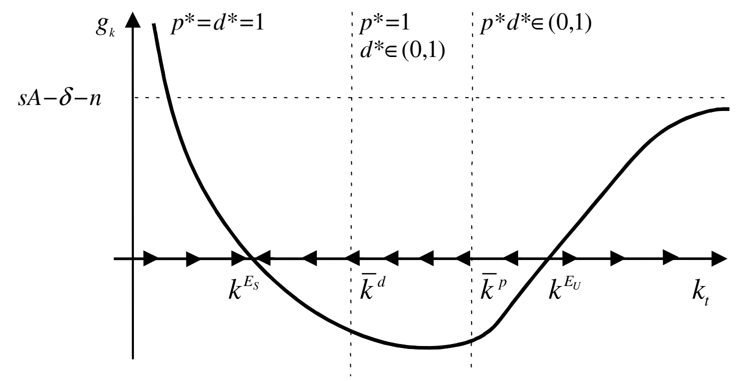


Figure 3.4. Growth path of the economy with two equilibria

The level of k^{E_U} is therefore the threshold of per capita capital which determines the long-run dynamics of economy. Remark 4 shows the relationship between k^{E_U} and the most relevant parameters of the economy.

Remark 4 *The threshold level of per capita capital* k^{E_U} *increases with* f, n, γ *and decreases with* s^G, A *and* s.

Proof Derivatives of k^{E_U} in Proposition 3 with respect to f, n, γ, s^G, A and s directly prove the results, given that $s^G < \gamma(n+\delta)/[2A(1-\gamma)]$ since $s^G < \beta^R \gamma(n+\delta)/[A(1-\gamma)]$ and $\beta^R \le 1/2$ (see Condition (3.6) in Proposition 3).

Remark 4 says that, given a certain level of per capita capital, the probability of a country being trapped in an equilibrium with low income and strong social conflict increases with income from natural resources (f), population growth rate (n), weakness of institutions (γ), and decreases with public and private saving rates (s and s^G) and productivity of the productive sector (A).

3.5.1. Dynamics of Per Capita Income

In the model the dynamics of per capita capital drives the dynamics of the economy. However, the country's per capita income depends both on the level of per capita capital and on the income from natural resources. Proposition 5 shows the per capita income for different levels of per capita capital.

Proposition 5 *Assume that* $\beta^R \leq 1/2$; *then in the Nash equilibrium of the one-shot game between* Citizens *and* Rebels *the per capita income of the economy is given by:*

$$y_t = \begin{cases} f & \text{when } k_t \in \left[0, \bar{k}^d\right]; \\ \left(1+\beta^R\right) Ak_t - \sqrt{\gamma f \beta^R A k_t} + f & \text{when } k_t \in \left[\bar{k}^d, \bar{k}^p\right] \\ Ak_t + \dfrac{f(2-\gamma)}{2} & \text{when } k_t \in \left[\bar{k}^p, +\infty\right), \end{cases} \tag{3.8}$$

where $\bar{k}^d = \gamma f \beta^R / A$ *and* $\bar{k}^p = \gamma f / \left(4\beta^R A\right)$.

Proof At period per capita income is given by:

$$y_t = \beta^C \left(1-d_t^*\right) Ak_t + \beta^R \left(1-p_t^*\right) Ak_t + f; \tag{3.9}$$

Proposition 1 and Equation (3.9) prove the results.

Proposition 6 states the dynamics of per capita income with a poverty trap.

Proposition 6 *Assume that* $\beta^R \leq 1/2$ *and Condition (3.6) holds. If* $y_0 < y^{E_U}$ *then the per capita income will be converging towards* $y^{E_S} = f$; *otherwise, if* $y_0 > y^{E_U}$ *then in the long run the per capita capital will be growing at rate* $sA-\delta-n$, *where:*

$$y^{E_U} = f\left[1+\frac{\gamma(n+\delta)-2s^G(1-\gamma)}{2(sA-n-\delta)}\right]. \tag{3.10}$$

Proof See Appendix E.

Propositions 2 and 6 show that in the case of zero saving by government, that is $s^G = 0$, in the poverty trap equilibrium capital is zero but per capita income is positive and entirely deriving from natural resources.

Remark 7 shows the relationships between y^{E_U} and the most relevant parameters of the economy.

Remark 7 *The threshold level of per capita income* y^{E_U} *increases with* f, n, γ *and decreases with* s^G, s *and* A.

Proof Derivatives of y^{E_U} in Proposition 6 with respect to f, n, γ, s^G, A and s directly prove the results.

Remark 7 says that, given a certain level of per capita income, the probability of a country to be trapped in an equilibrium with low income and strong social conflict increases with income from natural resources (f), growth rate of population (n), weakness of institutions (γ) and decreases with public and private saving rates (s and s^G) and productivity of productive sector (A).

