The Relative Richness of the Poor? Natural Resources, Human Capital and Economic Growth*

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Abstract

What is the role of natural resources in economic performance? Are there any special conditions in which natural resources can act as the engine of growth? Are natural resources a curse? In this paper we present a model where natural resources have a positive effect on level of income and a negative effect on its growth rate. However, we show that this effect is only relevant in countries with low levels of human capital.

We test our model using panel data for the period 1970-1990. We extend the usual specifications for economic growth regressions by incorporating an interaction term between human capital and natural resources. This exercise allows us to recover a list of countries that were in the past, or are in the present relatively rich in natural resources and human capital, and whose levels of human capital more than offset the negative effect of the natural resource abundance on growth. Overall the empirical evidence is consistent with the main predictions of the model.

Keywords: Economic Growth, Natural Resources, Human Capital, Empirical Determinant of Economic Growth, Comparative Studies of Countries.

JEL Classification: J24,O41,O57, Q00.

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1 Introduction

During the last decade many economists have returned to the old question of whether there is any relationship between the abundance of natural resources and economic growth or the levels of income. Few of them have asked under which circumstances natural resources can perform as an engine of growth. Moreover, the discussion has limited to study the effects on economic growth instead of looking at both growth of income and the level of income, with the latter more closely related to welfare. In this paper we analyze both effects. It is easy to imagine an economy where the discovery of natural resources may lead to a decline in growth, but an increase in income that ultimately raises welfare.

The economic history of the last two centuries shows mixed evidence in this regard. During the nineteenth and first half of the twentieth centuries there were several experiences of development where natural resources seem to have been the engine of economic growth.[1] However, it is hard to find successful experiences of development in the second half of the twentieth century. In fact, it is easy to find experiences where this sector has been blamed for the underdevelopment or low growth rates of some economies. This, of course, limit the ability of more recent data to underscore the whole variety of actual experiences on natural resources and development.

The mainstream literature on economic growth has focussed on technical change and on the accumulation of physical and human capital, disregarding the interaction between both factors at different economic structures. The main exception has been the research on the effects of openness on economic growth.[2] This situation has generated a conceptual gap in our understanding of the impact of the productive structure on economic growth.[3]

During the seventies many economists studied the macroeconomic effects and the changes in the productive structure resulting from a shock in the natural resources sector, the so-called Dutch Disease.[4] Nevertheless, this conceptual framework just explains the appreciation of the real exchange rate and the factor reallocation process, without deriving long run implications for economic growth. However, the idea behind the long run effects of the Dutch Disease is that the appreciation of the real exchange rate as a consequence of a natural resources boom is detrimental to an export-led growth process of development.

In order to understand the effects of the Dutch Disease on economic growth, it is necessary to identify long run mechanisms connecting the shocks on the natural resources sector, the productive structure and long run performance. Previous attempts have been developed by Matsuyama (1992), Sachs and Warner (1995), and more recently Asea and Lahiri (1999), among others. This paper tries to reduce the still open conceptual gap by developing a stylized model of two productive sectors that considers the dynamic effects of endogenous growth theory and the reallocative effects derived from the Dutch Disease literature.

[1] See Wright (1990) and Blomstrom and Meller (1990).
[2] See Edwards (1997).
[3] This issue is also discussed with different emphasis by Sachs and Warner (1995).
[4] On the literature on the Dutch Disease, see Neary and Van Wijnbergen (1986)

We emphasize the interaction between natural resources and human capital, and their effects on the levels of income and rates of economic growth, in order to explain why countries with abundance of natural resources and with high levels of human capital can reach a higher level of welfare. Moreover, we show that, under certain assumptions, a high level of human capital may offset the negative effects of the abundance of natural resources on economic growth.

In thinking about natural resources and development we can distinguish two main reasons why it may exert negative effects on growth. The first reason may be that weak institutions generate conditions for "voracity effects," through which interest groups try to capture the rents from natural resources (Lane and Tornell, 1996). In this case the allocation of talents in the economy is distorted and resources are deviated to unproductive activities.

Along similar lines, but with more focus on the productive structure of the economy, the second reason is related to the allocation of resources among activities with different spillovers on aggregate growth. For example, if there are a given stock of capital that can be allocated to the exploitation of natural resources or to the production of goods subject to endogenous growth, the existence of natural resources may diminish resources available for growth-enhancing activities. We follow this second idea, but since in a world with capital mobility the constraint on available capital stock may be relaxed, we focus on human capital, which is less mobile (Barro, Mankiw and Sala-i-Martin, 1995).[5] In most recent analysis of the growth-reducing effects of natural resources the idea of crowding-out is present (e.g., Sachs and Warner, 2001), and we follow this route.

Scandinavia is perhaps the most noticeable case of development based on natural resources (Blomstrom and Meller, 1990). Bravo-Ortega (1999) affirms that since the second half of the nineteenth century, high level of human capital and closeness to Europe made possible this process. Gylfason (2001) also emphasizes the role of education on the development of natural resource abundant countries. In this paper we also attribute an special role to human capital accumulation.

In the model we present in this paper we consider the effects on the level of income and on the rate of growth of having abundance of natural resources. The model presented in the next section considers the following stylized facts:

- According to Chenery and Syrquin (1975) the participation of the natural resources production in total output and the fraction of the labor force working in this sector decreases over the course of a country's development.
- An increase in the endowment of natural resources induces a shift in the fraction of human capital working in the industrial sector towards the natural resources sector, as has been traditionally understood in the study of the Dutch Disease.

In the next section we present the model. For simplicity, we assume that the production of natural resources is subject to decreasing returns to scale, while

[5]Even in periods with low capital mobility, there has been traditionally foreign direct investment available to exploit natural resources.

the industrial sector is subject to decreasing returns to scale at the firm level, but there is an externality that leads to aggregate constant returns to scale (Romer, 1986). The rate of growth of the economy is a weighted average between the rate of growth of both sectors. Having a high level of human capital, the higher income attained by the economy generates faster growth despite being abundant in natural resources. In this regard we capture the idea that natural resources limit growth as long as the level of human capital is low, and hence there is not enough resources to devote to growth-enhancing activities.[6] In section 3 we analyze the empirical implications of the model, studying the effects of natural resources on the level of GDP per capita and on its rate of growth. We find that, when ignoring the interactions with human capital, that abundance of natural resources reduce the rate of growth, but increases income. When we add an interaction term between human capital and natural resources we find that for high levels of human capital the rate of growth also increases with the abundance of natural resources. Section 4 concludes.

2 The Basic Model

The model that we present, follows from previous work on growth developed on two-sector models and natural resources developed by Solow (1974). Along this line we follow the work by Romer (1986,1990), Lucas (1988), Jones and Manuelli (1990), Krugman (1990), Matsuyama (1992), Mulligan and Sala i Martin (1993), Asea and Lahiri (1999), and Farzin (1999).

We consider a small open economy, with two productive sectors: Natural Resources and Industry. Both sectors utilize human capital along with the fixed endowments of specific factors in each one of the sectors. Assume that the natural resources sector exhibits decreasing returns to human capital, while the industrial sector exhibits constant returns to scale (CRS) due to the existence of externalities. All the production is sold in the international market, and it is used to buy a third consumption good. The prices of the three goods are determined in the world market, and therefore exogenous in the model. We use the price of the industrial good as numeraire, while p_1 denotes the price of the natural resources good, and p_2 the price of the consumption good.

Thus, the production functions for the natural resources and industrial sectors can be expressed as follows:

$$Y_{NR} = R \cdot H_R^{\delta} \qquad\qquad Y_I = a \cdot {H_I}^{\alpha} \cdot \bar{H}_I^{1-\alpha}, \tag{1}$$

respectively.

[6] We could assume decreasing returns in the industrial sector by including physical capital, but that would make the model less tractable and deviate from the main effects we want to examine. In addition, we can presume that natural resources are also able to generate endogenous growth, for example by inducing spillovers through R&D in other activities, but we want to focus on a sector that as the economy develops starts reducing its share in total output.

