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Research Work in Progress

n. 278, June 2008

Re-evaluating the impact of natural resources on economic growth

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FEP FACULDADE DE ECONOMIA UNIVERSIDADE DO PORTO

Re-evaluating the impact of natural resources on economic growth

Nuno Torres*[*] and Oscar Afonso[†]

Abstract

In this study we re-evaluate the impact of natural resources on economic growth. The reassessment is based on a growth model where, using panel-data analysis, natural-resource variables (geographically diffused and concentrated) affect the efficiency gains of labour and capital in production. We find an overall positive effect on growth arising from the increase in capital efficiency associated with concentrated resources, exactly the kind of resources that explain the resource curse in recent cross-section studies. We detect a negative effect of concentrated resources on labour efficiency only when either the resource proxies are unadjusted for re-export distortion (even with a fixed institutional quality, contrary to cross-section studies), or both the fixed country and time effects are not considered after the referred adjustment. Our results also dismiss a negative effect of the adjusted diffuse resources measure on capital efficiency if we assume a constant institutional quality, and fixed country and time effects.

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

JEL classification: C23, O13, O47, O50

June 2008

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CEMPRE is supported by the Fundação para a Ciência e a Tecnologia, Portugal.

1. Introduction

In this paper we reassess the impact of natural resources on economic growth. In the recent literature, physical limits to growth caused by natural-resource scarcity or excessive pollution have not been considered relevant (Nordhaus, 1992; Meier and Rauch, 2000; Romer, 2005). This occurs because 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.

In a series of cross-section studies initiated by Sachs and Warner (1995), the countries' natural-resource abundance has been associated with lower economic growth, an unexpected result that has become known as the "resource curse". Several explanations have been presented, but only a recent one has been sustained by the empirical research, stressing the value of institutional quality (*e.g.*, Isham *et al.*, 2003; Sala-i-Martin and Subramanian, 2003).

The first explanations were based on the structuralist theses of the 1950s, focusing on the decline in the terms of exchange between primary and manufactured products (Prebisch, 1950), the volatility of primary product prices, or the limited linkages between the natural-resource sector and the rest of the economy (Hirschman, 1958). However, none of these explanations was unequivocally confirmed by empirical tests (*e.g.*, Moran, 1983; Behrman, 1987; Cuddington, 1992; Lutz, 1994; Dawe, 1996; Fosu, 1996).

In the Dutch Disease thesis, natural resource booms hinder the industrial sector, assumed as the main driving force of the economy, either through real exchange rate appreciation or the absorption of production factors (Neary and van Wijnbergen, 1986). Thus, the expansion of the natural-resource sector is not enough to offset the negative effect of deindustrialisation on growth. In addition, there is a change in the composition of exports in favour of raw materials, or even a drop in total exports, thus reducing economic growth

(Gylfason, 2001a). The empirical evidence did not provide great support for the Dutch Disease as an explanation of the resource curse (*e.g.*, Sachs and Warner, 1995 and 1999; Leite and Weidmann, 2002; Sala-i-Martin and Subramanian, 2003). 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 resource curse.

Other explanations for the resource curse, often presented autonomously, can also be partly considered as symptoms of the Dutch Disease, which is not supported by empirical studies as we have seen. These arguments include the disincentive for entrepreneurship (Sachs and Warner, 2001), the decrease in savings and physical investment (Gylfason, 2001b) and lower investment in education and human capital (Gylfason, 2001a).

Another thesis stresses the negative effect on growth caused by rent-seeking activities associated with natural-resource abundance (*e.g.*, Torvik, 2002). Since 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 the results change according to different initial conditions (*e.g.*, Acemoglu, 1995; Baland and François, 2000).

Mehlum *et al.* (2006) conclude that the presence of better institutions can avoid the resource curse, but they identify some limitations in their empirical analysis, namely the possibility that natural resources might influence institutional quality. That possibility is recognised by the recent explanations based on endogenous institutions. Here, the kind of natural resource influences the institutional context, where the form of government and the quality of the policies are the most important aspects (Knight *et al.*, 1996; Auty, 2001a, b; Ross, 2001; Atkinson and Hamilton, 2003; Bulte *et al.*, 2005).

The importance of institutions and policies in growth is supported by a vast number of empirical studies (*e.g.*, Acemoglu and Robinson, 2006; Acemoglu *et al.*, 2006). 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 negatively affects growth (*e.g.*, Mauro, 1995).

This result was confirmed by Isham *et al.* (2003) 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, the natural-resource abundance has no direct impact on growth. Rather, this abundance penalises growth indirectly, through institutional quality, but only when resources are geographically concentrated, such as oil.[3] That is, these recent studies explain the resource curse through the negative effect of geographically concentrated resources on the quality of institutions.

The empirical studies on the resource curse are cross-section analyses, where countries' economic growth in a single extended period is regressed to a series of explicative variables, including natural resources, usually outside the framework of a formal growth model. In this study, we broaden the scope of the literature by assessing the premise of a resource curse in a panel-data analysis of a growth accounting model, where natural resources (geographically diffused and concentrated) affect the efficiency gains of labour and capital in production.

In growth accounting terminology, we attempt to "explain" the Solow residual in terms of improvements to the efficiency of inputs, which, in turn, are "explained" by a set of variables also related to natural resources. That is, we measure the contribution of natural resources to economic growth through the estimation of the associated efficiency gains of labour and capital, along with the most important growth determinants. In order to estimate the unobserved levels of efficiency, we use the duality qualities/prices of production factors, which is also an important growth accounting result, as recently 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

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

on the chosen growth determinants in two hundred and eight countries from 1970 to 2005). And through the developed model, we are able to control the presence of unobserved country and time effects, which, if not considered, lead to inconsistent estimates. Finally, taking into account institutional quality as a cause of labour efficiency we can show whether the recent explanation of the resource curse in cross-section studies is still relevant in a panel-data case.

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 the type of natural resources and institutional quality are relevant to that assessment, as in recent cross-section studies; (iii) the relative importance of the chosen growth determinants.

The paper proceeds as follows. In section 2, we deduce an estimated growth model, where: (i) labour and capital efficiency are determined by several variables, including natural resources and institutional quality; (ii) the first order condition for maximising profit in relation to labour is used to evaluate the contribution of the variables to real wage growth *per* worker and thus to productivity growth; (iii) the cross-section dimension is added to formalise the final panel model specification of the wage equation, which we differentiate according to the estimation procedures; and (iv) the wage equation is also used to test conditional convergence. In section 3, we present and discuss the estimation results, including the growth decomposition for eight representative countries in terms of resource abundance and economic performance. In section 4, we summarise with some concluding remarks.

