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Natural resources, economic growth and institutions – a panel approach

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Abstract

This study re-evaluates the impact of natural resources on growth using panel data and a factor-efficiency accounting framework. The resource-curse thesis is dismissed as capital efficiency is improved by geographically-concentrated natural resources, which hinder institutional quality in recent cross-section studies. This consensus does not hold in our case even when we use unadjusted resource proxies and the standard institutional approach, as both concentrated and diffuse resources show negative effects in low institutional-quality countries. Adequate fiscal policy seems to prevent the curse in that case, but reduces the positive effect of concentrated resources found with our adjusted proxy.

Keywords: Natural resources, Economic growth, Institutions, Country Studies, Panel data

JEL classification: C23, N50, O13, O40, O50

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I. Introduction

In this paper we reassess the impact of natural resources on economic growth. The analysis takes into account the latest developments in the recent literature of the "resource curse", a puzzling empirical result that associates countries' natural-resource abundance and dependence with lower economic growth after controlling for other relevant characteristics. The hypothesis of a resource curse was suggested by a large number of cross-section studies initiated by Sachs and Warner (1995),[1] becoming a stylized fact (Wright, 2001).

The first explanations for this paradox were based on the structuralist theses of the 1950s,[2] but none was unequivocally confirmed by empirical studies.[3] The same happened with tests on Dutch-Disease arguments,[4] where the non-resource sector, assumed as the long-run engine growth, is hindered by the resource sector, namely through real exchange rate appreciation or the absorption of production factors (*e.g.*, Neary and van Wijnbergen, 1986). The case study led by Auty (2001a) also dismisses this thesis by showing the complexity and diversity of cases among natural-resource abundant countries, including several exceptions to the curse, such as Norway, which has seized its oil abundance to become a rich country.

Other explanations for the resource curse, often presented autonomously, can also be partly considered as symptoms of the Dutch Disease. These arguments include the disincentive for entrepreneurship (Sachs and Warner, 2001),[5] the decrease in savings and

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[1] *E.g.*, Sachs and Warner (1995, 1999, 2001), and Sala-i-Martin and Subramanian (2003).

[2] *E*.g., Prebisch (1950), and Hirschman (1958).

[3] *E.g.*, Dawe (1996), and Fosu (1996).

[4] *E.g.*, Leite and Weidmann (2002) and Sala-i-Martin and Subramanian (2003).

[5] The general crowding-out logic of Dutch Disease can be extended to entrepreneurship: if wages in the natural resources sector pays well enough to attract potential innovators and entrepreneurs (in a limited number), this will reduce business talent in the manufacturing industry.

physical investment (Gylfason, 2001a) and lower investment in human capital (Gylfason, 2001b; Bravo-Ortega and Gregorio, 2007).

Another thesis stresses the negative effect on growth caused by rent-seeking activities linked with natural-resource abundance (*e.g.*, Torvik, 2002). As natural-resource abundance only penalises growth in some countries, this thesis has very little explanatory power (Bulte *et al*., 2005), leading to the development of models where results depend on initial conditions (*e.g.*, Acemoglu, 1995; Baland and François, 2000). In addition, the concern is not specific with natural resources, but with any source of rents (Lederman and Maloney, 2008).

There is now a growing consensus about the importance of institutions in explaining the resource curse,[6] as stressed by a recent World Bank publication (Hartford and Klein, 2005). Mehlum *et al.* (2006), for example, conclude that better institutions can avoid the resource curse, but they stress the possibility that natural resources affect institutional quality.

That possibility is recognised by explanations based on endogenous institutions, where the type of natural resource affects the institutional context, in which the form of government and the quality of policies are the main aspects (*e.g.*, Auty, 2001a,b; Ross, 2001; Atkinson and Hamilton, 2003). Leite and Weidmann (2002), for example, found no direct impact of natural-resource abundance on economic growth from 1970 to 1990, but they showed an important indirect effect through the impact of those resources on corruption, which, in turn, negatively affects growth (*e.g.*, Mauro, 1995).

This result was confirmed by Isham *et al.* (2005) and Sala-i-Martin and Subramanian (2003), who examined the influence of natural resources on broader indicators of institutional quality and policies. They confirmed that, for a given level of institutional quality, natural-resource abundance has no direct impact on growth. Rather, this abundance penalises growth

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[6] The high importance of institutions and policies to economic growth is stressed by a vast number of empirical studies (*e.g*., Acemoglu and Robinson, 2006; Acemoglu *et al*., 2005).

indirectly, through institutional quality, but only when resources are geographically concentrated (these agglomerations of resources are also known as "resource points"), such as oil.[7] That is, these recent studies explain the resource curse through the negative effect of geographically concentrated resources on the quality of institutions.[8]

Following Sachs and Warner (1995), these and the majority of studies on the resource curse measure natural-resource abundance as the share of total merchandise exports or GDP. Other studies, which explore the impact of more direct measures of mining production or reserves, find distinct results concerning the impact of geographically-concentrated resources, as pointed by Lederman and Maloney (2008). Stijins (2005) found no correlation of fuel and mineral reserves on growth during 1970-1989, while Davis (1995) showed that countries with a high share of minerals in exports and GDP performed relatively well in the same period. In fact, the mining share in GDP belongs to the set of variables positively associated with growth across the several million regressions in Sala-i-Martin *et al* (2004). Recently, Nunn (2008) found a positive relation between *per capita* production of gold, oil, and diamonds and GDP *per capita*, and Brunnschweiler (2008) showed that *per capita* mineral and fuel production in 1970 benefited growth during 1970-2000.

In addition, the vast majority of empirical results on the resource curse are based on cross-section analyses, where countries' economic growth in a single extended period is regressed to a series of explanatory variables, including natural resources.

A recent panel study by Manzano and Rigobon (2006) showed evidence of unobserved fixed country effects, implying that the estimates of the traditional cross-section regressions may be inconsistent. Using panels with two or four time series and Sachs and Warner (1995)

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[7] In turn, diffuse resources, such as agricultural and forest products, were not correlated with institutional quality.

[8] Boschini *et al* (2007) show the negative effect is larger in the case of diamonds and precious metals for countries with low institutional quality.

data, the authors found that the resource curse result disappears once one allows for fixed effects in a panel regression. They sustain that the degree of development and the quality of institutions are not the cause of the curse (they point, instead, to the debt overhang in resource-rich countries due to the rise and fall in commodity prices in the 70's and 80's, respectively), but they cannot allow for fixed effects in this case as their institutional quality proxy does not change over time. In addition, the results may depend on period aggregation.

We broaden the scope of literature by assessing the premise of a resource curse in a single extended-panel analysis of a growth accounting model where natural resources (geographically diffused or concentrated) affect the efficiency gains of labour and capital in production, along with the most important growth determinants. In order to estimate the unobserved efficiency gains (the Solow residual), we consider that factor's prices reflect their quality, which is also an important growth accounting result, as stressed by Barro (1999).

By using panel-data analysis, we increase the efficiency of our estimation, associated with the larger number of observations (around one thousand, arising from the available data on the chosen growth determinants in two hundred and eight countries from 1976 to 2005). We are also able to control the presence of unobserved country and time effects, which, if not considered, lead to inconsistent estimates, and we have evidence of such effects in the panel study by Manzano and Rigobon (2006). Finally, taking into account institutional quality as a cause of labour efficiency we can show whether the most recent and consensual explanation of the resource curse in cross-section studies is still relevant in a panel-data case. Unlike Manzano and Rigobon (2006), we also measure institutional quality over time to allow for fixed-effects estimation, considering the interpretation of institutions as a reflection of policy outcomes that are in a state of flux (*e.g.*, Dodrik *et al*, 2004; Brunnschweiler and Bulte, 2008).

In short, with the estimated panel growth accounting model we intend to assess: (i) the effect of natural resources on economic growth through capital and labour efficiency; (ii) if both the type of resource and institutional quality are relevant to that assessment, as stressed in recent cross-section studies; (iii) the relative importance of the proposed growth factors.

The paper proceeds as follows. In section II, we deduce an estimated growth model and present the estimation strategy. Section III shows the main estimation results, including the growth decomposition for two countries rich in concentrated resources but with distinct economic outcomes. In section IV, we present our conclusions.

II. Estimation procedures and data

In this section, we outline our empirical strategy, starting with the development of a growth accounting framework with factor efficiency, and present the data.

Growth accounting model with factor efficiency

Let us consider the following neoclassical (Cobb-Douglas) production function with constant returns to scale, at each time *t* (the sources of all proxies are shown in Appendix 1):[9]

$$Y(t) = \left[L(t) f(t)\right]^{\alpha} \left[K(t) g(t)\right]^{1-\alpha}, \text{ where:} \quad (1)$$

(i) *Y* is the real aggregate output; (ii) *L* is the labour level; (iii) *K* is the aggregate capital stock; (iv) *f* is the labour efficiency; (v) *g* is the capital efficiency; (vi) α is the labour share in production; and (vii) *Lf* and *Kg* are, respectively, the labour factor and the capital factor measured in units of efficiency, which compares with *L* and *K*, both expressed in conventional units. Thus, quality advances in physical inputs are captured by *f* and *g* in (1).