We denote the capital specific to the natural resources sector by R. It represents a measure of the endowment of natural resources and its impact on output. Thus, R considers factors as the quality of soil, climate, and quality of mineral deposits.[7] The capital specific to the industrial sector is denoted by a and can be interpreted as technological (or social) infrastructure. As usual, the subscripts under H (or L) indicate the productive sector where the human capital (or labor) is allocated. Finally, the term $\bar{H}_I^{1-\alpha}$ represents the externality in the industrial sector. To keep notation simple we omit time subscripts when possible.

Hence the economy faces the following constraint for the endowment of human capital in each period of time:

$$H_I + H_R = H. \tag{2}$$

In order to avoid scale effects we work with just one representative firm for each sector owned by a representative agent. We assume that although the representative agent owns both firms and the natural resources, she does not internalize the externalities in the industrial sector. We also assume that the elasticity of output with respect to human capital, perceived by the private agent, is bigger in the industrial sector than in the natural resources sector, that is, $\alpha > \delta$. Total labor in the economy is constant and equal to L, that we normalize to 1, and hence all variables are expressed in per capita terms. The proportion of labor and human capital allocated to the natural resource sector is equal to $L_R = H_R/H$, and to the industrial sector is $L_I = 1 - L_R = H_I/H$.

Thus, the representative agent must choose the allocation of human labor across sectors, and how much should be invested in human capital. This assumption seems to be reasonable as long as the return to human capital is greater than the return to any kind of investment.

The agent solves the problem:

$$\begin{array}{rc} & Max \int_0^\infty \frac{c_t^{(1-\sigma)}-1}{(1-\sigma)} \cdot e^{-\beta t} dt \\ st & L \cdot H_t = \dot{H}_t = Y - p_2 \cdot c_t \\ & Y = A \cdot (H_I)^\alpha \cdot H_I^{1-\alpha} + p_1 \cdot R \cdot H_R^\delta \\ & H_I + H_R = H = L \cdot H, \end{array} \tag{3}$$

where h represents the average level of human capital among the population.

With this setup we derive the following five propositions that are the basis of the empirical analysis presented in the next section of the paper. The first four propositions, assume conditions for the existence of two productive sectors (Assumption 1). The solution of the model and the proofs of the propositions are provided in Appendix A.

[7]This assumption is similar to those used by Matsuyama (1992).

Assumption 1 *Assume that the parameters of the model are such that in the equilibria both sectors have production greater than zero. This is equivalent to impose in period 0,* $H_R = H \cdot L_R = (\frac{\alpha a}{p_1 \cdot R \cdot \delta})^{\frac{1}{\delta - 1}} < H_{tot}$ *and that* $\alpha a > \beta$, where H_0 represents the endowment of human capital in the economy at period 0.

Proposition 1 *In the steady state the growth rate of income per capita, consumption per capita and human capital are equal to* $\gamma_{ss} = \frac{1}{\sigma}(\alpha \cdot a - \beta)$

Proof. See Appendix A. ∎

Note that in the steady-state, the rate of growth of the economy is constant, and depends only on the technology used in the industrial sector and not in the endowment of natural resources. This is a direct consequence of the following proposition.

Proposition 2 *In the steady state, the fraction of the labor force allocated to the natural resources sector converges asymptotically to zero. Output and human capital in the natural resource sector is constant.*

Proof. See Appendix A. ∎

Note that L_R, the fraction of the labor force working in the natural resources sector can be expressed:

$$L_R = \frac{1}{H}\left(\frac{p_1 \cdot R \cdot \delta}{\alpha a}\right)^{\frac{1}{1-\delta}} \tag{4}$$

The fraction of the labor force working in the natural resources sector is inversely proportional to the level of per capita human capital, H, and positively related to the amount of specific factor in the natural resource sector. Hence, as long as human capital increases, the labor force in the natural resources decreases proportionately, and the level of human capital remains constant.

Now, we turn to the effect of R on the level of income.

Proposition 3 *A greater level of the specific factor in the natural resources sector results in a increase in the level of income per capita.*

Proof. See Appendix A. ∎

The next proposition considers the growth effect of natural resources and the interplay with human capital. The proof redefines the variables in our system in order to get a system of two nonlinear differential equations, which are then linearized around the steady state of the auxiliary dynamic system.

Proposition 4 *The effect of a greater level in the specific factor of the natural resources sector will imply, ceteris paribus, a lower growth rate of income per capita in the transition to the steady state. However, economies with greater level of human capital per capita will experience a faster convergence to the steady state, as long as the human capital per capita surpasses a certain threshold* $H^* > 0$.

Proof. See Appendix A. ■

This proposition shows first that for low levels of human capital the growth effect of natural resources is negative, although the economy has higher income. The reason is that since the rate of growth is an average of the rates of growth in both sectors, and the natural resources sector has zero growth, the average declines. But, whenever human capital is large enough this composition effect is dominated by an income effect.

To understand these effects we can use figure 1. The economy converges with an increasing growth rate to the steady state rate of growth. During this process the natural resources sector diminishes in relative importance. For two economies with the same level of human capital, the one with natural resources will have higher income, but will grow slower, as seen in figure 1. But, an economy with higher level of human capital will be "closer" to the high steady-state rate of growth. For simplicity, and to illustrate more clearly our points, we have abstracted from convergence effect, but the model can be interpreted as converging to a Solow-type growth based on the exogenous growth of productivity in the industrial sector, but with a dynamic similar to the one described here.

Another interesting issue this model allows to explain is the existence of a zero growth equilibrium in which the economy only produces in the natural resources sector. Assumption 1 insures that the economy will never specialize in natural resources. However, the next proposition analyzes what we call the "poverty trap of natural resources." In this case we assume that given the productivity in each of the two sectors, and the initial level of human capital, the economy will produce only the natural resources sector, because it is not profitable to devote resources to the industrial sector. This is formalized in the following assumption.

Assumption 2 *We assume that the parameters of the model are such that the following inequalities hold:*

$H_R = H \cdot L_R = (\frac{\alpha a}{p_1 \cdot R \cdot \delta})^{\frac{1}{\delta - 1}} > H_0$

$\beta > \alpha a$

Note that the first condition, just implies relative abundance of natural resources with respect to the specific factor in the industrial sector. While the second implies that the economy will exhaust the returns to human capital in the natural resources sector for a given level of human capital accumulation.

Proposition 5 *Under the conditions of assumption 2, the economy will specialize in the production of the natural resources good, with zero growth of income per capita and zero rate of accumulation of human capital in the steady state.*

Proof. See Appendix A. ■

So far, we have proved that, under the proper assumptions, an increment in the specific factor in the natural resources sector will increase the level of income per capita, but will diminish the rate of growth in the economy. However, as shown in proposition 4, it is possible to reduce this negative effect by increasing the human capital per capita, and as long as it surpasses a certain threshold, the effect could be positive. Hence, the presented model explains the stylized facts presented in the introduction.

Finally, a direct extension of the model would allow us to incorporate the impact of political economy factors on the dynamic of the economy. Suppose that initially the economy produces in both sectors, and consider the existence of interests groups that may own the rents of at least one of the specific factors. Now suppose that these groups are able to tax the return on human capital. The impact of the tax on labor will have three main consequences: first it will reduce the return and the incentives for human capital accumulation, thereby reducing the growth rate of the economy over the transition and in the steady state. Second, the lower return to human capital will induce, ceteris paribus, a larger fraction of the labor force and larger share of GDP allocated in the natural resources sector. Third, under some circumstances the extent of the tax would inhibit the development of the industrial sector driving the economy to the "poverty trap" described by Proposition 5. The same mechanisms operate when the owners of the natural resources sector are able to tax the return to the specific factor in the industrial sector. The tax charged in the specific factor will decrease its return, and the productivity of human capital, which will finally imply a lower growth rate.