2. The effect of natural resources on economic growth

In this section, we develop a growth accounting framework with factor efficiency which, considering panel data for 208 countries between 1976 and 2005, is used to estimate the contribution of natural resources to economic growth. That is, given the evidence that natural-resource scarcity does not pose a crucial restriction on economic growth, the main concern is to assess the impact of the natural-resource abundance on growth. We also intend to observe whether the negative effect (resource curse) found in standard cross-section empirical studies, through regressions of conditional convergence, is confirmed, and to evaluate the hypothesis that institutional quality may explain the resource curse, as suggested by recent literature.

In subsections 2.1 and 2.2, we build the model and make a selective review of literature (namely empirical) supporting the variables. The model is first derived for a single country (subsection 2.1) and then extended to the final panel estimation forms (subsection 2.2).

2.1 Growth accounting model with factor efficiency

Let us consider the following neoclassical production function with constant returns to scale (Cobb-Douglas production function), at each time *t*:

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

(i) Y is the real aggregate output, measured by GDP at constant prices;[4] (ii) L is the labour level, measured by total employment;[5] (iii) K is the aggregate capital stock at constant 1990 dollars, calculated by the 'permanent inventory method' from gross capital formation data;[6] (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).

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

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

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

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[4] Data from the United Nations (National Accounts Database).

[5] The labour series was calculated using information from several sources: the International Labour Organization (yearly and periodical data), the OECD (Statistics Database), the World Bank (World Development Indicators 2007), the IMF (IFS) and the United Nations (UNECE and Statistics Division – Common Database).

[6] The source for gross capital formation data was the United Nations (National Accounts Database).

As the efficiency levels f and g are not observable, we consider that they are a function of (and thus instrumentable by) some variables, including natural resources. The assumption of constant returns to scale in labour and capital means that excluded factors are insignificant to growth. Since apparently the natural-resource scarcity does not place a direct restriction on growth (*e.g.*, Nordhaus, 1992; Romer, 2005), the omission as a productive factor is an adequate assumption. However, natural resources may affect labour and capital efficiency. Although this influence appears negative in a cross-country analysis (resource curse), the experience of several countries shows that these resources can be well managed (for instance, invested in human or physical capital) and thus positively affect growth.

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:

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

(i) F is a scale factor; (ii) I is the investment, assessed by gross capital formation at constant prices; (iii) T represents international trade, measured by the sum of exports and imports at constant prices in percentage of GDP (degree of economic openness); (iv) IQ is the institutional-quality variable, evaluated by the budget balance in percentage of GDP; (v) *NresP* conveys the geographically concentrated natural-resource abundance, assessed by the percentage of fuels, ores and metals in merchandise exports; (vi) *NresD* conveys the diffuse natural-resource abundance, assessed by the percentage of agricultural raw materials and food products in merchandise exports;[7] (vii) a_1 and a_2 are (constant) elasticities of labour efficiency in relation to $\frac{I}{L}$ and $\frac{T}{L}$; and (viii) a_3, a_4 and a_5 are (constant) semi-elasticities of

[7] As f refers to the efficiency of each worker, the variables were divided by the number of workers, except in the case of IQ, which already affects the efficiency of each worker.

labour efficiency in relation to IQ, $\frac{NresP}{L}$ and $\frac{NresD}{L}$, respectively. This set of variables is based on the previous studies (namely empirical) on the subject.

Next, we present a selective review of this evidence for each variable of (3) along with the reasons for the chosen proxies and the way they were introduced into the specification.

Investment, I: the contribution of investment to explain a substantial part of economic growth is stressed by several studies (*e.g.*, Englander and Gurney, 1994; Maddison, 1991; Levine and Renelt, 1992; Barro and Sala-i-Martin, 2004). To measure I we used gross capital formation at constant prices (1990 US dollars).[8]

Foreign trade, T: the weight of foreign trade in GDP or degree of openness measures the international-competition exposure, which affects the resource-allocation efficiency. The value of foreign trade for economic growth dates back to Adam Smith (1776) and has been stressed in several prominent theoretical and empirical studies (*e.g.*, Romer, 1990; Grossman and Helpman, 1991; Rivera-Bátiz and Romer, 1991; Englander and Gurney, 1994; Frankel and Romer, 1999; Wacziarg, 2001; Lewer and van den Berg, 2003). To evaluate T we use the ratio of total exports and imports to GDP (1990 US dollars).[9]

Institutional quality, IQ: the importance of institutions and policies on growth is supported by several empirical works (*e.g.*, Acemoglu and Robinson, 2006, Acemoglu *et al.*, 2006). For example, the effect of institutional quality on labour efficiency is analysed in Mauro's study (1995) on corruption, or in the rent seeking model of Mehlum *et al.* (2006). In this latter study, natural-resource booms redirect labour from productive to rent seeking activities, reducing labour efficiency. In cross-section studies of Isham *et al.* (2003) and Sala-i-Martin and Subramanian (2003), the institutional quality explains the resource curse.

[8] Data from the United Nations (National Accounts Database).

[9] Data from the United Nations (National Accounts Database).

In our case, the institutional-quality variable was captured by the government budget balance in percentage of GDP.[10] Thus, we consider that large budget deficits or their high variability may be signs of lower institutional quality as they show deficient macroeconomic government management – except the case when they are justified by the public investment effort, which is already reflected in the investment variable. This is in line with, for example, Wacziarg (2001), who showed the positive effect of macroeconomic stability on growth.

Natural-resource variables, *NresP* and *NresD*: Isham *et al.* (2003) and Sala-i-Martin and Subramanian (2003) consider that natural-resource abundance has an indirect adverse effect on growth, by institutional quality, when resources are geographically concentrated. Using *NresP* (abundance in geographically concentrated natural resources) and *NresD* (abundance in diffuse natural resources) we intend to verify whether there is any direct impact of natural resources on growth through the labour efficiency factor.

Variable *NresP* may not be significant or even have a positive effect if its eventual negative impact on growth has already been captured by *IQ*. The proxies used for *NresP* and *NresD* were, respectively, the weight of fuels, ores and metals in merchandise exports, and the weight of agricultural raw materials and food products in merchandise exports,[11] following previous studies such as Leite and Weidmann (2002).