The constant returns to scale assumption in *Lf* and *Kg* means that excluded factors are trivial to growth. Since apparently natural-resource scarcity does not place a direct restriction on growth (*e.g.*, Nordhaus, 1992; Meier and Rauch, 2000, Romer, 2005), the omission as a

[9] The assumption of a one-sector economy implies that we will not test the Dutch Disease thesis, which is dismissed by cross-section studies and does not account for the diversity of cases among natural-resource abundant countries (Auty, 2001a), as mentioned in the previous section.

productive factor or a windfall seems adequate.[10] However, considering recent resource-curse studies, natural resources may affect *f* and *g*. Although this effect appears negative in a cross-country analysis (the curse), the experience of several countries shows that these resources can be well managed (for instance, invested in human capital) and thus benefit growth.

From (1) we obtain the following expression for the product real growth rate:

$$\hat{Y}(t) = \alpha\left[\hat{L}(t) + \hat{f}(t)\right] + \left(1-\alpha\right)\left[\hat{K}(t) + \hat{g}(t)\right], \tag{2}$$

in which the circumflex accent conveys the growth rate of the respective variable.

As the efficiency levels *f* and *g* are not observable, we consider that they are a function of several variables, including natural resources. The empirical equations proposed below for *f* and *g*, which together evaluate Total Factor Productivity (TFP), are in line with Coe and Helpman (1995) and Coe *et al*. (1997). Thus, they are also built on endogenous growth models based on R&D (*e.g*., Aghion and Howitt, 1992; Barro and Sala-i-Martin, 2004) and on human capital (*e.g*., Lucas, 1988; Mincer, 1993).[11]

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[10] In recent literature, physical limits to growth caused by natural-resource scarcity or excessive pollution have not been considered relevant (Nordhaus, 1992; Meyer and Rauch, 2000; Romer, 2005). This occurs because those physical limits can be overcome by technological progress, forces of substitution and structural change when natural-resource scarcity is reflected in market prices (Meier and Rauch, 2000). If there is open access to resources, economic agents must be forced to consider the associated social value through adequate policies and institutions. It should be noted, however, that environmental impacts associated with climate change are much more difficult to reverse as they show a high persistence in time, posing tremendous immediate challenges to avoid aggravated economic costs in the future, as recognised by the Stern Report (2006). Nevertheless, this kind of analysis depends upon the social discount rate adopted, and climate changes are difficult to predict despite science advances. Thus, the impact on growth caused by climate change or the referred physical limits associated with natural-resource scarcity are not considered in this paper.

[11] Indeed, the specification forms are closely related with Coe and Helpman (1995) and Coe *et al*. (1997) and the independent variables embody domestic and foreign R&D and domestic human-capital accumulation.

Specification for labour efficiency

Assuming the functional form of constant elasticity, we propose the following expression for labour efficiency *per* worker at each time *t*:

$$f(t) = F\left(\frac{I(t)}{L(t)}\right)^{a_1}\left(\frac{T(t)}{L(t)}\right)^{a_2} e^{\int\left(a_3 IQ(t)+a_4 \frac{NresP(t)}{L(t)}+a_5 \frac{NresD(t)}{L(t)}\right)dt}\text{, where:} \qquad (3)$$

(i) *F* is a scale factor; (ii) *I* is the investment; (iii) *T* assesses international trade; (iv) *IQ* is the institutional-quality variable; (v) *NresP* (natural resource points) conveys the geographically-concentrated natural-resource abundance; (vi) *NresD* evaluates the diffuse natural-resource abundance; (vii) a_1 and a_2 are (constant) elasticities of labour efficiency in relation to $\frac{I}{L}$ and $\frac{T}{L}$; (viii) a_3, a_4 and a_5 are (constant) semi-elasticities of *f* in relation to *IQ*, $\frac{NresP}{L}$ and $\frac{NresD}{L}$, respectively; as *f* refers to the labour efficiency unit, variables were divided by *L*, except in the case of *IQ*. All variables are namely based on several empirical studies on the subject.[12]

Returning to expression (3), the growth rate of labour efficiency is:

$$\hat{f}(t) = a_1\left[\hat{I}(t)-\hat{L}(t)\right]+a_2\left[\hat{T}(t)-\hat{L(t)}\right]+a_3\ IQ(t)+a_4\frac{NresP(t)}{L(t)}+a_5\frac{NresD(t)}{L(t)}. \qquad (4)$$

Since $\hat{f}$ is not observable, the first order condition (FOC) for maximizing profit in relation to *L* is used to derive $\hat{f}$ as a function of: (i) real wage growth *per* worker, $\hat{w}$; (ii) $\hat{L}$; (iii) $\hat{K}$; and (iv) $\hat{g}$, which, in turn, is affected by a set of other variables, as shown below. From the FOC $\frac{\partial Y(t)}{\partial L(t)} = w(t)$, we obtain:[13]

[12] Among these studies, we stress for: *I* (*e.g.*, Englander and Gurney, 1994; Barro and Sala-i-Martin, 2004); *T* (*e.g.*, Frankel and Romer, 1999; Lewer and van den Berg, 2003); *IQ* (*e.g.*, Acemoglu *et al*., 2005, Acemoglu and Robinson, 2006); *NresP* and *NresD* (*e.g.*, Sala-i-Martin and Subramanian, 2003; Isham *et al*., 2005).

[13] This was preferred to the use of the first order condition for maximizing profit in relation to *K* because the human-capital improvements are already reflected in wages, as we explain later on.

$$\alpha\left[L(t)\right]^{\alpha-1}\left[f(t)\right]^{\alpha}\left[K(t)g(t)\right]^{1-\alpha} = w(t)\,, \tag{5}$$

and, in terms of growth factors,

$$\hat{w}(t) = (\alpha-1)\,\hat{L}(t) + \alpha\,\hat{f}(t) + (1-\alpha)\,\hat{K}(t) + (1-\alpha)\,\hat{g}(t)\,. \tag{6}$$

To some extent, wages reflect human-capital advances. Thus, the inclusion of wages through the use of the profit-maximizing condition justifies the exclusion of human capital in determining *f* in (3) and thus in (4), as suggested by endogenous-growth models (*e.g.*, Lucas, 1988, and Romer, 1990), or by empirical studies supported by these models (*e.g.*, Barro, 1991; Benhabib and Spiegel, 1994; Englander and Gurney, 1994).

In addition to human capital, the other crucial factor of long-run productivity growth is R&D (*e.g.*, Englander and Gurney, 1994),[14] which is included below in the specification of *g*.

Specification for capital efficiency

Assuming the functional form of constant elasticity, we propose the following expression for capital efficiency at each time *t*:

$$g(t) = G\left(\frac{RD(t)}{K(t)}\right)^{b_1}\left(\frac{Inf(t)}{K(t)}\right)^{b_2} e^{\int\left(b_3\frac{NresP(t)}{K(t)}+b_4\frac{NresD(t)}{K(t)}\right)dt}\,, \tag{7}$$

where: (i) *G* is a scale factor; (ii) *RD* stands for R&D; (iii) *Inf* represents infra-structures;[15] (iv) b_1 and b_2 are (constant) elasticities of *g* in relation to *RD* and *Inf*, respectively; and (v) b_3 and b_4 are (constant) semi-elasticities of capital efficiency in relation to $\frac{NresP}{K}$ and $\frac{NresD}{K}$,

[14] The introduction of R&D and monopolistic competition in growth theory began with Romer (1987, 1990) and included seminal contributions from Aghion and Howit (1992), namely.

[15] Notice that the direct impact of physical infrastructures on growth is already captured by *K* – here we evaluate the effect on overall capital efficiency.

respectively; as g refers to the capital-efficiency unit, variables were divided by K. This set of variables is also based on several (namely empirical) studies on growth.[16]

All explanatory variables in f could also be used in g and vice-versa. We chose to include variables other than natural resources where they are expected to have the greatest impact to preserve the usual functional form of constant elasticity. Indeed, due to perfect collinearity, this functional form does not allow a separate estimation of the variables' impacts in f and g, as will become clear later on. Since we want to analyze resource effects in f and g, the associated coefficients are included as semi-elasticities, overcoming problems of collinearity. Considering that natural resources affect IQ through labour efficiency in several recent resource curse studies (*e.g*. Torvik, 2002; Isham *et al.*, 2005; Sala-i-Martin and Subramanian, 2003), its coefficient is also included as semi-elasticity in f but not in g.