3.5.1.1. Government consumption

In the model government consumption could have a positive impact on the development of a country if it dissipates rents from natural resources. For the sake of simplicity, consider the share of government consumption on total income c_t^G around the threshold of the poverty trap y^{E_U}, that is:

$$c_t^G = \frac{\left(1-s^G\right)\left(1-\gamma\right) f}{y_t} = \frac{2\left(1-s^G\right)\left(1-\gamma\right) f}{2Ak_t + f\left(2-\gamma\right)};$$

a decrease in γ, that is a higher capacity of government to appropriate the income from natural resources, causes an increase in y_t and in c_t^G but also a decrease in y^{E_U}. An increase in the government consumption, therefore, increases the probability of a country of escaping from a poverty trap. The intuition of the result is straightforward: government consumption is a waste of resources, but if such a waste derives from a decrease in γ, it reduces the incentives to fight; more resources will be consequently allocated to productive sector. The latter positive effect outweighs the former negative effect.

3.6. CONCLUDING REMARKS

Taking k, f and n in the model as, respectively, proxies of per capita GDP, rents from primary sector and population size of a country, empirical evidence on the civil war onset provided by Collier and Hoeffler (2004) and Collier et al. (2006) supports our theoretical findings. In addition, Collier and Hoeffler (2004) find that the stagnant growth regime caused by civil war is persistent over time, which supports our claim for the existence of a poverty trap for sub-Saharan countries.

The model could be fruitfully extended to investigate the possibility that groups may reach self-enforcing agreement on the sharing of rents from natural resources; this could happen, for example, if the agents' time-horizon is infinite or indefinite, as in Muthoo (2004). This is the direction of our future research.

APPENDIX

A. Country List

Algeria, Argentina, Bangladesh, Benin, Bolivia, Botswana, Brazil, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Chile, China, Colombia, Congo, Dem. Rep., Congo, Rep., Costa Rica, Cote d'Ivoire, Cyprus, Dominican Republic, Ecuador, Egypt, El Salvador, Fiji, Gambia, Ghana, Greece, Guatemala, Guyana, Honduras, Hungary, India, Indonesia, Iran, Islamic Rep., Israel, Italy, Jamaica, Jordan, Kenya, Latvia, Madagascar, Malawi, Malaysia, Mali, Malta, Mauritania, Mexico, Morocco, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Rwanda, Saudi Arabia, Senegal, Seychelles, Sierra Leone, Singapore, South Africa, Sri Lanka, Sudan, Swaziland, Switzerland, Syrian Arab Republic, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Uruguay, Venezuela, Zambia, Zimbabwe.

B. Proof of Proposition 1

Suppose first that in the Nash equilibrium $p^*, d^* \in (0, 1)$. Then the first order conditions of the maximization of and are given by:

$$\frac{\partial U^R}{\partial p_t} = \frac{\gamma f \beta^C d_t}{\left(\beta^R p_t + \beta^C d_t\right)^2} - Ak_t = 0$$

$$\frac{\partial U^C}{\partial d_t}=\frac{\gamma f \beta^R p_t}{\left(\beta^R p_t+\beta^C d_t\right)^2}-Ak_t=0,$$

from which:

$$p_t^*=\frac{\gamma f}{4\beta^R Ak_t}\ ,\ d_t^*=\frac{\gamma f}{4\beta^C Ak_t}, \tag{3A.1}$$

Since $\beta^R \le 1/2$ then $p_t^* \ge d_t^*$. From equation (3A.1) the constraint on p_t^* (that is $p_t^* \in [0, 1]$) becomes binding for $k_t \le \bar{k}^p = \gamma f/(4\beta^R A)$, that is $p_t^* < 1$ for $k_t > \bar{k}^p$ and $p_t^* = 1$ for $k_t \le \bar{k}^p$. Taking $p^* = 1$, the first order condition for the maximization of U^C becomes:

$$\frac{\partial U^C}{\partial d_t}=\frac{\gamma f \beta^R}{\left(\beta^R+\beta^C d_t\right)^2}-Ak_t=0,$$

from which:

$$d_t^*=\left(\frac{1}{1-\beta^R}\right)\sqrt{\frac{\beta^R\gamma f}{Ak_t}}-\frac{\beta^R}{1-\beta^R}\ \text{for } k_t>\bar{k}^d$$

$$d_t^*=1\ \text{for } k_t\le\bar{k}^d,$$

where $\bar{k}^d = \gamma f \beta^R/A$ and $\beta^C = 1-\beta^R$. Finally since $\beta^R \le 1/2$ then $\bar{k}^d \le \bar{k}^p$.