3 Empirical Evidence

3.1 Previous Empirical Results

Sachs and Warner, in a series of papers, have produced the most persuasive recent empirical evidence connecting economic growth and relative abundance of natural resources, beginning with Sachs and Warner (1995). Subsequent work include Lane and Tornell (1996), Feenstra, Madani, Yang and Liang (1997), Gylfason, Herbertsson and Zoega (1999), Rodriguez and Sachs (1999), Sachs and Warner (1999, 2001), and Asea and Lahiri (1999), among others. However, the main empirical results can be found in Sachs and Warner (1995), Feenstra et al. (1997) and Gylfason et al. (1999).

The main finding of Sachs and Warner (1995) is the robust negative relationship between economic growth and natural resources, using cross-section regressions. They corroborate this relationship with different measures of resource abundance, such as: the share of mining production in GDP, land per capita, and share of natural resource exports in GDP.[8] Finally, they find that an increment in one standard deviation in the participation of natural resources exports in the GDP would imply a lower rate of growth on the order of 1% per

[8] It is noteworthy to mention that the inclusion of the participation of natural resources exports over GDP as an explanatory variable, can be derived directly from the model we developed. For more details see appendix A.

year.

Gylfason et al. (1999) postulate that the natural resources sector creates and needs less human capital than other productive sectors, which is similar to the assumption of this paper. A larger primary sector induces an appreciated currency which makes the development of a skill intensive sector difficult. Thus, the model they develop predicts an inverse relation between real exchange rate volatility and human capital accumulation and hence growth. Similarly, they predict a positive relationship between external debt and profitability in the secondary sector and also growth. However, the evidence they provide regarding these two explanatory variables is mixed; exchange rate volatility is not statistically significant and external debt is statistically significant but with the wrong sign.

According to Gylfason et al. (1999) the share of the labor force in the primary sector can be used as an explanatory variable. However, they find it to be statistically significant only when different measures of human capital are absent. This result may be due to high multicolinearity, which can be explained by our model, where the fraction of the labor force (or human capital) employed in the primary sector depends on the level of human capital. Thus, Gylfason et al. (1999) find that "an increase in either the share of the primary sector in the labor force or in the share of the primary exports on total exports from 5% to 30% from one country or period to another reduces per capita growth by about 0.5% percent per year, other things being equal". In short, the model we presented is consistent with the results found by Gylfason et al. (1999) related to the size of the labor force in the primary sector.

In a multisectoral study, Feenstra et al. (1997) test the hypothesis of semi-endogenous growth using bilateral trade data between the U.S. and South Korea and the U.S. and Taiwan. Their study focuses on sixteen industrial sectors for which they test whether changes in the relative varieties of inputs affects the growth rate of the relative total factor productivity between South Korea and Taiwan. They classify seven of these sectors as primary and nine as secondary. In particular, they consider firms using raw materials and natural resources as inputs, as belonging to the primary sector. Their results show that variety of inputs affects the growth rate of the total factor productivity in seven secondary sectors and only one primary sector. The mining sector displays a positive relationship, although this effect disappears after controlling for imperfect competition. The remaining sectors in the primary sector present mixed evidence, with either positive, negative or insignificant effect of variety of inputs on the growth rate of the total factor productivity.

3.2 Empirical Methodology and Results

We estimate the main empirical implications of the model using panel data for the period 1970-1990. The data used in the regressions are from the Penn World Tables, the Barro and Lee Educational Data Set (1994) and World Tables from World Bank (1993-1996). We describe the data and their sources in more details in the Appendix B.

In a first stage, similarly to Barro and Sala-i-Martin (1995), we regress the growth rate of GDP per capita on explanatory variables, using seemingly unrelated regression (SUR) with four sub-periods.[9] This technique allows for country random effects that are correlated across periods. In a second stage we estimate random effects regressions utilizing instrumental variables in order to overcome the possible bias introduced by the measurement error in our proxy for human capital[10].

Given that we are interested in determining the possible effect of natural resource abundance on economic growth, we extend traditional growth regressions incorporating the share of natural resources exports in the GDP as a proxy of resource abundance ($Natural$).[11] As control variables we use human capital measured by the average schooling years for the total population over 25 years (H), government expenditure as fraction of GDP (G), openness measured by the fraction of exports and imports over GDP ($OPEN$), terms of trade shocks (TT), [12] investment as fraction of GDP (I) and initial income (y). All the variables are measured at the beginning of each period of the panel. However, as a robustness test we also estimate regressions using average values of some variables for each period of the panel. In all our estimations we use period dummies and regional dummies for Africa and Latin America ($DREG$).[13]

The benchmark regression for the rate of growth γcan be expressed as:

$$\gamma_{y_{i,t}} = \alpha_{0t} + \alpha_1 \cdot y_{i,t} + \alpha_2 \cdot I_{i,t} + \alpha_3 \cdot H_{i,t} + \alpha_4 \cdot Natural_{i,t} + \\ + \alpha_5 \cdot G_{i,t} + \alpha_6 \cdot OPEN_{i,t} + \alpha_7 \cdot TT_{i,t} + DREG_i + \varepsilon_{i,t} \quad (5)$$

where i is a country index and t indicates the number of the cross section regression of the panel.

In a second stage, including interaction effects between human capital and natural resources, we estimate the following regression:

$$\gamma_{y_{i,t}} = \alpha_{0t} + \alpha_1 \cdot y_{i,t} + +\alpha_2 \cdot I_{i,t} + \alpha_3 \cdot H_{i,t} + \alpha_4 \cdot Natural_{i,t} + \\ + \alpha_5 \cdot G_{i,t} + \alpha_6 \cdot OPEN_{i,t} + \alpha_7 \cdot TT_{i,t} + \\ + \alpha_8 H_{i,t} Natural_{i,t} + DREG_i + \varepsilon_{i,t} \quad (6)$$

[9]Due to the limited availability of data we can not estimate our regressions using some other procedures recommended in the literature such as GMM, as proposed by Caselli, Esquivel and Lefort (1996).

[10]For a revision of this point see for example Krueger and Lindahl (1999).

[11]As most of the recent literature we use as data source World Tables CD Rom and as natural resources exports, the sum of the exports in the categories: fuels and non-fuel primary products.

[12]We replicate the measure of terms of trade shock developed by Easterly, Pritchett and Summers (1993). See Appendix B.

[13]For a detailed discussion on the control variables see Sachs and Warner (1995) and Temple (1999).

In our empirical specification we do not rule out the conditional converge hypothesis, hence we included the lag value of income per capita. Given the theoretical framework, it may be possible to recover conditional convergence to a given growth rate after including decreasing marginal return to capital.

Equation (6) incorporates the interaction term between natural resources and human capital. This term allows us to test whether the negative effect of natural resources on the rate of growth decreases with human capital. Hence, we must interpret the participation of natural resources exports over GDP as proxy of the specific factor, R, in our model.[14]

Before proceeding with regression analysis, figures 2 and 3 show the scatterplots between growth and income against natural resource abundance in our sample of countries. It appears a negative relationship between growth and natural resource abundance. In the case of income, there seems to be no bivariate relationship, although as shown below this relationship is positive when controlling by other variables.

In Tables 1 and 2 we test whether there is a negative relation between natural resources and economic growth according to equation (5). In regressions 1.1 and 1.3 we use the average schooling years in the male population over age 25 as a measure of human capital, while for regressions 1.2 and 1.4 we use the schooling years of the total population. Regressions 1.1. and 1.2 use the average values for the government expenditure and openness. However, this might result in endogeneity bias, we therefore re-estimate these equations using each period's initial values, results that are reported in regressions 1.3 and 1.4. Furthermore, we also estimated, but do not report, the same regressions but using as a measure of human capital the average secondary schooling years. In all cases we obtained similar results.

We replicated the regressions reported so far, but use the average investment and the average participation of natural resources in the GDP. We obtained similar results in terms of the magnitude and significance of natural resources and other variables. The exception to this result was investment, whose associated coefficient duplicated its magnitude and maintained its significance when its average value is utilized as a regressor. Overall it is important to note the robust statistical significance and the consistent sign of the natural resource coefficient regarding the different measures of human capital and different sets of control variables used.