Returning to (7), the capital efficiency growth rate obtained is:

$$\hat{g}(t) = b_1\left(R\hat{D}(t) - \hat{K}(t)\right) + b_2\left(In\hat{f}(t) - \hat{K}(t)\right) + b_3 \frac{NresP(t)}{K(t)} + b_4 \frac{NresD(t)}{K(t)}. \quad (8)$$

Substituting $\hat{g}$ in (6), we have:

$$\begin{aligned}\hat{w}(t) = {} & \delta_1\left[\hat{I}(t) - \hat{L}(t)\right] + \delta_2\left[\hat{T}(t) - \hat{L}(t)\right] + \delta_3 IQ(t) + \delta_4 \frac{NresP(t)}{L(t)} + \delta_5 \frac{NresD(t)}{L(t)} + \delta_6\left[\hat{K}(t) - \hat{L}(t)\right] + \\ & + \delta_7\left[R\hat{D}(t) - \hat{K}(t)\right] + \delta_8\left[In\hat{f}(t) - \hat{K}(t)\right] + \delta_9 \frac{NresP(t)}{K(t)} + \delta_{10} \frac{NresD(t)}{K(t)} + u(t), \text{ where :}\end{aligned} \quad (9)$$

$\delta_j = \alpha\, a_j$ if $j = 1, 2, 3, 4, 5$; $\delta_6 = (1-\alpha)$; $\delta_j = (1-\alpha)b_{j-6}$ if $j = 7, 8, 9, 10$; $u(t)$ is a white noise.

The estimation of (9) allows us to obtain estimates of α (from δ_6), a_1 up to a_5 and b_1 up to b_4. We can then use these values to estimate $\hat{f}$ in (4), $\hat{g}$ in (8) and $\hat{y}$ in (2). However, since the wage equation is based on the FOC for maximizing profit in relation to L, it expresses labour productivity growth. Thus, the assessment of the resource curse is made

[16] Among these studies, we highlight for: *RD* (*e.g*., Coe and Helpman, 1995; Barro and Sala-i-Martin, 2004); *Inf* (*e.g*., Argimón *et al*., 1997; Roller and Waverman, 2001).

directly in (9) through the analysis of the sign, intensity and significance of the *NresP* and *NresD* coefficients as the estimates also evaluate the impact of those variables on growth.

Panel estimation model

With panel data we also have variability from country to country. Besides improving estimation efficiency, panel estimation allows the control of unobserved individual heterogeneity (Wooldridge, 2002), an econometric problem leading to inconsistent estimates if there are omitted unobserved variables correlated with the explanatory variables.

The estimation of panel data models requires the choice of several assumptions to deal with the possibility of an unobserved individual element, which, in our case, can be a country effect and/or a time effect. Denoting:

$$X_j = \left\{ \left[\hat{I} - \hat{L}\right], \left[\hat{T} - \hat{L}\right], IQ, \frac{NresP}{L}, \frac{NresD}{L}, \left(\hat{K} - \hat{L}\right), \left[R\hat{D} - \hat{K}\right], \left[In\hat{f} - \hat{K}\right], \frac{NresP}{K}, \frac{NresD}{K} \right\},$$

the wage equation (9) in a panel data formulation with a constant term δ_0 is either:[17]

$$\text{(i)}\ \hat{w}_{it} = \delta_0 + \theta\, GDPpc75_i + \sum_{j=1}^{10} \delta_j \left(X_j\right)_{it} + \varphi_{it}, \tag{10}$$

in case of the Pooled OLS and the REM with time and country effects, where $\varphi_{it} = c_i + d_t + \omega_{it}$ (being i the country, c_i the country effect, d_t the time effect and ω_{it} a white noise); or

$$\text{(ii)}\ \hat{w}_{it} = \rho_{it} + \theta GDPpc75_i + \sum_{j=1}^{10} \delta_j \left(X_j\right)_{it} + \omega_{it}, \tag{11}$$

for the FEM with time and country effects, where $\rho_{it} = \delta_0 + c_i + d_t$.[18]

[17] Notice that we also consider lagged variables, not included in vector *X*, but only *RD* lags produced interesting results, as referred in the next section, in addition to the use of lags of *IQ* as an instrument of the variable in order to avoid endogeneity problems.

[18] The FEM asks how group and/or time affect the intercept, while the REM analyses error variance structures affected by group and/or time (Park, 2005). In both, slopes are assumed unchanged. The pooled OLS model is based on the idea that countries would react in the same way to changes in explanatory variables and that

By including GDP *per capita* in 1975 for each country i ($GDPpc75_i$), in (10) and (11), we want to assess the conditional-convergence hypothesis of countries: $\theta<0$ (>0) conveys a smaller (higher) productivity growth in richer countries and thus the convergence (divergence) of countries. In general, the FEM produces more robust results as it ensures the consistency of estimates without loss of observations. However, if we are interested in the effect of a time-constant variable in a panel-data study, the robustness of the fixed-effects estimator is almost useless (Wooldridge, 2002). In this case, we will get an inconsistent estimate if the FEM is the appropriate model. The fixed-country effect in (11) impedes our checking of conditional convergence: θ cannot be estimated by the FEM since $GDPpc75_i$ is independent of t. In section III, we report the results for this coefficient with regression (10).

Data statistics and choice of proxies for main variables and their interaction

The weight of natural resources in exports (or in GDP) has been used as a measure of a country's abundance of those resources since Sachs and Warner (1995).[19] It evaluates the reliance on resource exports and, as a flow, is only an imperfect proxy of a country's real stock of natural resources (*e.g.*, Bulte *et al.*, 2005). The share of natural resources in exports can only be a strict measure of natural-resource abundance if there is an invariable and consistent relationship between the stocks and exports of these resources.

To assess whether the abundance of resources is effectively a "curse" and that the results of the standard analyses are not spurious, Bulte *et al*. (2005) consider that empirical analyses

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intercepts are the same for all countries. The choice of the adequate estimation model is made in view of several test statistics, as we show in the next section when presenting our main results.

[19] Although both measures are used, the share of natural resource in exports proved more robust than the weight of resource exports in GDP in cross-section curse analyses (Lederman and Maloney, 2008), namely in the Sachs and Warner (1995) study.

must be based on resource stock measures (see also Stijins, 2005).[20] Yet, Gylfason (2001b) used the weight of natural capital in countries' wealth in 1994 (World Bank estimates, 1997) and also concluded that there is an inverse relationship between growth and natural-resource abundance assessed by that indicator, thus confirming the cross-section curse result.

In using the weight of natural resources in exports (or in GDP), we must also bear in mind that it is an imperfect measure of abundance and dependence due to possibility of re-exportation, which, in countries like Singapore, is crucial. Sachs and Warner (1995) adjusted this effect considering natural-resource net exports in this country, but using the unadjusted measure for other countries will lead to overestimation of resource abundance.

As we show in Appendix 1, our proxies for *NresP* and *NresD* are, respectively, the weight of fuels, ores and metals in merchandise exports, and the weight of agricultural raw materials and food products in merchandise exports, following previous studies such as Leite and Weidmann (2002). To alleviate the re-exportation problem, we subtracted, for each type of resource, the weight in merchandise imports to the share of merchandise exports (we also added 100 to get an index), in line with Owens and Wood (1997) net export dependence proxy. This means that the adjusted measures of abundance take into account the importance of each type of resource on export and import structures. In our estimations, we compare the results with the adjusted and unadjusted proxies to confront with previous studies' results.

In the case of the institutional quality variable, we consider, in line with the cross section study by Brunnshweiler and Bulte (2008), two different perspectives: one that sees institutions as "deep and durable" characteristics of societies (*IQ* 'stable' approach), usually considered in resource curse studies, and another that views them as a reflection of policy outcomes that are in a state of flux (*IQ* 'policies' approach). We agree that both

[20] Unfortunately, estimates of natural-capital stock in a significant number of countries are only available for few years, and thus are not suited for a single-extended panel study like ours.

interpretations are potentially relevant for the resource curse analysis, but we show that the *IQ* 'policies' approach is more adequate in a panel-data study.

Since proxies for the *IQ* 'stable' approach are, by definition, almost constant over time, they are not suited for a panel estimation allowing unobserved fixed effects and, as already mentioned, we have evidence of those effects in Manzano and Rigobon (2006) panel study. To evaluate the impact of this institutional approach, we conducted our initial estimations considering countries rated by the Freedom House as "Free" (average classification of civil liberties and politic rights bellow a value of 3) in 1975,[21] and countries classified as partially or not free, thus separating high from low institutional quality – from now on, we will denote these sub samples as *F75* and *PNF75*, respectively. Since our panel begins in 1976, we avoid potential endogeneity problems by using the 1975 rating.