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). This is a measure of the country's dependence on exports based on these resources, and as a flow, can only be considered an imperfect proxy of a country's real stock of natural resources (Bulte *et al.*, 2005). The weight of natural resources in exports can only be a strict measure of the natural-

[10] Data from the OECD (Statistics Database), IMF (IFS), United Nations (National Accounts Database) and World Bank (World Development Indicators 2007).

[11] Data from the World Bank (World Development Indicators 2007).

resource abundance if there is an invariable and consistent relationship between the stocks of resources and the annual exports of these stocks.

In addition, the weight of natural resources in exports (or in GDP) can be considered an imperfect measure of dependence on natural resources due to the possibility of their re-exportation, which is of importance in countries like Singapore. Sachs and Warner (1995) adjusted this effect using the natural-resource exports net of imports in this country, but it is clear that using the uncorrected measure for other countries will lead to overestimation of the true value of natural-resource exports. We used adjusted proxies for all countries (this was done by subtracting the weight of natural resources in merchandise imports and adding 100 to get an index) and confronted the results with those obtained using the unadjusted proxies.

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 analysis must be based on resource stock measures (see also Stijins, 2002). However, Gylfason (2001a) 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 countries' economic growth and the natural-resource abundance assessed by that indicator (cross-section analysis for 1994). Thus, it seems that, despite the limitations of the used proxies, the committed error should not be big enough to alter the conclusions significantly.

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

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

Since $\hat{f}$ is not observable, the first order condition for maximising profit in relation to labour is used to derive $\hat{f}$ as a function of the: (i) real wage growth *per* worker, *w*; (ii) labour stock, *L*; (iii) the capital stock, *K*; and (iv) capital efficiency, *g*, which, in turn, is influenced by a set of other variables, as is shown below. From the first-order condition for maximising profit in relation to the labour factor, $\frac{\partial Y(t)}{\partial L(t)} = w(t)$, we obtain:[12]

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

and, in terms of growth factors,

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

To some extent, wages reflect human-capital advances. Thus, the inclusion of wages through the use of the profit-maximising condition justifies the exclusion of human capital in determining *f* in (3) and thus in (4), as suggested by most of the theoretical 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), which is included below in the specification of *g*. The introduction of R&D and monopolistic competition in the growth theory began with Romer (1987, 1990) and included seminal contributions from Aghion and Howit (1992) and Grossman and Helpman (1991, chaps. 3 and 4). In these models, technological knowledge results from R&D activity as a means of obtaining some form of monopolistic power and, in some cases, human capital is included as an input (*e.g.*, Blackburn *et al.*, 2000).

Substituting $\hat{f}$, given by (4) into (6) we obtain:

$$\hat{w}(t) = \alpha \left[a_1\left(\hat{I}(t) - \hat{L}(t)\right) + a_2\left(\hat{T}(t) - \hat{L}(t)\right) + a_3 IQ(t) + a_4 \frac{NresP(t)}{L(t)} + a_5 \frac{NresD(t)}{L(t)} \right] + (1-\alpha)\left[\hat{K}(t) + \hat{g}(t) - \hat{L}(t) \right]. \qquad (7)$$

In (7) we still need to find $\hat{g}$, which conveys the growth of capital efficiency.

Specification for capital efficiency

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

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

$$g(t) = G\left(\frac{RD(t)}{K(t)}\right)^{b_1}\left(\frac{Inf(t)}{K(t)}\right)^{b_2} e^{\int\left(b_3\frac{NresP(t)}{K(t)}+b_4\frac{NresD(t)}{K(t)}\right)dt}, \text{ where:} \tag{8}$$

(i) G is a scale factor; (ii) RD stands for R&D, measured by the number of total patent applications; (iii) Inf is the variable infra-structures, assessed by the number of telephone lines and subscriptions for mobile telephone services; (iv) b_1 and b_2 are (constant) elasticities of capital efficiency 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 $\frac{NresD}{K}$, respectively.[13]

This set of variables is also based on several (namely empirical) studies on economic growth. Next, we present a selective review of these studies for each variable in (8).

Technological knowledge, *RD*: capital is more productive if it incorporates a higher technological-knowledge level or if it is used to create new products or processes, aspects related with R&D. Empirical evidence and theoretical models of the R&D growth mechanism have been revealed and analysed by several authors (*e.g.*, Griliches and Lichtenberg, 1984; Lichtenberg, 1993; Coe and Helpman, 1995; Barro and Sala-i-Martin, 2004, chps.6 and 7).

To measure the R&D variable, we used the number of patent applications to national patent offices due to the availability of data for a high number of countries and years (from 1970 to 2005).[14] The chosen proxy has the advantage of including patent applications from non-residents, which conveys an interest in protecting the inventions in a given country, meaning it will probably benefit from the invention. That is, we measure the effect of applied

[13] As g refers to the efficiency of each capital unit, variables were divided by K.

[14] Data from the World Intellectual Property Organization, WIPO. The international applications under Patent Cooperation Treaties (PCT) are also included, both in resident and non-resident applications. A single international patent application has the same effect as national applications filed in each designated Contracting State of the PCT. However, patent applications to regional patent offices (such as the European Patent Office), which concede protection in the area, are not reflected in our data.

domestic and foreign R&D on internal capital efficiency, since we are not only interested in measuring the domestic inventive effort – *i.e.*, 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;[15] 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.

Infrastructures, *inf*: it is known that capital is more productive when there are adequate infrastructures for economic activity and this is mainly important in less developed countries (*e.g.*, Gordon, 2006). Empirical studies seem to point globally to a positive effect of infrastructures on productivity (*e.g.*, Argimón *et al*., 1997); however, results rely on the methodology used and on the kind of infrastructures. In a seminal work, Aschauer (1989) found a crucial relationship between some infrastructures (roads and motorways, airports, public transport, water and sanitation systems, among others) and productivity, also associating the smaller productivity growth in the United States in the 1970s and 80s with the contemporary slowing of the infrastructure investment rate.

Ford and Poret (1991), for example, presented somewhat different results. In the case of the United States, and using data starting from the end of the 19th century, they only found a significant relation between infrastructures and productivity after the Second World War. Using data from twelve countries of the OECD since the 1960s,[16] the authors verified that only half of them recorded a significant effect of infrastructures on TFP, a result that also differs from the previously mentioned empirical study by Englander and Gurney (1994).