C. Proof of Proposition 2

First note that if $sA > \delta + n$ then:

$$\frac{\partial k_{t+1}}{\partial k_t}=\begin{cases}\dfrac{1-\delta}{1+n}<1 & \text{when } k_t\in\left[0,\bar{k}^d\right);\\[2ex] \dfrac{1}{1+n}\left[1-\delta+sA-\dfrac{1}{2}s\sqrt{\beta^R\gamma fA}k_t^{-1/2}\right] & \text{when } k_t\in\left(\bar{k}^d,\bar{k}^p\right)\\[2ex] \dfrac{1-\delta+sA}{1+n}>1 & \text{when } k_t\in\left(\bar{k}^p,+\infty\right),\end{cases} \tag{3A.2}$$

and

$$\frac{\partial^2 k_{t+1}}{\partial k_t^2}=\begin{cases}0 & \text{when } k_t\in\left[0,\bar{k}^d\right);\\[2ex] \dfrac{1}{4}\dfrac{s\sqrt{\beta^R\gamma fA}k_t^{-3/2}}{1+n}>0 & \text{when } k_t\in\left(\bar{k}^d,\bar{k}^p\right)\\[2ex] 0 & \text{when } k_t\in\left(\bar{k}^p,+\infty\right).\end{cases} \tag{3A.3}$$

Suppose that there exists an equilibrium in the range $k_t \in (\bar{k}^p, +\infty)$; then in this equilibrium per capita capital is given by

$$k^{E_U} = f\frac{s\gamma - 2s^G(1-\gamma)}{2(sA-\delta-n)}.$$

Condition for the existence of this equilibrium is that $\bar{k}^p < k^{E_U}$ (for the sake of simplicity in the proof of stability of k^{E_U} the frontier of range is excluded), that is

$$sA < \frac{\delta+n}{1-2\beta^R} - \frac{4s^G\beta^R A(1-\gamma)}{\gamma(1-2\beta^R)}. \qquad (3A.4)$$

This equilibrium is locally unstable since $sA > \delta + n$ (see Equation (3A.2)). If Condition (3A.4) holds then $k_{t+1} < k_t$ in $k_t = \bar{k}^p$, while $k_{t+1} \geq 0$ in $k_t = 0$. Since k_{t+1} is continuous in k_t in the range $[0, +\infty)$ at least an equilibrium in the range $[0, \bar{k}^p]$ must exist. The monotonicity and convexity of k_{t+1} with respect to k_t in the range $\left[0, \bar{k}^p\right]$ (see Equations (3A.2) and (3A.3)) ensures that there exists only a stable equilibrium k^{E_S} in the range, that is $\partial k_{t+1}/\partial k_t < 1$ in k^{E_S}. Indeed, in a possible second equilibrium $\partial k_{t+1}/\partial k_t > 1$, that is k_{t+1} should cross from below the bisector; in such a case, Equation (3A.3) implies that $\partial k_{t+1}/\partial k_t > 1$ for all levels of capital higher than the capital of equilibrium. But this contrasts with the fact that k_{t+1} must be below the bisector in $k_t = \bar{k}^p$.

D. Proof of Proposition 3

Under Condition (3.6) Proposition 2 states the existence of two equilibria, k^{E_S} and k^{E_U}, the first locally stable and the second locally unstable, with $k^{E_S} < k^{E_U}$ and that growth path is continuous. A simple graphical inspection of Figure 3.3 reveals that if $k_0 < k^{E_U}$ then economy will be converging towards k^{E_S} while if $k_0 > k^{E_U}$ then economy will be growing forever. In the latter case $\lim_{t\to+\infty} g_k = k_{t+1}/k_t - 1 = sA - \delta - n$.

E. Proof of Proposition 6

Proposition 5 shows that the dynamics of per capita income is driven by the dynamics of per capita capital. Under Conditions (3.6) in Proposition 6 there exists a threshold in per capita capital k^{E_U}; the corresponding value in term of per capita income, denote it y^{E_U}, is such that all the countries with a per capita income under y^{E_U} will see their income converge to f; on the contrary all the countries with a per capita income over y^{E_U} will see their income grow at the same rate of per capita capital, that is $sA-\delta-n$, in the long run. In fact as k_t increases y_t / k_t tends to A (the term $f(1-\gamma/2)/k_t$ tends to vanish as $k_t \to +\infty$). The threshold of per capita income y^{E_U} is calculated from the threshold of per capita capital k_U^E in Proposition 2, given that in that range of per capita capital $y_t = Ak_t + f$.

NOTES

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1. All the variables are drawn from World Development Indicators (2006). The country list is in Appendix A.
2. More precisely, $NM.EXP$ includes agricultural commodities, raw materials, ores, metals, fuels and food.
3. The estimate is made with *R* using package *sm* with standard settings by Bowman and Azzalini (2005).
4. In a more general setting the number of groups should be endogenously determined by the trade-off between the advantage to coordinate actions within a group and the free-riding behaviour within the same group. Empirical evidence suggests that groups are generally composed of members who share some cultural, economic and/or social characteristics and their number depends on how such factors are distributed among the population (see Weinstein, 2005). Therefore social fractionalization of a country matters, as indeed highlighted by empirical evidence discussed above.