The *IQ* variable included in estimation forms corresponds to the *IQ* 'policies' approach, allowing for higher time variability. We chose as a proxy the government budget balance in percentage of GDP, which captures the fiscal-policies quality in studies such as Easterly and Rebelo (1993) and Burnside and Dollar (2000), with the advantage of data availability for a large number of countries and years.[22] We argue that fiscal-policy quality is related to the quality of policies in general,[23] and may be, in itself, central for the study of the resource curse. Norway, an example of good natural-resource state-management, saves part of the associated rents and distributes them between generations through a public fund – this is captured by an increase in our institutional quality measure.

[21] We use the first available value when the information does not exist for 1975.

[22] Notice that an increase of public investment, which decreases the budget balance and fosters growth, is already captured by the investment variable *I* in our model.

[23] According to Mauro (1995), the measures of corruption and various aspects of bureaucratic efficiency are highly correlated, while Stein (2005) associates the quality of legislative capabilities, in general, to the quality of policies, namely fiscal. Thus, we assume that the quality of different policies is also correlated.

To consider the deferred effect of policies on growth and avoid potential endogeneity problems, we first instrument our proxy with its period lags and then we estimate the main regression using a 2SLS approach.[24] We hypothesize that past and present good fiscal policies (and good policies, in general) can prevent a negative effect of natural resources on growth.

Table 1 presents the descriptive statistics of the available data for the main variables in our unbalanced panel of 208 countries from 1976 to 2005.

Table 1 – descriptive statistics of main variables

	All countries (n=208)		*F75* sub sample (n=59)		*PNF75* sub sample (n=129)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
$GDPpc$ growth	1.491	7.171	2.115	5.590	1.133	7.915
$\hat{w}$	1.379	8.841	1.510	5.872	1.183	11.981
$(\hat{I} - \hat{L})$	1.464	22.413	1.881	16.686	1.001	27.361
$(\hat{T} - \hat{L})$	3.779	14.980	3.748	14.155	3.813	15.842
IQ	-3.149	6.002	-2.520	4.936	-3.538	6.545
$NresD$ unadjusted	29.592	27.361	27.708	27.770	30.939	26.990
$NresP$ unadjusted	24.128	30.738	16.416	23.811	29.556	33.761
$NresD$ adjusted	114.677	26.520	113.935	25.204	115.215	27.428
$NresP$ adjusted	108.573	32.905	100.216	21.933	114.531	37.773
$\hat{L}$	1.492	5.129	1.609	3.936	1.362	6.188
$\hat{K}$	3.581	4.251	3.709	3.347	3.505	4.703
$(In\hat{f} - \hat{K})$	9.040	14.349	6.407	10.355	10.507	15.965
$(R\hat{D} - \hat{K})$	-3.202	43.934	-3.998	33.121	-2.598	50.626

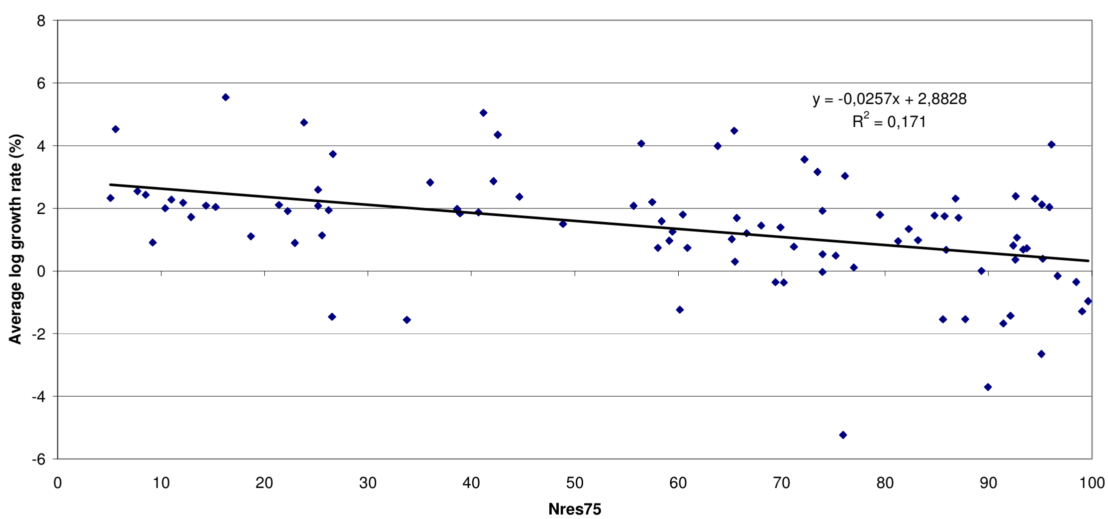
Notes: percent values (of growth rates and ratios) except in the case of adjusted resource proxies, which convey indices.

[24] This also dilutes the positive correlation of our *IQ* proxy (the budget balance) with the natural-resource proxies due to the contemporaneous associated rents captured by the state, as they are generally not completely spent.

We highlight the higher real growth rates of *per capita* GDP and wage *per* worker in free countries, reflecting the positive impact of institutional quality, which is confirmed by above average budget balances, our measure for the quality of policies. Free countries present higher increases in *I*, *K* and *L*, but smaller augments in *Inf* compared to other countries (mostly developing countries, still insufficiently infrastrutured). They also present a surprising worse *RD* performance, probably due to a superior number of patent applications to regional patent offices, which are not covered by the available data as pointed in Appendix 1. The proxies for natural resources show that free countries are slightly less abundant in diffuse resources and significantly less rich in concentrated resources with adjusted and unadjusted measures.

Figure 1 plots the growth in real *GDPpc* from 1975 to 2005 for 94 countries against their natural-resource abundance in 1975, measured by the sum of *NresD* and *NresP*. As expected, it depicts the negative correlation that embodies the resource curse. This was also found separately for *NresD* and *NresP* with unadjusted and adjusted proxies.

Figure 1 - GDP*pc* average growth rate from 1975 to 2005 and resource abundance in 1975 (unadjusted proxy)



III. Results

Table 1 shows the main estimation results for the wage equation without the conditional convergence variable – estimation forms (10) and (11). We remember that the estimate of $(\hat{K} - \hat{L})$ represents capital elasticity, and the other coefficients correspond to the impacts of the associated variables on real wage growth *per* worker, $\hat{w}$, equal to labour productivity growth in our model, and thus on output growth, $\hat{Y}$, where we focus the analysis.[25]

The estimations with our unbalanced panel data produced 880 observations using the full sample and the instrumented *IQ* variable.[26] This instrumentation reduced the estimation period to 1976-2002 as we used a three-period lag of the variable as an instrument. In the last regression (8), we extended the period to 1976-2005 using the original *IQ* proxy since the results did not alter our final conclusions with the instrumented proxy in regression 7, obtaining near one thousand observations for eighty countries. Since unbalanced panels may suffer from selectivity bias, in Appendix 2 we present the estimated number of years for each of those countries. An inspection of the Table reveals enough variability of resource abundance and economic outcomes to exclude severe selectivity bias problems.

According to the test statistics, the FEM is the adequate estimation procedure in most regressions (estimation form 11), except in 2, where the REM was used. Under fixed-country effects, the convergence-variable estimate is inconsistent since only the Pooled OLS or the REM procedure can be used – estimation form (10). The convergence variable is statistically insignificant with either of these estimations in view of the different scenarios for inclusion of

[25] The estimated impact of $\hat{K}$ on $\hat{Y}$ is given in Table 1 by the coefficient of $(\hat{K} - \hat{L})$, which we then subtract from 1 to obtain the effect by $\hat{L}$.

[26] We used as instruments, besides the constant term, a three-period lag of *IQ* with the full sample, and a two-period lag with the sub samples, as they revealed low correlation with $\hat{w}$ and high correlation with *IQ*. The instrumental regressions are not presented, but they can be made available upon request.

IQ and the adjustment of resource variables, while most growth econometrics provide support for conditional convergence (*e.g.*, Sala-i-Martin, 2000). However, as already stated, our analysis of convergence is not correct if the adequate model is the FEM.