In our case, the proxy used for infrastructures is the number of telephone lines and subscriptions to mobile telephone services, due to the availability of data for a wide group of

[15] Firms may choose alternative property-protection methods, such as trade secrecy or marketing techniques.

[16] The USA, Japan, Germany, France, the UK, Canada, Australia, Belgium, Finland, Greece, Norway, Sweden.

countries and years and the evidence of the positive impact of telecommunications infrastructure on economic growth (*e.g.*, Roller and Waverman, 2001).[17]

Natural resource variables, *NresP* and *NresD*: here, these variables evaluate if there is any direct impact of natural resources on growth via capital efficiency, following the analysis in (3) and bearing in mind Isham *et al.* (2003) and Sala-i-Martin and Subramanian (2003).

Returning to (8), the growth rate of capital efficiency obtained is:

$$\hat{g}(t) = b_1\left(R\hat{D}(t) - \hat{K}(t)\right) + b_2\left(In\hat{f}(t) - \hat{K}(t)\right) + b_3\frac{NresP(t)}{K(t)} + b_4\frac{NresD(t)}{K(t)}. \tag{9}$$

Substituting $\hat{g}$ in (7), we have:

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

$\delta_j = \alpha\, a_j$ 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.

We found wage data for a wide range of countries and years using labour compensation variation (National Accounts approach) from several sources.[18] Real wage growth *per* worker was then obtained by subtracting the product deflator growth and labour growth.[19]

The OLS estimation of (10) allows us to obtain estimates of α (from δ_6), a_1 up to a_5 and b_1 up to b_4. Next, we substitute the values found in (4) and (9) to achieve estimates for $\hat{f}$ and $\hat{g}$ (note that the tilde symbol designates estimated values):

$$\tilde{\hat{f}}(t) = \tilde{a}_1\left[\hat{I}(t) - \hat{L}(t)\right] + \tilde{a}_2\left[\hat{T}(t) - \hat{L}(t)\right] + \tilde{a}_3 IQ(t) + \tilde{a}_4\frac{NresP(t)}{L(t)} + \tilde{a}_5\frac{NresD(t)}{L(t)}. \tag{11a}$$

[17] Data from the United Nations (Common Database) and the World Bank, World Development Indicators 2007.

[18] World Bank (World Development Indicators 2007), United Nations (Common Database) and OECD (Statistics Database).

[19] The source for the product deflator was the United Nations (National Accounts Database); in some countries, we extended the series a few years using wage data from the IMF (IFS), since we obtained growth rates close to the ones obtained from the National Accounts approach.

$$\tilde{g}(t) = \tilde{b}_1\left[R\hat{D}(t) - \hat{K}(t)\right] + \tilde{b}_2\left[In\hat{f}(t) - \hat{K}(t)\right] + \tilde{b}_3\frac{NresP(t)}{K(t)} + \tilde{b}_4\frac{NresD(t)}{K(t)}\cdot \qquad (11b)$$

Knowing $\tilde{\hat{f}}$ and $\tilde{\hat{g}}$, we can finally estimate real product growth from (2):

$$\tilde{\hat{Y}}(t) = \tilde{\alpha}\left[\hat{L}(t) + \tilde{\hat{f}}(t)\right] + \left(1-\tilde{\alpha}\right)\left[\hat{K}(t) + \tilde{\hat{g}}(t)\right]\cdot \qquad (12)$$

The estimate procedure followed to attain $\tilde{\hat{Y}}$ is thus the instrumental variables method. From (12) it is possible to estimate the growth in *TFP*, which is the part of the product increase in real terms not accountable by the physical growth of labour and capital factors.

$$T\tilde{\hat{F}}P(t) = \tilde{\hat{Y}}(t) - \left[\tilde{\alpha}\hat{L} + (1-\tilde{\alpha})\hat{K}\right] = \tilde{\alpha}\,\tilde{\hat{f}} + (1-\tilde{\alpha})\,\tilde{\hat{g}}\cdot \qquad (13)$$

Finally, from (11a), (11b) and (12) we can estimate the contribution to $\tilde{\hat{Y}}$ of $\hat{L}$, $\hat{K}$, and each explanatory variable of $\tilde{\hat{f}}$ and $\tilde{\hat{g}}$:

$$\begin{aligned}\tilde{\hat{Y}}(t) = \tilde{\alpha}&\left\{\hat{L}(t) + \tilde{a}_1\left[\hat{I}(t) - \hat{L}(t)\right] + \tilde{a}_2\left[\hat{T}(t) - \hat{L}(t)\right] + \tilde{a}_3 IQ(t) + \tilde{a}_4\frac{NresP(t)}{L(t)}\tilde{a}_5\frac{NresD(t)}{L(t)}\right\} \\ &+\left(1-\tilde{\alpha}\right)\left\{\hat{K}(t) + \tilde{b}_1\left[R\hat{D}(t) - \hat{K}(t)\right] + \tilde{b}_2\left[In\hat{f}(t) - \hat{K}(t)\right] + \tilde{b}_3\frac{NresP(t)}{K(t)} + \tilde{b}_4\frac{NresD(t)}{K(t)}\right\}\end{aligned}\cdot \qquad (14)$$

Subtracting $\hat{L}(t)$ from both sides of (14) we get an expression on labour productivity growth, which, as expected, is similar to (10). Indeed, the wage equation is derived from the first order condition for maximising profit and thus equates real wage to marginal labour productivity. Thus, the assessment of the resource curse is made directly in the wage equation (10) through the analysis of the sign, intensity and significance of the *NresP* and *NresD* coefficients as the estimates also represent the impact of those variables on economic growth.

2.2 Panel estimation model

With panel data we also have variability from country to country. Besides providing more information (higher degrees of freedom, allowing a reduction of co-linearity between the explicative variables and an increased estimation efficiency), panel data enables the inclusion of some effects not considered in either sectional or temporal data alone, also providing some control over the problem of unobserved individual heterogeneity (Wooldridge, 2002). This econometric problem refers to the omission of unobserved variables that are correlated with the explicative variables, leading to inconsistent estimates.

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. When the unobserved element is uncorrelated with the explanatory variables it is referred to as an "individual-random effect" and we use either the Random Effects Model (REM) or the pooled OLS model. The option depends on the variability of the unobserved effect, which can be tested with the Lagrange Multiplier Test, for example – Wooldridge, 2002. The pooled OLS model requires the robust variance matrix estimator and robust test statistics due to the presence of serial correlation when we have an unobserved individual element. The REM estimation is made with (Feasible) Generalised Least Squares.