REFERENCES

Acemoglu, D. (1995), ‘Reward Structures and the Allocation of Talent’, *European Economic Review*, **39**,17-33.

Auty, R. (ed.) (2001), *Resources Abundance and Economic Development*, New York: Oxford University Press.

Benhabib, J. and A. Rustichini (1996), ‘Social Conflict and Growth’, *Journal of Economic Growth*, **1**(1), 125–42.

Bowman, A.W. and A. Azzalini (1997), *Applied Smoothing Techniques for Data Analysis: the Kernel Approach with S-Plus Illustrations*, Oxford: Oxford University Press.

Collier, P. and J. Gunning (1999), ‘Explaining African Economic Performance’, *Journal of Economic Literature*, **37**(1), 64–111.

Collier, P. and A. Hoeffler (2002), ‘On the Incidence of Civil War in Africa’, *Journal of Conflict Resolution*, **46**(1), 13–28.

Collier, P. and A. Hoeffler (2004), ‘Greed and Grievance in Civil War’, *Oxford Economic Papers*, **56**(4), 563–95.

Collier, P. and A. Hoeffler (2007), ‘Civil War’, in T. Sandler and K. Hartley (eds), *Handbook of Defense Economics*, Vol. 2, Amsterdam: North-Holland, pp. 711–39.

Collier, P., A. Hoeffler and N. Sambanis (2005), 'The Collier–Hoeffler Model of Civil War Onset and the Case Study Project Research Design', in P. Collier, A. Hoeffler and N. Sambanis (eds), *Understanding Civil War: Evidence and Analysis*, Vol. 1, Africa, Washington: World Bank Publications.

Collier, P., A. Hoeffler and D. Rohner (2006), 'Beyond Greed and Grievance: Feasibility and Civil War', *CSAE WPS 10*.

Dixit, A. (2004), *Lawlessness and Economics*, Princeton: Princeton University Press.

Durlauf, S., P. Johnson and J. Temple (2005), 'Growth Econometrics', in P. Aghion and S. Durlauf (eds), *Handbook of Economic Growth*, vol. 1A, Amsterdam: North-Holland, pp. 555–677.

Garfinkel, M. and S. Skaperdas (2007), 'Economic of Conflict: An Overview', in T. Sandler and K. Hartley (eds), *Handbook of Defense Economic*s, Vol. 2, Amsterdam: North-Holland, pp. 649–709.

Gonzales, F., (2007), 'Effective Property Rights, Conflict and Growth', *Journal of Economic Theory*, **137**(1), 127–39

Grossman, H. and M. Kim (1996), 'Predation and Accumulation', *Journal of Economic Growth*, **1**(3), 333–50.

Gylfason, T. (2001), 'Natural Resources, Education, and Economic Development', *European Economic Review*, **45**(4-6), 847–59.

Hirshleifer, J. (2001), *The Dark Side of the Force: Economic Foundations of Conflict Theory*, Cambridge: Cambridge University Press.

Humphreys, M., J. Sachs and J. Stiglitz (2007), *Escaping the Resource Curse*, New York: Columbia University Press.

Mehlum, H., K.O. Moene and K. Torvik (2003), 'Predator or Prey? Parasitic Enterprises in Economic Development', *European Economic Review*, **47**(2), 275–94.

Mehlum, H., K.O. Moene and K. Torvik (2006), 'Institutions and the Resources Curse', *Economic Journal*, **116**(508), 1–20.

Murphy, K., A. Shleifer and R. Vishny (1993), 'The Allocation of Talent: Implication for Growth', *Quarterly Journal of Economics*, **106**(2), 503–30.

Muthoo, A. (2004), 'A Model of the Origins of Basic Property Rights', *Games and Economic Behavior*, **49**(2), 288–312.

Olsson O. (2006), 'Diamonds Are a Rebel's Best Friend', *The World Economy*, **29**(8), 1133–49.

Olsson O. (2007), 'Conflict Diamonds', *Journal of Development Economics*, **82**(2), 267–86.

Sachs, J. and A.M. Warner (2001), 'The Curse of Natural Resources', *European Economic Review*, **45**(4-6), 827–38.

Sambanis, N. (2003), 'Using Case Studies to Expand the Theory of Civil War', *CPR Working Paper*, no. 5.

Weinstein, J. (2005), 'Resources and the Information Problem in Rebel Recruitment', *Journal of Conflict Resolution*, **49**(4), 598–624.

World Development Indicators (2006), Washington: World Bank.