Table 2 – Wage equations (1976-2005)

Regression	1	2	3	4	5	6	7	8
Model	FEM G&T [(a)]	REM G&T	FEM G&T	FEM G&T	FEM G&T	FEM G&T	FEM G&T	FEM G&T
F [(b)]	4.518	1.634	3.083	5.314	4.539	5.145	4.891	4.436
LM [(c)]	3.06	14.98	0.44	7.02	3.00	7.03	7.55	6.80
Hausman [(d)]	134.16	6.53	25.08	45.44	129.56	46.48	42.94	106.02
Sample	Full	F 75	PNF 75	Full	Full	Full	Full	Full
Res. Proxies	Unadj.	Unadj.	Unadj.	Unadj.	Adj.	Adj.	Adj./K, L	Adj./K, L
IQ included	No	No	No	Yes	No	Yes	Yes	Yes, not instr.
Dependent variable, $\hat{w}$								
Constant	2.190^{***}	0.928^{**}	10.982^{**}	1.955	-10.003^{***}	-6.487	2.837^{***}	1.593
	(1.892)	(2.089)	(2.555)	(1.439)	(-1.652)	(-1.003)	(1.919)	(1.242)
$(\hat{I} - \hat{L})$	0.129^{*}	0.092^{*}	0.179^{*}	0.135^{*}	0.126^{*}	0.133^{*}	0.139^{*}	0.118^{*}
	(8.948)	(7.313)	(5.595)	(9.038)	(8.738)	(8.905)	(9.227)	(7.853)
$(\hat{T} - \hat{L})$	0.118^{*}	0.060^{**}	0.193^{*}	0.089^{*}	0.111^{*}	0.086^{**}	0.085^{**}	0.118^{*}
	(3.970)	(2.308)	(2.904)	(2.636)	(3.735)	(2.557)	(2.523)	(3.647)
IQ				0.340^{***}		0.372^{**}	0.304	0.148^{**}
				(1.850)		(2.012)	(1.632)	(2.492)
$\frac{NresD}{L}$ [(e)]							-0.005	0.000
							(-0.295)	(0.024)
$\frac{NresP}{L}$ [(e)]							-0.042	-0.029
							(-1.270)	(-0.936)
$\frac{NresD}{K}$ [(e)]							-0.635	-0.676
							(-1.415)	(-1.536)

$\frac{NresP}{K}$ (e)							0.905**	0.825***
							(1.963)	(1.827)
NResD	-0.083***	0.008	-0.455*	-0.055	0.019	0.022		
	(-1.860)	(0.666)	(-2.933)	(-1.201)	(0.485)	(0.542)		
NresP	-0.075***	-0.012	-0.274**	-0.038	0.077**	0.047		
	(-1.844)	(-1.038)	(-2.314)	(-0.894)	(2.467)	(1.404)		
$(\hat{K}-\hat{L})$	0.257*	0.318*	0.209**	0.305*	0.262*	0.310*	0.306*	0.299*
	(7.014)	(11.003)	(2.245)	(8.099)	(7.163)	(8.228)	(8.159)	(8.104)
$(\hat{Inf}-\hat{K})$	0.138*	0.020	0.226*	0.219*	0.137*	0.218*	0.224*	0.157*
	(5.127)	(0.874)	(3.963)	(6.552)	(5.120)	(6.527)	(6.683)	(5.679)
$(\hat{RD}-\hat{K})$	-0.007	-0.002	-0.017	-0.002	-0.007	-0.002	-0.004	-0.005
	(-1.232)	(-0.394)	(-1.261)	(-0.318)	(-1.114)	(-0.295)	(-0.543)	(-0.764)
$(\hat{RD}-\hat{K})_{-1}$	0.012***	0.002	0.018	0.014**	0.012**	0.014***	0.013***	0.011***
	(1.920)	(0.401)	(1.165)	(1.972)	(1.902)	(1.912)	(1.828)	(1.721)
$(\hat{RD}-\hat{K})_{-2}$	0.007	0.004	0.009	0.003	0.006	0.003	0.002	0.003
	(1.162)	(0.806)	(0.666)	(0.498)	(1.139)	(0.439)	(0.337)	(0.425)
Observations	1086	723	363	880	1086	880	880	1005
R^2	0.461	0.421 (f)	0.540	0.512	0.462	0.518	0.521	0.495
Adjusted R^2	0.394	0.355 (f)	0.408	0.449	0.396	0.449	0.451	0.427

Notes: T-ratios appear below the coefficients' estimates. *, ** and *** mean that the coefficient is significant at 1%, 5% and 10%, respectively. (a) G&T stands for a joint Group (country) and Time effect. (b) The F test determines the choice between the *Pooled* OLS Model and the FEM (c) The LM test determines the choice between the Pooled OLS Model and the REM. (d) The Hausman test determines the choice between the FEM and the REM. In the F, LM and Hausman tests we prefer the joint time and country effect model to models with only one of those effects whenever the G&T test statistics are significant; (e) To avoid values close to zero, ratios with *L* were multiplied by 10^3 and ratios with *K* by 10^9, expressing in all cases indices of export abundance *per* unit of factor; (f) From the FEM G&T; estimations obtained with Limdep 8.0 software.

In regression 1, we exclude our *IQ* 'policies' variable and focus on the impact of unadjusted resource proxies on overall factor efficiency and growth as they are left undivided by *L* and *K* to better compare the results with previous resource-curse studies. Leaving *NresD* and *NresP* undivided by labour and capital stocks in expression (9), the associated coefficients become, respectively, $(\delta_5+\delta_{10})$ and $(\delta_4+\delta_9)$, representing the effects on $\hat{w}$ and $\hat{Y}$. We observe a significant, at 10%, negative effect of both measures on growth. This is in line with cross-section curse results but not with Manzano and Rigobon (2006) panel study, which shows an insignificant natural-resource impact on growth allowing for fixed effects.[27]

When we consider the standard 'stable' institutional quality approach, using the Freedom House classification in 1975, we find that natural-resources impacts are not significant at 10% in countries rated as Free, our proxy for good quality of institutions (see regression 2). The unadjusted resource measures hinder growth only in countries with low institutional quality (regression 3), but the negative impact is not confined to concentrated resources in our case, unlike recent cross-section curse explanations based on institutions.

We then introduced our instrumented *IQ* 'policies' variable in the sample of low institutional quality countries, and found that resource proxies no longer have a significant effect.[28] This also happens when we consider the whole sample (regression 4), suggesting that adequate past and present fiscal policy (in countries with low 'stable' institutional quality), significant at 10%, can prevent a negative impact of natural resources on growth. Thus, it seems that the more flexible time variant *IQ* 'policies' approach dismisses the cross-section curse explanation based on 'stable' institutions hindered by concentrated resources.

However, the conclusions change when we use our preferred adjusted resource proxies (net export dependency ratios). In this case, we find a positive impact of concentrated resources (significant at 5%) when we leave out the *IQ* variable (regression 5). Diffuse resources are not significant. Including *IQ*, the concentrated-resource variable is only significant for a p-value of 16% (regression 6), probably because good fiscal policies save part of the associated rents, reducing the significance of the concentrated-resource impact.

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[27] However, Manzano and Rigobon (2006) consider a different time frame (two and four panels from 1970 to 1989) and a different natural-resource measure (the ratio of primary exports to GDP).

[28] In this case, however, the *IQ* estimate is not significant at 10% in a REM estimation, maybe due to a decreased number of observations, 280. We don't present these results, but they can be made available upon request.

Nevertheless, in regression 7 we disaggregate the impacts of the adjusted resource proxies between factor efficiencies considering the *IQ* variable, and show that concentrated resources have a positive effect (significant at 5%) on growth through capital efficiency, while the other resource impacts are insignificant at 10%. This result is in line with the positive impact found by studies that use more direct product or reserves measures, such as the mining share in GDP, one of the robust growth regressors in Sala-i-Martin *et al*. (2004). The positive impact by capital efficiency may reflect capital and technological intensity owing to the exploitation of those resources, in addition to economies of scale, since the geographic concentration allows the dilution of high fixed costs.

We thus reject the thesis of a resource curse even if the aggregate average effect of resource variables is negative, as it results from the sum of non-significant components. We stress the average positive contribution of concentrated resources to growth by *g* (1.6 p.p.).

In relation the other growth factors in regression 7,[29] the effects of *I* and *T* to growth are close and smaller than the estimate for *Inf*. The positive effect of *RD* (significant at 10%) occurs with a one year lag and is much smaller than expected compared to *I*, *T* and *Inf* (significant at 1%, 5% and 1%, respectively) probably due to the limitations of our proxy.[30] The estimate for instrumented *IQ* is positive but only significant at 10.3%. Capital elasticity is 30.6% (significant at 1%), below the usual one third estimate considering *K* income share.