When the unobserved element is correlated with the explanatory variables – this can be evaluated by the Hausman Test – it is referred to as a "fixed effect" and we can use either the Fixed Effects Model (FEM) or the first difference model. The latter model implies the loss of data and is only more efficient than the FEM if the disturbance term follows a random walk (Wooldridge, 2002). The fixed effect estimator is usually named dummy variable estimator, since dummy variables are used to estimate the individual effects in a panel OLS estimation.

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 the intercepts are the same for all countries.

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 (10) in a panel data formulation with a constant term δ_0 is either:

$$\text{(i)}\ \hat{w}_{it} = \delta_0 + \sum_{j=1}^{10} \delta_j (X_j)_{it} + \varphi_{it} \text{ or } \hat{w}_{it} = \delta_0 + \theta\, GDPpc70_i + \sum_{j=1}^{10} \delta_j (X_j)_{it} + \varphi_{it}, \tag{15}$$

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);

$$\text{(ii)}\ \hat{w}_{it} = \rho_{it} + \sum_{j=1}^{10} \delta_j (X_j)_{it} + \omega_{it} \text{ or } \hat{w}_{it} = \rho_{it} + \theta GDPpc70_i + \sum_{j=1}^{10} \delta_j (X_j)_{it} + \omega_{it}, \tag{16}$$

for the FEM with time and country effects, where $\rho_{it} = \delta_0 + c_i + d_t$. By using the GDP *per capita* for each *i* in dollars, $GDPpc70_i$,[20] the latter expressions in (15) and (16) allow us to assess the conditional-convergence hypothesis of countries: $\theta<0$ ($\theta>0$) conveys a smaller (higher) productivity growth in richer countries and thus the convergence (divergence) of countries. In general, the FEM produces more robust results since 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, the random-effects estimator is probably the only choice without an instrumental variable approach, but we will get an inconsistent estimate if the FEM is the apt model. The fixed-country effect in (16) impedes our checking conditional convergence: θ cannot be estimated by the FEM since $GDPpc70_i$ is independent of *t*.

3. Results

In this section we present and discuss the most relevant results concerning our panel model and the theoretical and empirical evidence presented above.

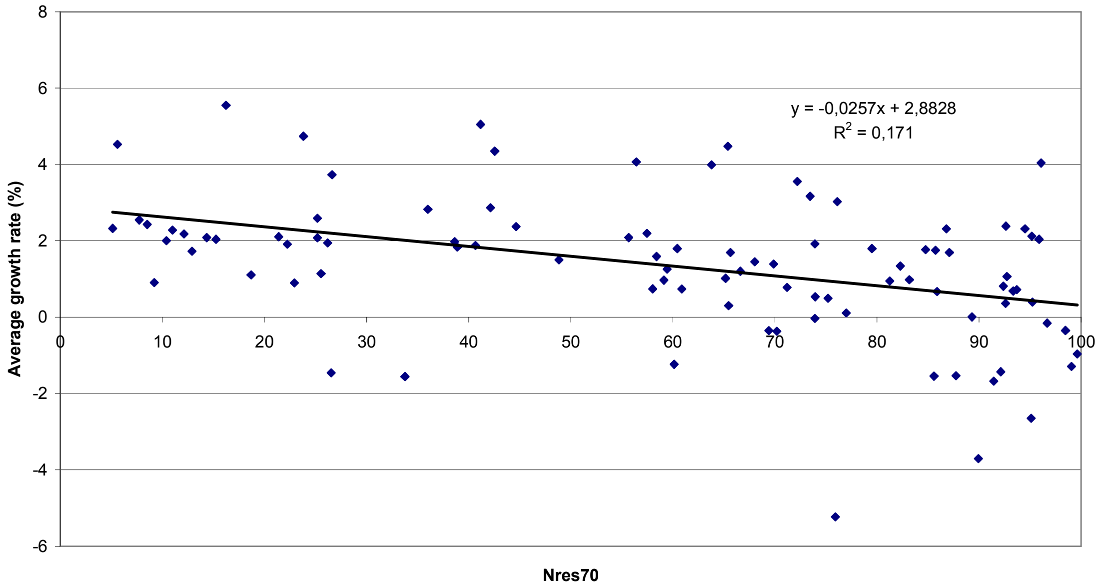
First, we show the usual cross-section resource-curse presentation in Figure 1, which plots the growth in real GDP *per capita* between 1970 and 2005 for 94 countries against their natural-resource abundance in 1970, measured by the sum of *NresD* and *NresP*.[21] As

[20] Data from the United Nations (National Accounts Database).

[21] Real GDP *per capita* growth obtained from United Nations (Common and National Accounts databases).

expected, Figure 1 depicts the negative correlation that embodies the resource curse. This was also found separately for *NresD* and *NresP*, both with the unadjusted and adjusted proxies.

Figure 1 - GDP*pc* average growth rate from 1970 to 2005 and resource abundance in 1970 (unadjusted proxy)



The model estimation was based on information regarding 208 countries from 1970 up to 2005.[22] Since the panel estimation only considers the years with complete data in each country, we got close to one thousand observations in our regressions, corresponding to an unbalanced panel data for 80 countries from 1976 up to 2005 with all variables. Nevertheless, the capital stock includes values regarding investment beginning in 1970. Since unbalanced panel data may suffer from selectivity bias, Table 1 presents the estimated number of years for each country. An inspection of countries reveals enough variability of resource abundance and economic outcomes to exclude severe selectivity bias problems.

[22] The estimation outputs were obtained with Limdep 8.0 software.