The results of table 1 show an elasticity of the growth rate with respect to the relative abundance of natural resources between -0.04 and -0.05. The estimations largely support the hypothesis that natural resources affect growth through its impact on the productive structure, even when our estimations are controlled by investment, trade policy, fiscal policy and shocks in the terms of trade.

Finally, regression 1.6 shows a positive relationship between relative abundance of natural resources and levels of per capita income after controlling for the same set of variables as before with the obvious exception of the lag value of income. Thus, the empirical evidence shown in table 1 confirms two of the main predictions of the model: the positive effect of natural resource abundance over per capita income and the negative effect on growth rates.

[14] Bravo-Ortega and De Gregorio (2000) derive more closely this second specification in a more general setting.

Table 1: Determinants of Economic Growth (1.1-1.5) and Determinants of Level of Income (1.6). SUR.

	1.1 *Growth*	1.2 *Growth*	1.3 *Growth*	1.4 *Growth*	1.5 *Growth*	1.6 *IncomeLevel*
Initial Income	−0.018	−0.018	−0.017	−0.017	−0.016	
	(0.003)***	(0.003)***	(0.003)***	(0.003)**	(0.003)***	
Openess	0.025	0.025	0.019	0.019	0.019	0.293
	(0.005)***	(0.005)***	(0.005)***	(0.005)**	(0.005)***	(0.086)***
Investment	0.056	0.056	0.054	0.055		1.255
	(0.025)**	(0.025)**	(0.025)**	(0.025)**		(0.337)***
Government	−0.106	−0.109	−0.087	−0.090	−0.093	−1.146
	(0.022)***	(0.022)***	(0.022)***	(0.022)**	(0.022)***	(0.315)***
Natural Res.	−0.044	−0.043	−0.046	−0.045	−0.043	0.583
	(0.014)***	(0.014)***	(0.014)***	(0.014)**	(0.015)***	(0.196)***
Human Capital		0.003		0.003	0.003	0.180
		(0.001)***		(0.001)***	(0.001)***	(0.015)***
Human (male)	0.003		0.003			
	(0.001)***		(0.001)***			
Shock Terms	0.182	0.180	0.178	0.174	0.159	1.863
of Trade	(0.046)***	(0.046)***	(0.048)***	(0.047)***	(0.047)***	(0.511)***
R^2 (Obs)	0.23(79)	0.23(80)	0.19(79)	0.19(80)	0.12(80)	0.77(80)
$R^2(Obs)$	0.25(89)	0.25(89)	0.20(89)	0.20(89)	0.22(89)	0.81(89)
$R^2(Obs)$	0.34(92)	0.33(92)	0.30(92)	0.30(92)	0.29(92)	0.82(92)
$R^2(Obs)$	0.35(82)	0.36(82)	0.33(82)	0.33(82)	0.33(82)	0.81(82)

Standard errors in parentheses * significant at 10 percent ; ** significant at 5 percent; *** significant at 1 percent. All the regressions estimated with temporal and regional dummies for African and Latin American countries. Coefficients and standard errors rounded to the last decimal. All the regressions estimated with regional dummies for African and Latin American countries. Coefficients and standard errors rounded to the last decimal

Table 2 reports the results of our estimations using instrumental variables. These are used in order to overcome the measurement errors in our human capital variables, a fact that has been well documented by Krueger and Lindahl (1999). We use as instruments the ten years lag value of our measure of human capital, the ten-year lag value of government expenditure in education, and the ten-year lag value of the average years of higher education for the population over twenty five years. Further, Hausman specification test confirms the need of correcting the measurement error. However, we should note that all the coefficients show very small variations in their magnitudes, with the exception of the natural resources coefficient which increases its magnitude in the regressions on growth and on the level of per capita income.

Table 2: Determinants of Economic Growth (2.1-1.4) and Determinants of Level of Income (2.5). Instrumental Variables estimations.

	2.1 *Growth*	2.2 *Growth*	2.3 *Growth*	2.4 *Growth*	2.5 *Income Level*
Initial Income	−0.02	−0.018	−0.019	−0.017	
	(0.004)***	(0.004)***	(0.004)***	(0.004)***	
Openess	0.020	0.020	0.021	0.021	0.202
	(0.006)***	(0.006)***	(0.006)***	(0.006)***	(0.087)**
Investment	0.057		0.058		1.192
	(0.027)**		(0.026)**		(0.289)***
Government	−0.094	−0.097	−0.098	−0.100	−0.787
	(0.025)***	(0.025)***	(0.025)***	(0.024)***	(0.303)**
Natural Res.	−0.059	−0.057	−0.059	−0.057	0.497
	(0.016)***	(0.016)***	(0.015)***	(0.015)***	(0.209)**
Human			0.003	0.004	0.208
			(0.001)***	(0.001)***	(0.017)***
Human (male)	0.004	0.004			
	(0.001)***	(0.001)***			
Shock Terms	0.193	0.172	0.183	0.162	1.003
of Trade	(0.049)***	(0.048)***	(0.048)***	(0.047)***	(0.386)**
R2 overall	0.41	0.4	0.40	0.39	0.78
Observations	318	318	319	319	329

Standard errors in parentheses * significant at 10 percent ; ** significant at 5 percent; *** significant at 1 percent. All the regressions estimated with regional dummies for African and Latin American countries. Coefficients and standard errors rounded to the last decimal

Finally, we must note that in specifications 1.5 and 2.2 and 2.4 we have not controlled for investment, while in all other specifications we do. We interpret the stability in the natural resources coefficient and its significance as indicative that the negative effect of natural resources on growth does not go through the investment channel but through the relative productivity among sectors, and consequently through their relative sizes.[15]

The values of the parameters of tables 1 and 2 indicate that an increase in 10 percentage points in the ratio of exports of natural resources over GDP would reduce growth by about 0.4% to 0.6% a year, but would increase national per capita income between 5% and 6%. But as presented below, the effect on growth depends on the level of human capital.

Table 3 shows the effect of the interaction between natural resources and

[15]Consistently Gylfason et al (1999) find that the share of the labor force employed in the primary sector (farming, forestry, hunting, and fishing) affects negatively the rates of growth. Indeed, they found this variable more robust than the measures of human capital they utilized.

Table 3: Determinants of Economic Growth. Interaction Effect Among Natural Resources and Human Capital. SUR.

	3.1	3.2	3.3	3.4
Initial Income	−0.018	−0.014	−0.017	−0.013
	(0.003)$_{***}$	(0.003)$_{***}$	(0.003)$_{***}$	(0.003)$_{***}$
Openess	0.025	0.026	0.019	0.020
	(0.005)$_{***}$	(0.005)$_{***}$	(0.005)$_{***}$	(0.005)$_{***}$
Investment	0.057	0.069	0.055	0.067
	(0.025)$_{***}$	(0.024)$_{***}$	(0.025)$_{**}$	(0.025)$_{***}$
Government	−0.108	−0.106	−0.089	−0.085
	(0.022)$_{***}$	(0.021)$_{***}$	(0.022)$_{***}$	(0.022)$_{***}$
Natural Res.	−0.052	−0.080	−0.052	−0.082
	(0.026)$_{**}$	(0.022)$_{***}$	(0.027)$_{**}$	(0.023)$_{***}$
Human	0.003		0.003	
	(0.001)$_{**}$		(0.001)$_{**}$	
Human·Nat Res	0.002	0.009	0.002	0.009
	(0.006)	(0.005)$_{**}$	(0.006)	(0.005)$_{*}$
Shock Terms	0.181	0.166	0.174	0.157
of Trade	(0.046)$_{***}$	(0.045)$_{***}$	(0.047)$_{***}$	(0.047)$_{***}$
$R^2(Obs)$	0.23(80)	0.24(80)	0.19(80)	0.20(80)
$R^2(Obs)$	0.27(89)	0.24(89)	0.20(89)	0.18(89)
$R^2(Obs)$	0.33(92)	0.30(92)	0.29(92)	0.27(92)
$R^2(obs)$	0.33(82)	0.35(82)	0.33(82)	0.32(82)

Standard errors in parentheses * significant at 10 percent ; ** significant at 5 percent; *** significant at 1 percent. All the regressions estimated with regional dummies for African and Latin American countries. Coefficients and standard errors rounded to the last decimal

human capital. In a similar manner to the results reported in table 1, in regressions 3.1 and 3.2 we use average values of the government expenditure and openness. Due to the possible endogeneity problems of the previous specifications, regressions 3.3 and 3.4 reestimate them using the values of each variable at the beginning of each period.