These conclusions are similar in regression 8, where we use the original *IQ* variable (significant, in this case, at 5%) mainly to extend the estimation period and the growth decompositions for Norway and Venezuela – Figures 2 and 3 below. Both these countries are

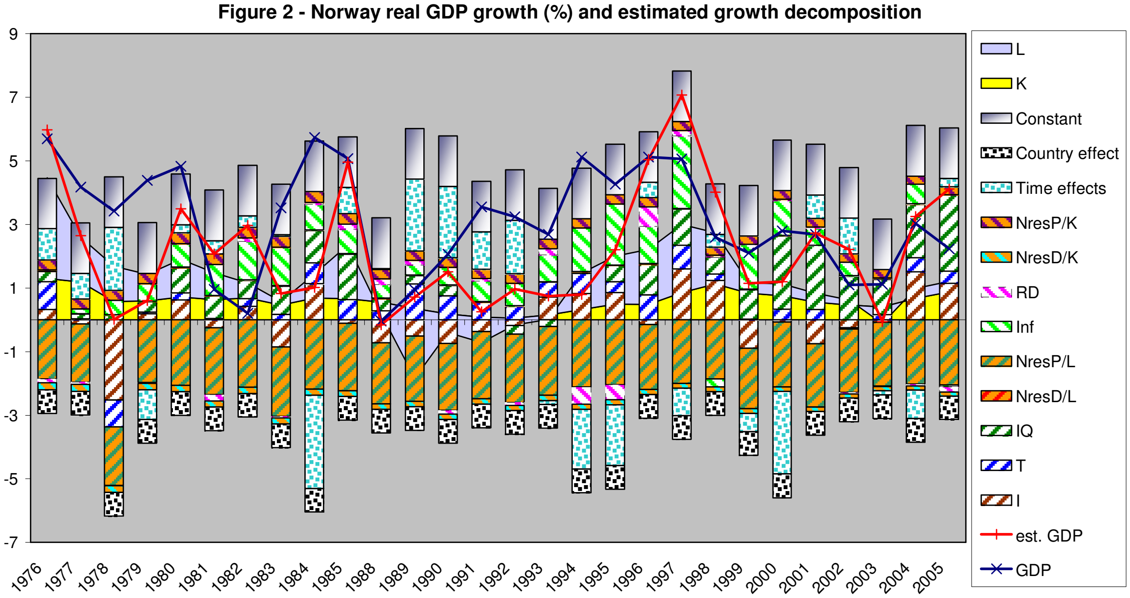
[29] Considering R^2 as a measure of fit to our final estimation, the explanatory variables, with fixed country and time effects, capture 52.1% of the variation in $\hat{w}$ (the adjusted R^2 is slightly lower, close to 45%).

[30] The introduction of time lags only produced interesting results in the R&D variable, hence they are not considered in other variables (in Table 2), except for the instrumentation of *IQ*.

rich in oil but presented quite different economic performances from 1975 to 2005 (average real *GDPpc* log growth rates of 2.6% and -0.6%, respectively). We highlight the close connection between estimated and actual growth over the period in both cases. As for the estimated country effects, they were only significant at 10% for Venezuela.

Figure 2 depicts the decomposition for Norway from 1976 to 2004. Moreover the positive contribution of *L* and *K*, we stress the favourable effects of *IQ* and *T* by way of *f* and also of *Inf* and *NresP* by way of *g*. *NresP* hinders *f*, but this impact is not significant.

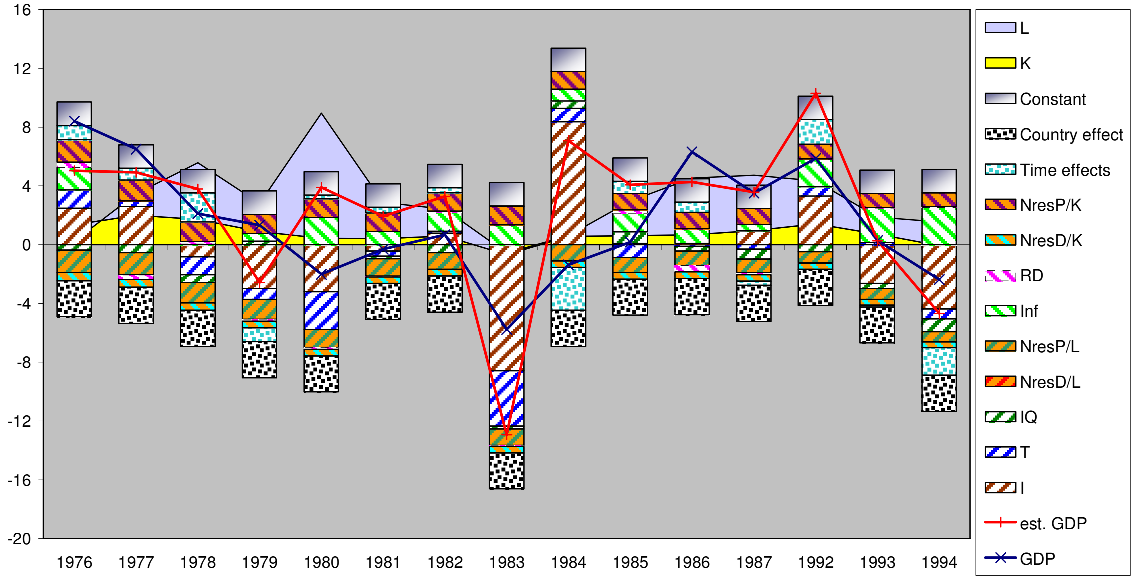
Figure 2 - Norway real GDP growth (%) and estimated growth decomposition



Notes: the lines represent real GDP growth, actual and estimated values; the ones with shaded areas below stand for the physical impacts of labour and capital stocks to estimated GDP growth in each year; the columns constitute the TFP impact disaggregated between the several items; here, the rectangles with dots are the fixed country and time effects which, along with the blue-grey area (the constant term of the wage equation), constitute the share of GDP growth not accountable by the explanatory variables; the rectangles associated with labour efficiency are illustrated with ascending lines, while the ones related to capital efficiency have descending lines; the impacts of natural resources by labour and capital efficiency are highlighted by an orange background.

In Figure 3, we show the decomposition for Venezuela in the estimated period of 1976-1994. In this case, the most positive effect to Venezuela's growth comes from *L*, followed by *K*, and the effect of *Inf* and *NresP* through *g*. In addition, we find negative effects of *NresP* by way of *f* and also of *NresD* through *g*, but they are non-significant. Moreover, *T*, *I* and *IQ* hinder growth through *f* in several years. The negative fixed-country effect also penalises growth.

Figure 3 - Venezuela real GDP growth (%) and estimated growth decomposition



IV. Concluding remarks

In this study we re-evaluate the impact of natural resources on economic growth. Since physical restrictions related to natural resources are not decisive to growth (except, perhaps, in the case of climate change, which is not considered in this paper), we focused on its negative correlation with resource abundance found in cross-section studies, a result that was named the 'resource curse'. Several theories have been presented to justify this surprising result, but only a recent one was sustained by empirical cross-section studies, explaining the curse by the negative effect of geographically-concentrated resources on institutional quality, which benefits growth. Despite this consensus view, other studies, which explore the impact of more direct measures of production or reserves, find positive impacts of concentrated resources. In addition, a recent panel study by Manzano and Rigobon (2006) dismissed the curse by allowing for unobserved fixed effects, implying that the estimates of the traditional cross-section regressions may be inconsistent. However, their institutional quality proxy could not allow for fixed-effects estimation, and its impact could not be adequately evaluated.

Bearing in mind these results, we developed a growth accounting framework to estimate the contribution of concentrated and diffuse natural resources in a panel-data analysis (which allows an increased estimation efficiency and the control of unobserved effects), along with the main growth determinants, through their impact on labour and capital efficiency. We estimated the growth of unobserved levels of efficiency (which constitutes the Solow residual) using the duality qualities/prices of production factors. Unlike most cross-section studies and also Manzano and Rigobon (2006) panel analysis, we also measured institutional quality over time to allow its estimation in a fixed-effects model. We considered the interpretation of institutions as a reflection of policies, which we evaluate through fiscal policy (measured by the budget balance). This proxy for institutional quality 'policies' was instrumented with its own lags to avoid endogeneity problems in our analysis, and also to reflect the impact of past and present fiscal policies.

Our results show that the resource curse thesis is dismissed: we find a positive effect on capital efficiency arising from our proxy of geographically-concentrated natural resources (adjusted for re-exportation), exactly the resources that cause the curse in recent cross-section studies, by hindering institutional quality. This consensus view does not hold in our case even when we use unadjusted resource measures and the standard 'stable' institutional approach to compare with previous studies, as both concentrated and diffuse resources show negative effects in countries with low institutional quality. Adequate past and present fiscal policy (in countries with low 'stable' institutional quality), seems to prevent the curse in that case, but reduces the positive effect of concentrated resources found with our preferred adjusted proxies (net export dependency ratios). This positive effect is in line with studies using more direct measures of production or reserves, such as the mining share in GDP, confirmed as a robust growth regressor by Sala-i-Martin *et al*. (2004). The positive impact by capital efficiency may reflect capital and technological intensity owing to the exploitation of those resources, in addition to economies of scale, since the geographic concentration allows the dilution of high fixed costs.

In the final fixed effects estimation, the product elasticity in relation to capital has a value slightly below the reference level of one third. The impacts of investment and trade to growth are close and smaller than the estimate for infrastructures. All these coefficients have a significance level of 1% or 5%, whereas institutional quality is only significant at 10.3%. The positive impact of R&D only occurs with a one year lag (with a significance level of 10%) and is much smaller than anticipated due to the limitations of the available proxy.