Table 1 – Estimated countries and years

Country		Year			Country		Year		
		$t = t_0$	$t = T$	Number			$t = t_0$	$t = T$	Number
1	Algeria	1994	2002	9	41	Luxembourg	1999	2003	5
2	Armenia	2003	2004	2	42	Macedonia, FYR	1996	2004	3
3	Australia	1976	2005	30	43	Malaysia	1991	1995	5
4	Austria	1976	2005	29	44	Malta	1976	2002	23
5	Belarus	1998	2003	6	45	Mauritius	1990	1998	9
6	Belgium	1976	2003	28	46	Mexico	1992	2004	13
7	Brazil	1993	1998	3	47	Moldova	1996	2004	8
8	Bulgaria	1996	2004	9	48	Mongolia	1996	2004	4
9	Canada	1976	2003	28	49	Morocco	1991	1991	1
10	Chile	1976	2004	26	50	Netherlands	1976	2005	28
11	Colombia	1976	2002	14	51	New Zealand	1987	2004	17
12	Costa Rica	1977	1990	9	52	Nicaragua	2000	2000	1
13	Croatia	1997	2004	8	53	Norway	1976	2005	28
14	Czech Republic	1996	2005	10	54	Panama	1992	1996	5
15	Denmark	1976	2005	30	55	Peru	1993	2004	4
16	Ecuador	1989	1994	2	56	Philippines	1999	2000	2
17	Egypt, Arab Rep.	1978	2003	9	57	Poland	1984	2005	17
18	Estonia	1998	2004	7	58	Portugal	1979	2003	24
19	Finland	1976	2005	30	59	Romania	1998	2005	7
20	France	1978	2004	27	60	Russian Federation	1996	2004	8
21	Georgia	1998	2004	7	61	Saudi Arabia	2000	2000	1
22	Germany	1976	2005	30	62	Singapore	1998	2004	5
23	Greece	1988	2004	17	63	Slovak Republic	1996	2005	10
24	Guatemala	1991	1995	5	64	Slovenia	1995	2005	11
25	Hungary	1993	2004	12	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, Islamic Rep.	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, RB	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.

Table 2 shows the main estimation results for the wage equation without the conditional convergence variable – (15) and (16). As the natural-resource curse explanation backed by cross-section studies associates the negative effect of geographically concentrated resources with a reduction in institutional quality, we estimated the wage equation with and without *IQ* to check whether it is relevant for the evaluation of the resource curse in our panel estimation.

Table 2 – Wage equations (1976-2005)

Resource Proxies	Unadjusted				Adjusted			
IQ variable	Absent		Included		Absent		Included	
Panel model	FEM G&T [(a)]	Pooled OLS	FEM G&T [(a)]	Pooled OLS	FEM G&T [(a)]	Pooled OLS	FEM G&T [(a)]	Pooled OLS
F [(b)]	4.027		4.234		4.235		4.436	
LM [(c)]	6.24		9.09		3.80		6.80	
Hausman [(d)]	77.96		81.89		102.49		106.02	
Dependent variable, $\hat{w}$								
Constant	0.432 (0.796)	0.172 (0.606)	0.832 (1.462)	0.452 (1.436)	1.076 (0.847)	-0.026 (-0.092)	1.593 (1.242)	0.162 (0.528)
$(\hat{I} - \hat{L})$	0.128* (8.768)	0.099* (6.444)	0.114* (7.582)	0.081* (5.100)	0.132* (9.064)	0.088* (5.809)	0.118* (7.853)	0.071* (4.505)
$(\hat{T} - \hat{L})$	0.120* (4.010)	0.160* (5.594)	0.125* (3.890)	0.173* (5.658)	0.113* (3.788)	0.175* (6.117)	0.118* (3.647)	0.189* (6.156)
IQ			0.153* (2.615)	0.155* (3.454)			0.148** (2.492)	0.128* (2.862)
$\frac{NresD}{L}$	-0.047*** (-1.669)	0.023* (4.004)	-0.050*** (-1.847)	0.023* (4.016)	0.001 (0.090)	0.017* (2.893)	0.000 (0.024)	0.016* (2.840)
$\frac{NresP}{L}$	-0.127*** (-1.895)	-0.087* (-4.650)	-0.132** (-2.021)	-0.088* (-4.613)	-0.028 (-0.876)	-0.021* (-2.914)	-0.029 (-0.936)	-0.021* (-2.873)
$\frac{NresD}{K}$	0.620 (0.770)	-0.581* (-2.630)	0.752 (0.954)	-0.577* (-2.640)	-0.845*** (-1.913)	-0.671* (-3.792)	-0.676 (-1.536)	-0.643* (-3.627)
$\frac{NresP}{K}$	1.904** (2.176)	1.761* (6.236)	1.887** (2.207)	1.756* (6.240)	1.004** (2.194)	0.876* (4.474)	0.825*** (1.827)	0.852* (4.296)
$(\hat{K} - \hat{L})$	0.261* (7.087)	0.242* (6.695)	0.304* (8.207)	0.276* (7.464)	0.256* (7.006)	0.232* (6.356)	0.299* (8.104)	0.263* (7.014)
$(\widehat{Inf} - \hat{K})$	0.142* (5.262)	0.067* (3.001)	0.156* (5.627)	0.086* (3.723)	0.144* (5.344)	0.064* (2.865)	0.157* (5.679)	0.085* (3.674)
$(\widehat{RD} - \hat{K})$	-0.008 (-1.373)	-0.007 (-1.096)	-0.005 (-0.795)	-0.008 (-1.212)	-0.008 (-1.319)	-0.007 (-1.028)	-0.005 (-0.764)	-0.007 (-1.079)
$(\widehat{RD} - \hat{K})_{-1}$	0.012*** (1.837)	0.015** (2.272)	0.011*** (1.735)	0.013*** (1.870)	0.012*** (1.886)	0.015** (2.221)	0.011*** (1.721)	0.013*** (1.834)
$(\widehat{RD} - \hat{K})_{-2}$	0.006 (1.134)	0.007 (1.185)	0.003 (0.456)	0.003 (0.395)	0.007 (1.205)	0.006 (0.957)	0.003 (0.425)	0.001 (0.185)
Observations	1086	1086	1005	1005	1086	1086	1005	1005
R^2	0.461	0.214	0.495	0.232	0.462	0.203	0.495	0.219
Adjusted R^2	0.394	0.206	0.427	0.223	0.395	0.195	0.427	0.210

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.

The first regressions were estimated keeping the natural-resource variables unadjusted for the re-exportation distortion (Sachs and Warner, 1995, corrected this for Singapore) as in most empirical studies. In the last regressions, we remove the problem, by using the adjusted proxies, and find whether the correction is relevant for the resource-curse proof or dismissal.

We present the FEM results with country and time effects since, according to the test statistics, it is always the most adequate estimation procedure. Under fixed-country effects, the inclusion of the convergence variable renders inconsistent estimates, since only the Pooled OLS or the REM procedure can be used – estimation form (15). In any case, it can be shown that the convergence variable is statistically insignificant with the Pooled OLS and the REM in view of the different scenarios for inclusion of *IQ* and the adjustment of resource variables.