As we previously mentioned, it is expected that higher levels of human capital reduce the negative effect of natural resources on growth. Thus, equations 3.1 to 3.4 include the interaction between natural resources and human capital. Although in regression 3.1 and 3.3 the coefficient associated with the interaction term has the correct sign it is statistically insignificant.[16] In the regressions 3.2 and 3.4, we follow the specification derived from proposition 4, just keeping the interaction variable, without considering the direct effect of human capital on growth. For this specification the coefficient for the interaction term has

[16]The Wald Test with the null hypothesis that both coefficients associated with human capital are equal to zero, is rejected with a p-value of 0.01 in both equations.

p-values of 6 percent in both cases, keeping its predicted positive sign.

Given the economic significance of the coefficient of the interaction term we investigate whether it would be feasible not just to decrease but to change the sign of the effect of natural resources on growth. Therefore, based on the coefficient of the interaction term, we solve for the number of schooling years such that it is possible to recover a net positive effect of natural resources on growth. This is equivalent to recover from our estimations $H*$ such that:

$$\frac{d\gamma_y}{dNatural} = \alpha_4 - \alpha_8 \cdot Human \geq 0 \tag{7}$$

According to regression 3.2 this threshold is 9.06 years of average schooling for the population over 25 years, while for regression 3.4 this threshold is increased to 9.36 years.

Table 4: Determinants of Economic Growth. Interaction Effect Among Natural Resources and Human Capital. Instrumental Variables estimations.

	4.1 *Growth*	4.2 *Growth*	4.3 *Growth*
Initial Income	−0.019	−0.019	−0.016
	(0.004)$_{***}$	(0.004)$_{***}$	(0.003)$_{***}$
Openess	0.021	0.021	0.022
	(0.006)$_{***}$	(0.006)$_{***}$	(0.006)$_{***}$
Investment	0.069	0.074	
	(0.028)$_{**}$	(0.028)$_{***}$	
Government	−0.094	−0.090	−0.091
	(0.025)$_{***}$	(0.026)$_{***}$	(0.027)$_{***}$
Natural Res.	−0.139	−0.172	−0.180
	(0.073)$_{*}$	(0.038)$_{***}$	(0.040)$_{***}$
human	0.001		
	(0.002)		
Human·Natural Res	0.020	0.028	0.031
	(0.018)	(0.009)$_{***}$	(0.009)$_{***}$
Shock Terms	0.196	0.203	0.183
of Trade	(0.049)$_{***}$	(0.049)$_{***}$	(0.049)$_{***}$
R2 overall	0.40	0.38	0.36
Observations	319	319	321

Standard errors in parentheses * significant at 10 percent ; ** significant at 5 percent; *** significant at 1 percent. All the regressions estimated with regional dummies for African and Latin American countries. Coefficients and standard errors rounded to the last decimal

Table 4 reports the results of the estimations of the above specifications reported in Table 3, but using instrumental variables. This time when the interaction term is present together with the human capital variable neither is statistically significant, but the null hypothesis that considers both coefficients equal to zero is rejected. Moreover, the coefficient associated to the interaction term has higher statistical significance than the one associated to human capital. Based on the coefficients estimated in equations 4.1 and 4.2 we obtain that 6.95 and 6.14 are the minimum of schooling years needed for recovering a net positive effect of natural resources on growth.

Table 5 shows the list of countries whose level of human capital is high enough in 1970 to outweigh the negative effect of natural resources on growth considering the lowest threshold obtained in our estimations, which is 6.18 years. Table 5 also shows the participation of the natural resources exports in their GDP ($\frac{X_{NR}}{Y}$). At a glance it is interesting to note the presence of countries whose participation of natural resources in the GDP is above the average of the sample. We identified them with an asterisk.

An most striking fact from table 5 is a list of countries that are widely known to be richly endowed with natural resources, although the share of exports of primary products on GDP is sometimes small. In this group we recognize Australia, Belgium, Canada, Denmark, Finland, New Zealand, Norway, Sweden and USA. With respect to the experience of the United States, G. Wright (1990) established that for the period 1880-1920 the most distinctive characteristic of the American exports was intensity in non-reproducible natural resources. Nevertheless, for the period 1879-1899, he finds that net manufacturing exports depend negatively on natural resources, although for the period 1909-1940 this is reversed. Can this results be explained by the human capital accumulation process? The evidence in this paper supports such a hypothesis. Certainly, whether the same history applies and to which countries among those shown in table 5 deserves a closer look, and may comprise our future research.

In short, the evidence we found seems to indicate that natural resources are damaging for economic growth in countries with low levels of human capital. Our model predicts that this effect would materialize by drawing resources from other economic sectors capable of generating further economic growth. However, as the process of development goes on, the accumulation of human capital may eliminate this effects. Hence, the impact of natural resources could be offset through the accumulation of human capital.

4 Conclusion

We find an inverse relationship between economic growth and the relative abundance of natural resources and a positive relationship between levels of income and natural resources. These findings agree with the main predictions of our model. Moreover, and as a main difference with previous work in this topic, we find statistical evidence of a positive relationship between human capital and economic growth, after controlling for natural resource abundance.[17] Based on the model's predictions, we also extend the usual specifications for economic

[17]See Sachs and Warner (1995), Gylfason et al (1999), and Asea and Lahiri (1999).

growth regressions by incorporating an interaction term between human capital and natural resources. This exercise allows us to recover a list of countries that were in the past, or are in the present relatively rich in natural resources and human capital, and whose levels of human capital more than offset the negative effect of the natural resource abundance on growth.

The results seems to indicate that natural resources are damaging for economic growth in countries with low levels of human capital. This effect would materialize by drawing resources from other economic sectors capable of generating further economic growth. However, this effect could be offset through the accumulation of human capital. Therefore, the aggregate data provides supporting evidence for the model presented in the paper. In addition, we have shown that abundance in natural resources leads to higher income, and hence one cannot infer from the growth effect the benefits of being rich in natural resources.

In this paper, a country rich in natural resources starts with high levels of income, accumulates human capital, and growth accelerates. In this sense, natural resources are not a curse, although extremely low levels of human capital may cause the economy to stagnate, becasue it would specialize in a sector with low productivity.

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Appendix A

Model Derivation and Proofs of Propositions

Thus, the Hamiltonian of the problem (3) can be expressed as follows:
$J = u(c_t) \cdot e^{-\beta t} + \lambda \cdot e^{-\beta t}(a \cdot (H_I)^{\alpha} \cdot H_I^{1-\alpha} + p_1 \cdot R \cdot H_R^{\delta} - p_2 \cdot c_t) + \tau_2 \cdot e^{-\beta t}(H_I + H_R - 1 \cdot H)$

The first order conditions of the problem are given by:

$$\frac{dJ}{dc_t} = 0 \Leftrightarrow u'(c_t)e^{-\beta t} = p_2 \cdot \lambda \tag{8}$$

$$\frac{dJ}{dH_I} = 0 \Leftrightarrow \lambda \cdot e^{-\beta t} \cdot \alpha \cdot a \cdot (H_I)^{\alpha} \cdot H_I^{\alpha-1} + e^{-\beta t} \cdot \tau_2 = 0 \tag{9}$$

$$\frac{dJ}{dH_R} = 0 \Leftrightarrow \lambda \cdot e^{-\beta t} p_1 \cdot R \cdot \delta \cdot H_R^{\delta-1} + e^{-\beta t} \cdot \tau_2 = 0 \tag{10}$$

$$\frac{dJ}{dH} = -\dot{\lambda} + \lambda\beta = -\tau_2 \Rightarrow \frac{-\dot{\lambda}}{\lambda} + \beta = -\frac{\tau_2}{\lambda} \Rightarrow \frac{-\dot{\lambda}}{\lambda} = \alpha a - \beta \tag{11}$$

Hence we can express the return to human capital accumulation as follows: $r_H = -\frac{\tau_2}{\lambda} = \alpha a = p_1 \cdot \delta \cdot H_R^{\delta-1}$

Finally, we can verify that the system satisfies Michel's transversality condition[18] $\lim_{t->\infty} J(t) = 0$ as long as $\alpha a < \beta(1+\sigma)$

Proof. Proposition 1

Taking the log and differentiating equation (8) we get:

$$\frac{\dot{c}}{c} = \frac{1}{\sigma}(\alpha \cdot a - \beta) \tag{12}$$

Note that the rate of growth of consumption is constant at any moment of time, and depends on the technology utilized in the industrial sector.