Finally, using similar results of the regression with the uninstrumented institutional quality variable (to extend our estimation period), we decomposed the estimated economic growth for Venezuela and Norway, two countries rich in oil but with contrasting performances from 1975 to 2005. From the two decompositions we conclude that oil benefits growth through capital efficiency but this does not prove decisive. Venezuela has a higher impact of concentrated resources, but, contrary to Norway, presents negative contributions from important growth factors such as trade, investment and institutional quality across several years, which justify the lower rates of economic growth.

Appendix I – Data treatment and sources

Variable	Name	Measure	Source	Comments
Y	Output	GDP at constant prices	U.Nations (National Accounts Database)	
L	Labour	Employment	ILO (yearly and periodical data) OECD (Statistics Database) World Bank (World Development Indicators 2007) IMF (IFS) UN (UNECE and Statistics Division – Common Database)	The series was extended using growth rates of employment, thus reducing problems of compatibility between sources.
K	Capital Stock		Authors own calculations with *I* and *Y*	Estimated by the Permanent Inventory method[31]
I	Investment	Gross capital formation (constant prices)	U.Nations (National Accounts Database)	
T	Trade	Exports + Imports (constant prices)	U.Nations (National Accounts Database)	
IQ	Institutional Quality	Budget balance in percentage of GDP	U.Nations (National Accounts Database) OECD (Statistics Database) World Bank (World Development Indicators 2007) IMF (IFS)	We used compatible data on budget balance in percentage of GDP from different sources to extend the series.
NresP	Concentrated natural-	Weight of fuels, ores and metals in	World Bank (World Development Indicators 2007)	

[31] The initial capital was obtained following the standard procedure by Harberger (1978). Since 1970 was the first year with available information for *I*, we calculated $K70 = \frac{I70}{r+d}$, in which *K70* is the initial capital in 1970, *I70* represents the investment in that year (at constant prices), *r* is the average annual growth rate of GDP between 1970 and 1980 and *d* is the depreciation rate (we assumed a value of 6%, as in Hall and Jones, 1999). Ideally, we should use investment data prior to 1970 (since 1960, for example) to calculate the initial capital in that year, allowing for a lower instability of capital estimates in the first years (this constitutes a drawback of either of these methods), but that was not possible. However, our panel estimations only begin in 1976, so this shouldn't be a major drawback. The value of capital for the remaining years was calculated using the equation of capital dynamics in the Solow-Swan Model: $K(t) = [1-d]K(t-1) + I(t)$.

	resource abundance (resource points)	merchandise exports (unadjusted for re-exportation) net of its proportion in imports (adjusted measure)		
NresD	Diffuse natural-resource abundance	Weight of agricultural raw materials and food products in merchandise exports (unadjusted for re-exportation) net of its proportion in imports (adjusted measure)	World Bank (World Development Indicators 2007)	
$\hat{w}$	Real wage per worker growth	Labour compensation variation (National Accounts approach) minus variations in GDP deflator and *L*	Sources for labour compensation: UN (Common Database) OECD (Statistics Database) World Bank (World Development Indicators 2007) Source for product deflator: UN (Common Database)	Only compatible labour compensation series were used.
RD [32]	R&D	number of patent applications to national patent offices	WIPO	Includes international applications under PCT (resident and non-resident); excludes applications to regional patent offices.
Inf	Infra-structures	number of telephone lines and subscriptions for mobile telephone services	UN (Common Database) World Bank (World Development Indicators 2007)	Data is compatible between sources.
GDPpc	Income	GDP *per capita*	UN (National Accounts Database)	

[32] This proxy was chosen due to data availability for a high number of countries and years. A single international patent application has the same effect as national applications filed in each designated Contracting State of the PCT. Unfortunately, patent applications to regional patent offices, which concede protection in the area, are not reflected in our data. The chosen proxy measures the effect of applied domestic and foreign R&D on internal capital efficiency since it includes patent applications from both residents and non-residents, which means that multiple counting is not a problem. According to the WIPO, although patent applications assess R&D activity, three major reflections must be considered: not all inventions are patented; the place and time of filing a patent application may not correspond to the place and time of the inventive activity; the number of patent applications may vary across countries due to differences in patent systems.

Appendix II – Estimated countries and years

	Country	Year		
		$t = t_0$	$t = T$	Number
1	Algeria	1994	2002	9
2	Armenia	2003	2004	2
3	Australia	1976	2005	30
4	Austria	1976	2005	29
5	Belarus	1998	2003	6
6	Belgium	1976	2003	28
7	Brazil	1993	1998	3
8	Bulgaria	1996	2004	9
9	Canada	1976	2003	28
10	Chile	1976	2004	26
11	Colombia	1976	2002	14
12	Costa Rica	1977	1990	9
13	Croatia	1997	2004	8
14	Czech Republic	1996	2005	10
15	Denmark	1976	2005	30
16	Ecuador	1989	1994	2
17	Egypt	1978	2003	9
18	Estonia	1998	2004	7
19	Finland	1976	2005	30
20	France	1978	2004	27
21	Georgia	1998	2004	7
22	Germany	1976	2005	30
23	Greece	1988	2004	17
24	Guatemala	1991	1995	5
25	Hungary	1993	2004	12

	Country	Year		
		$t = t_0$	$t = T$	Number
41	Luxembourg	1999	2003	5
42	Macedonia	1996	2004	3
43	Malaysia	1991	1995	5
44	Malta	1976	2002	23
45	Mauritius	1990	1998	9
46	Mexico	1992	2004	13
47	Moldova	1996	2004	8
48	Mongolia	1996	2004	4
49	Morocco	1991	1991	1
50	Netherlands	1976	2005	28
51	New Zealand	1987	2004	17
52	Nicaragua	2000	2000	1
53	Norway	1976	2005	28
54	Panama	1992	1996	5
55	Peru	1993	2004	4
56	Philippines	1999	2000	2
57	Poland	1984	2005	17
58	Portugal	1979	2003	24
59	Romania	1998	2005	7
60	Russian Federation	1996	2004	8
61	Saudi Arabia	2000	2000	1
62	Singapore	1998	2004	5
63	Slovak Republic	1996	2005	10
64	Slovenia	1995	2005	11
65	South Africa	1976	2004	14

26	Iceland	1992	2005	14	66	Spain	1990	2005	16
27	India	1995	1998	4	67	Sri Lanka	1991	1994	4
28	Indonesia	2004	2004	1	68	Sweden	1976	2000	25
29	Iran	2001	2001	1	69	Switzerland	1976	2002	26
30	Ireland	1976	2005	29	70	Tajikistan	2000	2000	1
31	Israel	1991	2004	12	71	Thailand	1982	2004	19
32	Italy	1980	1985	6	72	Trinidad and Tobago	1978	2004	8
33	Jamaica	1976	1979	4	73	Tunisia	2000	2004	5
34	Japan	1976	2004	28	74	Turkey	1989	2003	14
35	Kazakhstan	1995	2001	7	75	Ukraine	1999	2004	5
36	Kenya	1986	1999	4	76	United Kingdom	1976	2005	30
37	Korea, Rep.	1976	2004	23	77	United States	1976	2004	25
38	Kyrgyz Republic	1998	2003	6	78	Uruguay	1994	2000	7
39	Latvia	1995	2004	10	79	Venezuela	1976	1994	15
40	Lithuania	1994	2004	11	80	Zimbabwe	1986	1993	5

Data based on authors own estimations.

Notes: $t = t_0$ and $t = T$ indicate the initial and final years, respectively; and Number represents the total number of estimated years.

References

Acemoglu, D., 1995. Reward Structures and the Allocation of Talent. *European Economic Review* 39(1), 17-33.

Acemoglu, D., Robinson, J.A., 2006. Economic backwardness in political perspective. *American Political Science Review* 100(1), 115-131.

Acemoglu, D., Johnson, S., Robinson, D., 2005. Institutions as the fundamental cause of long-run growth. In: Aghion, P., Durlauf, S. (Eds.), *Handbook of Economic Growth*, vol. 1A. Elsevier, London, chap. 6.

Aghion, P., Howitt, P., 1992. A Model of Growth through Creative Destruction. *Econometrica* 60(2), 323-351.

Argimón, I., Gonzalez-Paramo, J.M., Roldan, J.M., 1997. Evidence of public spending crowding-out from a panel of OECD countries. *Applied Economics* 29(8), 1001-1010.

Atkinson, G., Hamilton, K., 2003. Savings, growth and the resource curse hypothesis. *World Development* 31(11), 1793–1807.

Auty, R.M., 2001a. *Resource Abundance and Economic Development*. Oxford University Press, Oxford.

Auty, R.M., 2001b. The Political Economy of Resource-driven Growth. *European Economic Review* 45(4), 839-846.