In addition to the FEM results, we also present the inconsistent estimates from the pooled OLS approach, which is the panel data equivalent to the classic regression model used in the traditional cross-section analyses of the resource curse (*e.g.*, Sachs and Warner, 1995).[23] In this way, we can observe whether the consideration of the fixed country and time effects is important for the confirmation or dismissal of the resource-curse hypothesis.

Wage equation with unadjusted resource variables and without *IQ*

In the first regression of Table 2, the wage equation is estimated with the unadjusted resource variables and leaving out *IQ*. The estimates represent the impact of the explanatory variables on real wage growth *per* worker, $\hat{w}$, and thus on output growth, $\hat{Y}$, – see (15).[24] Investment, trade and infrastructure variables are all significant at 1%. In the R&D variable we introduced two lags to capture a significant positive impact on $\hat{w}$ (and $\hat{Y}$), which only occurs a year after the application was filed, with a significance level of 10% in this first regression. The variable

[23] Remember that, in addition to the inclusion of the time dimension in panel data, our pooled OLS estimations differ from the usual cross-section results due to the use of a growth model with factor efficiency.

[24] The estimated impact of $\hat{K}$ on $\hat{Y}$ is given in Table 2 by the coefficient of $(\hat{K} - \hat{L})$, which we then subtract from 1 to obtain the contribution of $\hat{L}$.

is not significant in the first and third years, but its final impact is positive, although smaller than expected, reflecting the limitations of the available proxies – see subsection 2.1.

The coefficient of $(\hat{K}-\hat{L})$, 26,1% (significant at 1%), is the estimated product elasticity in relation to capital and is below the usual reference of one third (Romer, 2005). Concerning the natural-resource variables, only $\frac{NresP}{K}$ has a positive crucial effect (significant at 5%); i.e., the relative abundance in *NresP* is beneficial to $\hat{Y}$ through $\hat{g}$ when the proxy is unadjusted for the re-exportation distortion. This impact overcomes the negative effects of $\frac{NresD}{L}$ and $\frac{NresP}{L}$ on $\hat{f}$ (both significant at 10%). Variable $\frac{NresD}{K}$ has no impact with a significance level of 10%.

The Pooled OLS estimates are similar in signal and magnitude, except in the case of $\frac{NresD}{K}$ (which is significant at 1% with a negative signal) and $\frac{NresD}{L}$ (which is significant at 1% with a positive signal). We also find higher significance levels of the resource estimates in the Pooled OLS estimation. The combined effect of natural resources on $\hat{w}$ (and thus on $\hat{Y}$) remained positive, due to the positive effect of $\frac{NresP}{K}$ (and, to a smaller extent, of $\frac{NresD}{L}$) on $\hat{g}$, which more than compensated for the negative effects of $\frac{NresD}{K}$ and $\frac{NresP}{L}$. However, now the estimates are inconsistent since there is statistical evidence of fixed country and time effects.[25]

Overall, the first two regressions with unadjusted resource proxies dismiss the resource-curse hypothesis found by the cross-section studies (*e.g.*, Sachs and Warner, 1995). The FEM regression shows that the negative impact on $\hat{Y}$ coming from the reduced $\hat{f}$ caused by $\frac{NresD}{L}$ and $\frac{NresP}{L}$ is more than compensated for by the increase in $\hat{g}$ associated with $\frac{NresP}{K}$, which is exactly the type of resource that explains the curse in most recent cross-section studies (*e.g.*, Isham *et al.*, 2003; Sala-i-Martin and Subramanian, 2003), where it is linked with a reduction of institutional quality – we take into account this variable in regressions 3 and 4 of Table 2.

[25] As stated, the reason for the analysis of the pooled OLS estimates is to assess whether the presence and correct estimation of the referred effects is important to the confirmation or dismissal of the resource curse hypothesis.

The dismissal of the curse is reinforced by the presence of fixed country and time effects in the FEM estimation since $\frac{NresD}{K}$ does not present the significant negative impact found in the inconsistent pooled OLS estimates (this more than compensates for the positive influence of $\frac{NresD}{L}$ found with this procedure), which do not take into account the referred effects.

Complete wage equation with unadjusted resource variables

The third and fourth regressions in Table 2 show the FEM with country and time effects and pooled OLS estimations of the complete wage equation using the unadjusted natural-resource proxies. In both cases, *IQ* has a positive and significant (at 1%) effect on $\hat{w}$ and $\hat{Y}$. The addition of *IQ* only slightly alters the magnitude of the other coefficients, so the previous conclusions remain unaltered. Thus, the positive effect of $\frac{NresP}{K}$ still overcomes the negative effect on $\hat{f}$ induced by $\frac{NresP}{L}$ and/or $\frac{NresD}{L}$. This means that, in contrast with recent cross-section studies, the negative effect of $\frac{NresP}{L}$ on $\hat{f}$ persists with a fixed *IQ*.

Let us now see if these conclusions still stand when we adjust the natural-resource variables to correct the distortion introduced by the re-exportation of these resources.

Wage equation with adjusted resource variables and without *IQ*

When we leave out *IQ* and use the adjusted resource proxies, some resource coefficients become non-significant or change signal in the FEM with country and time effects estimation (see the fifth and the first regressions in Table 2), and the remaining estimates present similar values. We find that the resource variables have no impact on $\hat{f}$ and that $\frac{NresD}{K}$ has a negative effect on $\hat{w}$ (and $\hat{Y}$), with a significance level of 10%. Variable $\frac{NresP}{K}$ has a smaller positive effect on $\hat{w}$ (and $\hat{Y}$), still significant at 5%, compared to the first regression, but higher than the negative effect of $\frac{NresD}{K}$. Thus, the final impact of natural resources is still favourable.

Country and time fixed effects are decisive in explaining most of the changes as we find no major differences in the pooled OLS regression when we use the adjusted resource proxies (basically, $\frac{NresP}{K}$ has now a smaller effect – see the sixth and second regressions of Table 2).

Complete wage equation with adjusted resource variables

Including *IQ*, $\frac{NresD}{K}$ becomes non-significant at 10% in the FEM with country and time effects (see the seventh and the fifth regressions in Table 2), and the effect of natural resources on $\hat{w}$ (and thus on $\hat{Y}$) is positive and comes from the increased $\hat{g}$ due to $\frac{NresP}{K}$. However, its estimate is smaller and less significant (at only 10%) than before. Again, fixed country and time effects are crucial in explaining the changes associated with *IQ* since the pooled OLS estimation remains essentially the same (see the eighth and the sixth regressions in Table 2). As before, *IQ* has a positive effect on $\hat{w}$ in both estimations (with a significance level of 5%).