Now we derive the steady state growth rates for each variable. Dividing the budget constraint by the average level of human capital, H, and rearranging:

$$\frac{H}{H} = aL - \frac{1}{H}(\frac{\alpha a}{p \cdot R \cdot \delta})^{\frac{1}{\delta-1}} + \frac{R(\frac{\alpha a}{p_1 \cdot R \cdot \delta})^{\frac{\delta}{\delta-1}}}{H} - \frac{c_t}{H} \tag{13}$$

Imposing the fact that in steady state the rates of variation of human capital and consumption are constant and deriving with respect to the time to get:

$$0 = \frac{H}{H^2}(\frac{p_1 \cdot R \cdot (1-\delta)}{(1-\alpha)a})^{1/\delta}) - \frac{R(\frac{p_1 \cdot R \cdot (1-\delta)}{(1-\alpha)a})^{(1-\delta)/\delta}}{H}\frac{H}{H} - (\frac{\dot{C}}{C}\frac{C}{H} - \frac{H}{H}\frac{C}{H}) \tag{14}$$

Multiplying by H and deriving with respect to time again, implies:

$$0 = -(\frac{\dot{C}}{C} - \frac{H}{H})\dot{C} \tag{15}$$

Then, in the steady state, human capital and consumption will grow at the same rate. The amount of human capital in the natural resources sector will be constant, while that human capital in the industrial sector will growth at the same rate that the total human capital. Consequently the "reduced" product also will growth at the same rate. It is important to note that the evolution of the variables in steady state doesn't depend on the relative abundance of natural resources, and that the growth rate of the economy depends just on the productivity of the sector with externalities. ■

Proof. Proposition 2

The first order conditions have some interesting implications with respect to the evolution of the productive structure of the economy. In order to analyze them, we first solve H_R, which can be expressed:

$$H_R = \left(\frac{p_1 \cdot R \cdot \delta}{\alpha a}\right)^{\frac{1}{1-\delta}} = constant = L_R \cdot H \tag{16}$$

[18] See Michel (1982).

with L_R the fraction of the labor force in natural resources. Note that the fraction of human capital working in the natural resources sector is inversely proportional to the level per capita of human capital, H . Consistently with this setting, the industrial sector will produce using a share L_I of the labor force, which will increase with H. Indeed,

$$L_I = 1 - L_R = 1 - \frac{1}{H}\left(\frac{p_1 \cdot R \cdot \delta}{\alpha a)}\right)^{\frac{1}{1-\delta}} \tag{17}$$

At the same time, the output in the natural resources sector is constant, and as long as the level of human capital grows the fraction of the total output belonging to this sector will be decreasing in the time. ■

Proof. Proposition 3
Differentiating total output yields:

$$\frac{d}{dR}(Y_0) = \frac{d}{dR}\left[a \cdot (H - H_e - H_R(R))^{\alpha} \cdot \bar{H}_I^{1-\alpha} + p_1 \cdot R \cdot H_R^{\delta}(R)\right] =$$
$$= -a \cdot \frac{\partial}{\partial R} H_R(R) + p_1 \cdot H_R^{\delta}(R) + p_1 \cdot R \cdot \delta \cdot H_R^{\delta-1}(R) \cdot \frac{\partial}{\partial R} H_R(R) \tag{18}$$

Rearranging the equilibrium conditions for the allocation of labor in the productive sectors as $p_1 \cdot R \cdot \delta \cdot H_R^{\delta-1}(R) - \alpha \cdot a = 0$, and substituting in equation (18), it can be shown that:

$$\frac{d}{dR}(Y_0) = c \cdot p_1 \cdot H_R^{\delta}(R) > 0 \tag{19}$$

With $c = \frac{(\alpha-\delta)}{\alpha(1-\delta)}$. Therefore under our model assumptions, an increase in the specific factor of the natural resources sector will induce an increase in output per capita. ■

Transitional dynamics

This analysis closely follows Barro and Sala i Martin (1995). Define $\psi = \frac{Y}{H_i}$, and $\chi = \frac{C}{Hi}$

Then $\dot{\psi} = \frac{d}{dt}(\frac{Y}{H_i}) = \frac{d}{dt}(a + \frac{p_1 R H_R^{1-\delta}}{H_i}) = \frac{d}{dt}(a + \frac{B}{H_i}) = -\frac{B}{H_i}\frac{\dot{H}_i}{H_i}$
and

$$\dot{\psi} = (a - \psi)\frac{\dot{H}_i}{H_i} \tag{20}$$

Noting that $\frac{\dot{H}_i}{H_i} = \frac{\dot{H}}{H - H_R} = \frac{\dot{H}}{H_i} = \psi - \chi$, we can express equation (20) as:
$\dot{\psi} = (a - \psi) \cdot (\psi - \chi)$
Differentiating χ respect to the time yields:
$\dot{\chi} + \chi \cdot \frac{\dot{H}_i}{H_i} = \frac{\dot{C}}{H_I}$, replacing in the growth rate of consumption implies:
$\frac{\dot{C}}{H_I} = \frac{C}{\sigma H_I}(\alpha \cdot a - \beta) = \frac{\chi}{\sigma}(\alpha \cdot a - \beta)$

$\dot{\chi} + \chi \cdot (\psi - \chi) = \frac{\chi}{\sigma}(\alpha \cdot a - \beta)$

Hence, the system evolves according to the following two differential equations:

$$\dot{\psi} = (a - \psi) \cdot (\psi - \chi) \tag{21}$$

$$\dot{\chi} = \frac{\chi}{\sigma}(\alpha \cdot a - \beta) - \chi \cdot (\psi - \chi) \tag{22}$$

¿From Proposition 1 we know that in the steady state all the variables growth at the same rate. Therefore $\dot{\psi} = \dot{\chi} = 0$, which replaced in equations (21) and (22) allow us to find the steady state values for each one of our variables. Then those are determined by:

$$(a - \psi_{ss}) \cdot (\psi_{ss} - \chi_{ss}) = 0 \tag{23}$$

$$\chi_{ss}(\frac{\alpha \cdot a - \beta}{\sigma} - \psi_{ss} + \chi_{ss}) = 0 \tag{24}$$

Then the system has three steady states, two of them for the level of consumption equal to zero, and one for positive consumption. Indeed the solutions to the equations (23) and (24) are:

$\{\psi = 0, \chi = 0\}, \{\chi = 0, \psi = a\}, \left\{\chi = \frac{-\alpha a + \beta + \sigma a}{\sigma}, \psi = a\right\}$

Linearizing the system of equations (21), and (22) around the steady states we get:

$$\begin{bmatrix} \dot{\psi} \\ \dot{\chi} \end{bmatrix} = \begin{bmatrix} a - 2 \cdot \psi_{ss} + \chi_{ss} & -(a - \psi_{ss}) \\ -\chi_{ss} & \frac{1}{\sigma}(\alpha \cdot a - \beta) + 2 \cdot \chi_{ss} - \psi_{ss} \end{bmatrix} \begin{bmatrix} \psi - \psi_{ss} \\ \chi - \chi_{ss} \end{bmatrix} \tag{25}$$

Around the steady state $\{\psi_{ss} = 0, \chi_{ss} = 0\}$ the system is completely unstable. When the equilibria is $\{\chi_{ss} = 0, \psi_{ss} = a\}$the system is completely stable, while for the third equilibrium, $\left\{\chi_{ss} = \frac{-\alpha a + \beta + \sigma a}{\sigma}, \psi_{ss} = a\right\}$, the system has a saddle path as long as $(-\alpha a + \beta) < 0$ and $\frac{1}{\sigma}(\alpha \cdot a - \beta) + 2 \cdot \frac{-\alpha a + \beta + \sigma a}{\sigma} - a = \frac{-\alpha a + \beta + \sigma a}{\sigma} > 0$, which seems to be a plausible assumption given standard values for the parameters of the model.