Baland J.M. and Francois, P., 2000. Rent Seeking and Resource Booms. *Journal of Development Economics* 61(2), 527-42.

Barro, R. J., 1991. Economic growth in a cross-section of countries. *Quarterly Journal of Economics* 106(2), 407-443.

Barro, R., 1999. Notes on growth accounting. *Journal of Economic Growth* 4(2), 119-137.

Barro, R. J., Sala-i-Martin, X., 2004. *Economic Growth*. McGrawHill.

Benhabib, J., Spiegel, M., 1994. The role of human capital in economic development: evidence from aggregate cross-country data. *Journal of Monetary Economics* 34(2), 143-173.

Boschini, A., Petersson, J., Roine, J., 2007. Resource curse or not: a question of appropriability. *Scandinavian Journal of Economics* 109(3), 593-617.

Bravo-Ortega, C., Gregorio, J., 2007. The relative richness of the poor? Natural resources, human capital and economic growth. In: Lederman, D., Maloney, W. (Eds.), *Resources, Neither Curse nor Destiny*. Stanford University Press, Washington, DC, Chapter 4, pp. 71-99.

Brunnschweiler, C., Bulte, E., 2008. The resource curse revisited and revised: a tale of paradoxes and red herrings. *Journal of Environmental Economics and Management* 55(3), 248-264.

Bulte, E., Damania, R., Deacon, T., 2005. Resource Intensity, Institutions, and Development. *World Development* 33(7), 1029–44.

Burnside, C. and Dollar, D., 2000. Aid, policies, and growth. American Economic Review}, 90(4), 847-68.

Coe, D.T., Helpman, E., 1995. International R&D spillovers. *European Economic Review* 39(5), 859-897.

Coe, David T., Helpman, E., Hoffmaister, A., 1997. North-South R&D spillovers. *The Economic Journal* 107(440), 134-149.

Davis, G., 1995. Learning to love the Dutch disease: evidence from the mineral economies. *World Development* 23(10), 1765-79.

Dawe, D., 1996. A new look at the growth in developing countries. *World Development* 24(12), 1905-1914.

Dodrik, D., Subramanian, F., Trebbi, F., 2004. Institutions rule : the primacy of institutions over geography and integration in economic development. *Journal of Economic Growth* 9(2), 131-65.

Easterly, W., Rebelo, S., 1993. Fiscal policy and economic growth : an empirical investigation. *Journal of Monetary Economics* 32(3), 485-512.

Englander, A., Gurney, A., 1994. La productivité dans la zone de L'OCDE: les déterminants a moyen terme. *Revue économique de l'OCDE* 22, Printemps, 53-119.

Fosu, A., 1996. Primary exports and economic growth in developing countries. *World Economy* 19(4), 465–475.

Frankel, J.A., Romer, D., 1999. Does trade cause growth? *American Economic Review* 89(3), 379-399.

Gylfason, T., 2001a. Natural resources and economic growth; what is the connection. *CESifo working paper* 50.

Gylfason, T., 2001b. Natural Resources, Education and Economic Development. *European Economic Review* 45(4), 847-859.

Hall, Robert E., Jones, Charles I., 1999. Why do Some Countries Produce so Much More Output per Worker Than Others? *Quarterly Journal of Economics* 114(1), 83-116.

Harberger, A.C., 1978. Perspectives on capital and technology in less developed countries. In: Artis, M.J., Nobay, R.A. (Eds.), *Contemporary economic analysis*. Croom Helm, London.

Hartford, T., Klein, M., 2005. Aid and the resource Curse. The world Bank Group, private Sector Development Presidency, Note #291. Washington, DC.

Hirschman, A., 1958. *The strategy of economic development*. Yale University Press, New Haven.

Isham, J., Woodcock, M., Pritchett, L., Busby, G., 2005. The Varieties of Resource Experience: Natural Resource Export Structures and the Political Economy of Economic Growth. *The World Bank Economic Review* 19(2), 141-74.

Lederman, D., Maloney, W., 2008. In Search of the Missing Resource Curse. *World Bank Policy Research paper 4766*. World Bank, Washington DC.

Leite, C., Weidmann, J., 2002. Does mother nature corrupt? Natural resources, corruption and economic growth. In: Abed, G., Gupta S. (Eds.), *Governance, corruption, and economic performance*. International Monetary Fund, Washington DC, pp. 156–169.

Lewer, J.J., van den Berg, H., 2003. How large is international trade's effect on economic growth? *Journal of Economic Surveys* 17(3), 363-396.

Lucas, R.E., 1988. On the mechanics of economic development. *Journal of Monetary Economics* 22(1), 3-42.

Manzano, O., Rigobon, R., 2006. Resource curse or debt overhang? In: Lederman, D., Maloney, W. (Eds.), *Resources, Neither Curse nor Destiny*. Stanford University Press, Washington, DC, Chapter 4, pp. 71-99.

Mauro, P., 1995. Corruption and Growth. *Quarterly Journal of Economics* 90, 681-712.

Mehlum, H., Moene, K., Torvik, R., 2006. Institutions and the resource curse. *The Economic Journal* 116(508), 1-20.

Meier, Gerald M., Rauch, James E., 2000. *Leading Issues in Economic Development*. Oxford University Press, Oxford.

Mincer, J., 1993. *Studies in human capital: collected essays of Jacob Mincer*. Edward Elgar, Cambridge.

Neary, P., van Wijnberger, S., 1986. *Natural Resources and the Macroeconomy*. Cambridge University Press, Cambridge.

Nordhaus, W.D., 1992. Lethal Model 2: The Limits to Growth Revisited. *Brookings Papers on Economic Activity* 2(1), 1-43.

Nunn, N., 2008. The long-run effects of Africa´s Slave Trades. *The Quarterly Journal of Economics* 123(1), 139-76.

Owens, T., Wood, A., 1997. Export-oriented industrialization through primary processing? *World Development* 25(9), 1453-70.

Park, H;M, 2005. Linear Regression Models for Panel Data Using SAS, STATA, LIMDEP, and SPSS. *2005-2008 The Trustees of Indiana University* (4/13/2008). Available at www.indiana.edu/~statmath/stat/all/**panel/panel**.pdf .

Prebisch, R., 1950. *The economic development of Latin America and its principal problems*. United Nations, New York.

Roller, L.W., Waverman, L., 2001. Telecommunications Infrastructure and Economic Development: A Simultaneous Approach. *American Economic Review* 91(4), 909-923.

Romer, P.M., 1987. Growth Based on Increasing Returns Due to Specialization. *American Economic Review* 77(2), 56-62.

Romer, P.M., 1990. Endogenous technological change. *Journal of Political Economy* 98(5), S71-S102.

Romer, D., 2005. *Advanced Macroeconomics* 3rd ed.. McGraw-Hill.

Ross, M. L., 2001. Does oil hinder democracy? *World Politics* 53(3), 325–361.

Sachs, J.D, Warner, A.M., 1995. Natural Resource Abundance and Economic Growth. *NBER Working Paper Series 5398*, Cambridge.

Sachs, J.D., Warner, A.M., 1999. The Big Push, Natural Resource Booms and Growth. *Journal of Development Economics* 59(1), 43-76.

Sachs, J.D, Warner, A.M., 2001. The Curse of Natural Resources. *European Economic Review* 45(4), 827-838.

Sala-i-Martin, X., 2000. The Classical Approach to Convergence Analysis. In: Dixon, H.D. (Ed.), *Controversies in Macroeconomics: Growth, Trade and Policy*. Blackwell, Oxford.

Sala-i-Martin, X., Doppelhofer, G. , Miller, R, 2004. Determinants of long-term growth: a Bayesian averaging of classical estimates (BACE) approach. *American Economic Review* 94(4), 813-35.

Sala-i-Martin, X., Subramanian, A., 2003. Addressing the Natural Resource Curse: An Illustration from Nigeria. *NBER Working Paper Series 9804*, Cambridge.

Stein, E., Tommasi, M., Echebarría, K, Lora, E, Payne, M., eds., 2005. *The Politics of Policies: Economic and Social Progress in Latin America*. IDB, Washington DC.

Stern, N.H., Treasury, G. Britain, 2006. *Stern Review on the Economics of Climate Change*. G.B.Treasury.

Stijns, J., 2005. Natural resource abundance and economic growth revisited. *Resources policy* 30(2), 107-30.

Torvik, R., 2002. Natural Resources Rent Seeking and Welfare. *Journal of Development Economics* 67(2), 455-70.

Wooldridge, J. M., 2002. *Econometric Analysis of Cross Section and Panel Data*. MIT Press, Cambridge, MA

World Bank, 1992. Overview: Development and the Environment. *World Development Report 1992*. Oxford University Press, New York, pp.1-5.

Wright, G., 2001. Resource-based Growth Then and Now, prepared for the World Bank Project "Patterns of Integration in the Global economy", Stanford University.

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