However, noting that the minimum possible value for ψ is a, the equilibria $\{\psi = 0, \chi = 0\}$ is unfeasible. Given that the second equilibrium is fully stable, we will analyze the dynamic around the third unstable one.

In this third equilibrium the linearized system is:

$\begin{bmatrix} \dot{\psi} \\ \dot{\chi} \end{bmatrix} = \begin{bmatrix} -\frac{1}{\sigma}(\alpha a - \beta) & 0 \\ -\frac{-\alpha a + \beta + \sigma a}{\sigma} & \frac{-\alpha a + \beta + \sigma a}{\sigma} \end{bmatrix} \begin{bmatrix} \psi - a \\ \chi - \frac{-\alpha a + \beta + \sigma a}{\sigma} \end{bmatrix}$

The solution for the system is the following:

$$\chi = \chi_{ss} + (\chi_0 - \chi_{ss}) \cdot e^{-\frac{1}{\sigma}(\alpha a - \beta) \cdot t} \tag{26}$$

$$\psi - \psi_{ss} = -(\chi - \chi_{ss}) \cdot (\frac{\frac{-\alpha a + \beta + \sigma a}{\sigma} - -\frac{1}{\sigma}(\alpha a - \beta)}{-\frac{-\alpha a + \beta + \sigma a}{\sigma}}) = (\chi - \chi_{ss}) \cdot (\frac{a}{\frac{-\alpha a + \beta + \sigma a}{\sigma}}) = (\chi - \chi_{ss}) \cdot (\frac{\psi_{ss}}{\chi_{ss}}) \tag{27}$$

Now we can plot the dynamic under the assumptions needed for having the third equilibria with a saddle path. For the figure 1 we use the following parameters values:

$a = 3.5$, $\sigma = 1.1$, $\alpha = 0.8$ and $\beta = 1.05$ The steady state condition is given by:

$\frac{\chi}{1.1}(0.8 \cdot 3.5 - 1.05) - \chi \cdot (\psi - \chi) = 0, (10 - \psi) \cdot (\psi - \chi) = 0$

Now we will derive the growth rates for income per capita, expressing it as a function of the variables used in linearizing the system. Thus we obtain:

$$\gamma_y = \gamma_\psi + \gamma_{hi} \tag{28}$$

¿From the original system of equations we have:

$\gamma_\psi = \gamma_{hi} \cdot (\frac{a}{\psi} - 1) = \gamma_{hi} \cdot (\frac{\psi_{ss}}{\psi} - 1)$

Thus, replacing in equation (28)

$\gamma_y = \gamma_\psi \cdot (1 + (\frac{\psi}{\psi_{ss} - \psi})) = \gamma_\psi \cdot (\frac{\psi_{ss}}{\psi_{ss} - \psi})$

Recalling the solution for the linearized system we obtain:

$\gamma_\psi = -(\frac{\psi_{ss}}{\chi_{ss}}) \cdot \frac{(\chi_0 - \chi_{ss}) \cdot \gamma_{ss} e^{-\gamma_{ss} \cdot t}}{\psi}$

Therefore, we can express the rate of growth of output as

$\gamma_y = -(\frac{\psi_{ss}}{\chi_{ss}}) \cdot \frac{(\chi_0 - \chi_{ss}) \cdot \gamma_{ss} e^{-\gamma_{ss} \cdot t}}{\psi} \cdot (1 + (\frac{\psi}{\psi_{ss} - \psi}))$

Using equation (26) and equation (27) this can be reduced to

$$\gamma_y = (\frac{\psi_{ss}}{\psi}) \cdot \gamma_{ss} = \frac{H_i}{Y} \cdot \psi_{ss} \cdot \gamma_{ss} \tag{29}$$

After some algebra and recalling the fact that $\psi_{ss} = a$ and remembering that γ_{ss} is the steady state growth rate, we can rewrite equation (29) as follows:

$$\gamma_y = \frac{a \cdot H_i}{Y} \cdot \gamma_{ss} = (1 - X_{nr}) \cdot \gamma_{ss} = \gamma_{ss} - \gamma_{ss} \cdot X_{nr} \tag{30}$$

Hence, we have derived the inclusion of the fraction of natural resources exports on GDP as an explanatory variable. This may be consider as an extension of the of previous empirical specifications existing in the literature.

Thus, for proving Propositions 4 we can differentiate equation (29).

Proof. Proposition 4

From Proposition 3 we have that:

$$\frac{d}{dR}(Y_0) = c \cdot p_1 \cdot H_R^\delta(R) > 0 \tag{31}$$

Now we can express the human capital allocated in the industrial sector as function of the total human capital and the specific factors. This is: $H_i = H - H_R = H - (\frac{\alpha a}{p \cdot R \cdot \delta})^{\frac{1}{\delta - 1}}$

Therefore, we can express the total derivative of the growth rate with respect to the specific factor in the natural resources sector as follow:

$$\frac{d}{dR}(\gamma_y(R,H,Z)) = K_0 \cdot \frac{d}{dR}(\frac{H_i}{Y}) = \frac{\frac{\partial}{\partial R}(H_i)Y - H_i \frac{\partial}{\partial R}(Y)}{Y^2} \tag{32}$$

Noting that $\frac{\partial}{\partial R}(H_i) < 0$ and $\frac{\partial}{\partial R}(Y) > 0$, we proved that $\frac{d}{dR}(\gamma_y(R,H,Z)) < 0$

Now, after some manipulations on $\frac{d}{dR}(\gamma_y(R,H,Z))$ we can derive $\frac{d^2}{dhdR}(\gamma_y(R,H,Z))$, which can be rewritten as:

$$\frac{d^2}{dHdR}(\gamma_y(R,H,Z)) = c \cdot H_R^{\delta} \cdot (2 \cdot \frac{Y_I}{Y_{Total}} - 1) + 2 \cdot a \cdot \frac{H_R}{R}\left(\frac{1}{1-\delta}\right) \tag{33}$$

If R is big enough the fraction of production in the industrial sector is small (the same can be argued for low level of human capital) and the first term becomes negative, while the second term will be small. On the other hand, we might note that for any value of R there exists a level of human capital such that is equation (33) is positive because the fraction of GDP belonging to the industrial sector is and increasing function of the level of human capital accumulation. Whether the total effect is negative will depend on the parameters. What it is guaranteed is the existence of $H^* > 0$,and hence $H^* > 0$ such that $\forall$ $H > H^*$ the cross differentiation is positive. ■

Natural Resources and zero growth

In this section we assume that given the productivity of each of the two sector, and the initial level of human capital, the economy will produce just in the natural resources sector. For that we need to impose

Assumption 2 *Given the population in the economy, the marginal productivity of human capital in the natural resources sector is greater than $\alpha \cdot a$, which implies $(\frac{p_1 \cdot R \cdot \delta}{\alpha a})^{\frac{1}{1-\delta}} > H_0$. we also assume that $\beta > \alpha a$.*

Note that the first condition, just implies relative abundance of natural resources with respect to the factor specific to the industrial sector. Hence, there may be cases where this relative abundance can induce geater welfare levels even in absence of growth, when compared with the alternative of non-production in the natural resources but with positive growth rate.

Thus, the problem is reduced to a simplified version of the Ramsey model:

$$\begin{array}{l} Max \int_0^{\infty} \frac{c_t^{(1-\sigma)}-1}{(1-\sigma)} \cdot e^{-\beta t} dt \\ st \\ \dot{H} = p_1 R H_R^{\delta} - C_t \end{array} \tag{34}$$

After redefining constants and variables in per capita terms the problems reduces to impose first order conditions over the following Hamiltonian:

$J = u(Ct) \cdot e^{-\beta t} + \lambda \cdot e^{-\beta t}(pRH^{\delta} - c_t)$

$\frac{dJ}{dc_t} = 0 \Leftrightarrow u'(c_t)e^{-\beta t} = \lambda$

$\frac{dJ}{dH} = -\dot{\lambda} + \lambda\beta = \lambda p_1 \delta RH^{\delta-1} \Rightarrow \frac{-\dot{\lambda}}{\lambda} + \beta = p_1 \delta RH^{\delta-1}$

Proof. Proposition 5

Taking the log and differentiating $\frac{dJ}{dC} = 0$, we get

$$\frac{\dot{c}}{c} = \frac{1}{\sigma}(p_1 \delta RH^{\delta-1} - \beta) \tag{35}$$

As usual, in the steady state the economy grows at rate zero, because the firm utilizes human capital up to the point at which decreasing returns to human capital equalizes the discount rate of the representative agent. Consequently, there are no incentives for human capital accumulation. If eventually there is more human capital than can be utilized in the natural resources sector, there may be deaccumulation of human capital.

In order to analyze the steady state growth rates, we divide by H and differentiate the budget constraint getting

$\frac{d}{dt}\frac{\dot{H}}{H} = \frac{d}{dt} p_1 \delta RH^{\delta-1} - \frac{d}{dt}\frac{C_t}{H}$

$0 = 0 - \frac{C_t}{H}(\gamma_c - \gamma_H)$

Thus, we have that:

$$\gamma_c = \gamma_H = 0. \tag{36}$$

■

Appendix B: Data

Penn World Tables, version 5.6: Real GDP per capita in constant dollars, base 1985 (RGDPCH), Real Investment share of GDP (I), Real Government share of GDP (G), Openness (Exports+Imports)/GDP (OPEN)

Barro and Lee Database, 1994.: Average schooling years in the total population over age 25 (HUMAN), Average schooling years in the male population over age 25 (HUMAN (MALE)), Average years of secondary schooling in the total population over age 25 (SYR)

World Tables CD Rom, 1993-1996. The following variables

Exports of Fuel: Comprise commodities in SITC Revision 1, Section 3 (Mineral Fuels and Lubricants and related Materials); (TX VAL FUEL CD)

Exports of Non Fuel Primary Products: commodities in SITC Revision 1, Sections 0,1,2,4, and Division 68 (food and live animals, beverages and tobacco, inedible crude materials, oils, fats, waxes, and non ferrous metals); (TX VAL NFPP CD).

Exports of Metals and Minerals: Exports of metals and minerals comprise commodities in SITC Revision 1, Sections 27 (crude fertilizer, minerals nes), 28 (metaliferrous Ores, Scrap) and 68 (Non-Ferrous Metals); (TX VAL METM CD).

GDP at Market Prices: Measures the total output of goods and services for final use occurring within the domestic territory of a given country, regardless of the allocation to domestic and foreign claims. Gross Domestic Product at purchaser values (market prices) is the sum of GDP at factor cost and indirect taxes less subsidies. Data are expressed in current US dollars.

The figures for GDP are dollar values converted from domestic currencies using single year official exchange rates. For a few countries where the official exchange rate does not reflect the rate effectively applied to actual foreign transactions, an alternative conversion factor is used.

Merchandise Exports: refer to all movable goods (excluding non monetary gold) involved in a change of ownership from residents to nonresidents. Merchandise exports are valued free on board (F.O.B) at the customs frontier includes the value of the goods, and the value of outside packaging, and related distributive services used up to, and including, loading the goods onto the carrier at the customs frontier of the exporting country. (TX VAL MRCH CD)

The primary source is UNCTAD database supplemented with data from the UN COMTRADE database, IMF's International Financial Statistics, national and other sources. Because of the source change the data for some countries may differ significantly from those presented last year. Also, export and import component values may not sum to the total shown.

Merchandise Imports: Merchandise imports refer to all movable goods (excluding non-monetary gold) involved in a change of ownership from nonresidents to residents. Merchandise imports are valued at their c.i.f. (cost, insurance and freight) price. In principle, this price is equal to the f.o.b. transaction price plus the costs of freight and merchandise insurance involved in shipping goods beyond the f.o.b. point. Data are in current U.S. dollars.

The primary source is the UNCTAD database supplemented with data from the UN COMTRADE database, IMF's International Financial Statistics, national and other sources. Because of the source change the data for some countries may differ significantly from those presented last year. Also, export and import component values may not sum to the total shown.(TM VAL MRCH CD).

All the previous variables expressed in current US$ dollars.

Merchandise Export Price Index: This item is a price index measuring changes in the aggregate price level of a country's merchandise exports f.o.b. over time.(TX PRI MRCH XD).

Merchandise Import Price Index: This item is a price index measuring changes in the aggregate price level of a country's merchandise imports c.i.f. over time.(TM PRI MRCH XD).

Table 5: Countries whose Human Capital would Cancel the negative effect of Natural Resources.

Country	Human 1970	$\frac{X_{NR}}{Y}$ 1970	Human 1975	$\frac{X_{NR}}{Y}$ 1975	Human 1980	$\frac{X_{NR}}{Y}$ 1980	Human 1985	$\frac{X_{NR}}{Y}$ 1985
New Zealand	9.69	0.17_*	11.16	0.13	12.14	0.19_*	12.04	0.19_*
U.S.A.	10.14	0.01	10.77	0.02	11.89	0.03	11.79	0.01
Norway	6.76	0.10	10.19	0.10	10.32	0.22_*	10.38	0.24_*
Canada	8.55	0.09	9.50	0.10	10.16	0.12	10.37	0.10
Denmark	9.63	0.10	9.91	0.10	10.14	0.11	10.33	0.12
Australia	10.09	0.09	10.01	0.09	10.08	0.10	10.24	0.11
Finland	8.34	0.07	8.81	0.04	9.61	0.08	9.49	0.06
Sweden	7.47	0.05	7.90	0.05	9.47	0.05	9.45	0.06
Israel	7.62	0.04	8.15	0.03	9.14	0.04	9.41	0.04
Belgium	7.71		8.36	0.10	8.79	0.14	9.15	0.16_*
Switzerland	6.22	0.03	6.26	0.02	9.67	0.03	9.09	0.02
U.K.	7.32	0.03	8.17	0.03	8.35	0.06	8.65	0.07
Netherlands	7.67	0.15_*	7.90	0.18_*	8.20	0.21_*	8.57	0.26_*
W Germany	8.14	0.02	8.21	0.02	8.46	0.03	8.54	0.04
Japan	6.80	0.01	7.29	0.00	8.17	0.01	8.46	0.00
Poland	7.56		8.05		8.65	0.12	8.41	0.06
Ireland	6.52	0.14_*	6.73	0.19_*	7.61	0.18_*	8.01	0.16_*
Iceland	6.37	0.27_*	6.86	0.21_*	7.40	0.25_*	7.89	0.25_*
Barbados	9.06	0.13_*	8.31	0.16_*	6.75	0.09	7.48	0.03
Variable Average	3.83	0.16	3.99	0.19	4.50	0.20	4.91	0.16
Variabel S.D.	2.61	0.16	2.78	0.19	2.88	0.20	2.84	0.14
Sample Average	3.98	0.13	4.13	0.14	4.64	0.17	5.23	0.13
Sample S.D.	2.68	0.11	2.88	0.14	2.99	0.15	2.89	0.11

Countries whose natural resources exports as fraction of GDP are greater than the sample average are indicated with an asterisk. All the reported countries are included in our sample, which implies all the variables are available for at least one period of the panel.