In the final FEM with country and time effects (seventh regression in Table 2), the product elasticity in relation to capital is 29.9% (significant at 1%), slightly below the usual one third estimated with the share of income paid to capital. The effects of investment and trade to $\hat{w}$ (and $\hat{Y}$) *per* worker are similar (significant at 1%) and slightly less than the estimate for infrastructures. The positive effect of R&D (significant at 10%) occurs with a one year lag and is much smaller than expected due to the limitations of the available proxies.[26]

Therefore, there is no evidence of a resource curse in our panel-data analysis of a growth model where the resource variables affect labour and capital efficiency. If the natural resource proxies are unadjusted for the re-exportation distortion, as in most cross-section studies, the adequate fixed-effect model estimation (FEM with country and time effects estimation) shows that the negative impact of $\frac{NresD}{L}$ and $\frac{NresP}{L}$ on $\hat{f}$ (the effect of $\frac{NresP}{L}$ persists keeping *IQ*

[26] Considering R^2 as a measure of fit to our final estimation, the explanatory variables, with fixed country and time effects, capture 49.5% of the variation in $\hat{w}$ (the adjusted R^2 is slightly lower, close to 43%).

constant, in contradiction to the most recent cross-section studies) is more than compensated for by the positive effect on $\hat{g}$ arising from $\frac{NresP}{K}$.

When we use the adjusted resource proxies in the fixed effects model there is no significant impact of natural resources on $\hat{f}$. We also obtain a smaller positive effect of $\frac{NresP}{K}$ on $\hat{g}$ but bigger than the negative impact now coming from $\frac{NresD}{K}$ that becomes non-significant considering *IQ,* and therefore the overall impact of natural resources is favourable.

The positive impact of *NresP* may reflect the effects associated with economies of scale, and capital and technological intensity owing to the exploitation of those resources. Since poor institutional quality seems to induce a loss of capital efficiency in diffuse natural-resource abundant countries,[27] we can consider that better policies and institutions are needed to offset low capital level and technological intensity in the exploitation of those resources.

Comparing these final results with those of the inconsistent pooled OLS estimates, we find that the presence of fixed country and time effects dismiss the significance of both the negative effect of diffuse resources on capital efficiency and the impact of resources on labour efficiency, which are negative if they are concentrated and positive if they are diffuse.

Estimated growth decomposition

Based on the seventh regression in Table 2, we now analyse the evolution of real GDP growth and the estimated GDP growth decomposition for some representative countries in terms of resource abundance and economic growth. First, we ranked the countries in Table 1 according to the adjusted resource-abundance measures. Then, we chose a country above and another below the average of 1.55% of GDP *per capita* growth between 1970 and 2005,[28] from those with high and low measures of resource abundance for each type of natural resource (geographically diffused and concentrated), reaching a selection of eight countries.

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[27] In our case *IQ* is only introduced in *f*, and we could not estimate the direct effect on *g* at the same time.

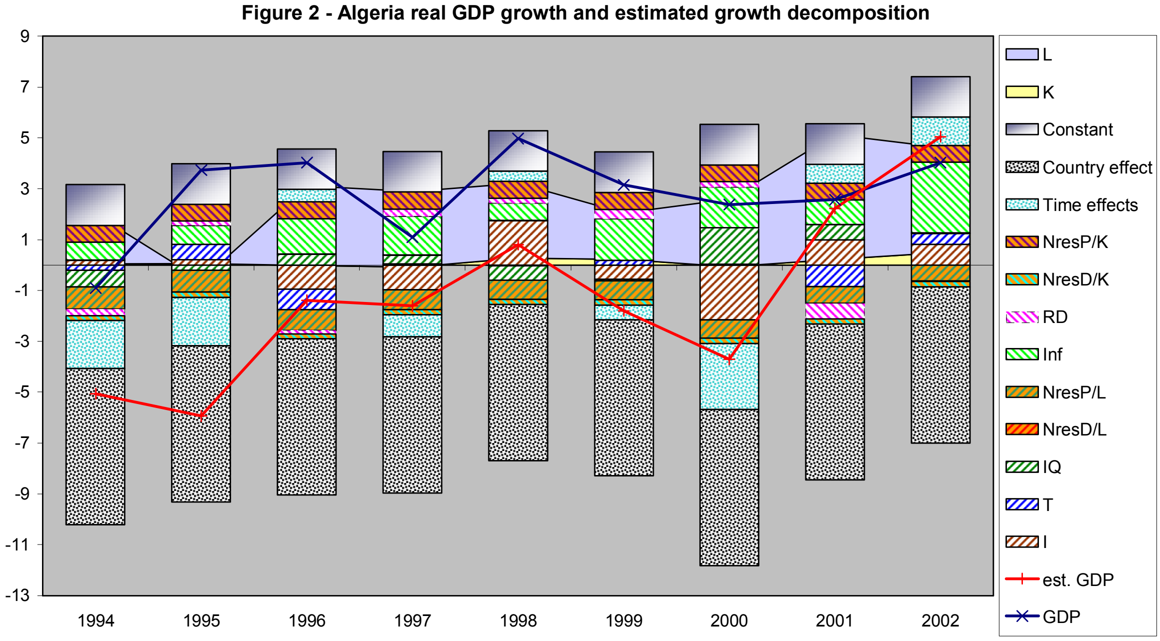
[28] For the countries included in the UN National Accounts Database.

Although only concentrated natural resources have a statistically significant and positive effect on growth by capital efficiency, if we add the other statistically non-significant effects of natural resources we reach a global average impact of -1.60 percentage points, p.p.; i.e., the average positive effect on estimated growth of $\frac{NresP}{K}$ (1.50 p.p.) is reverted to.[29] In the remainder of the analysis, we will stress the natural-resources significant positive impact.

Below, we present a brief analysis for each selected country. The first conclusion that emerges is the close connection between estimated and actual growth over the period. As for the estimated country effects, they were only significant at 10% for Algeria and Venezuela.

(i) Low *NresD* adjusted measure and below average economic growth – The Algeria case

Figure 2 - Algeria real GDP growth and estimated growth decomposition



Notes: the lines represent real GDP growth, actual and estimated values; the lines with shaded areas below stand for the physical impacts of the labour and capital stocks to the 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.

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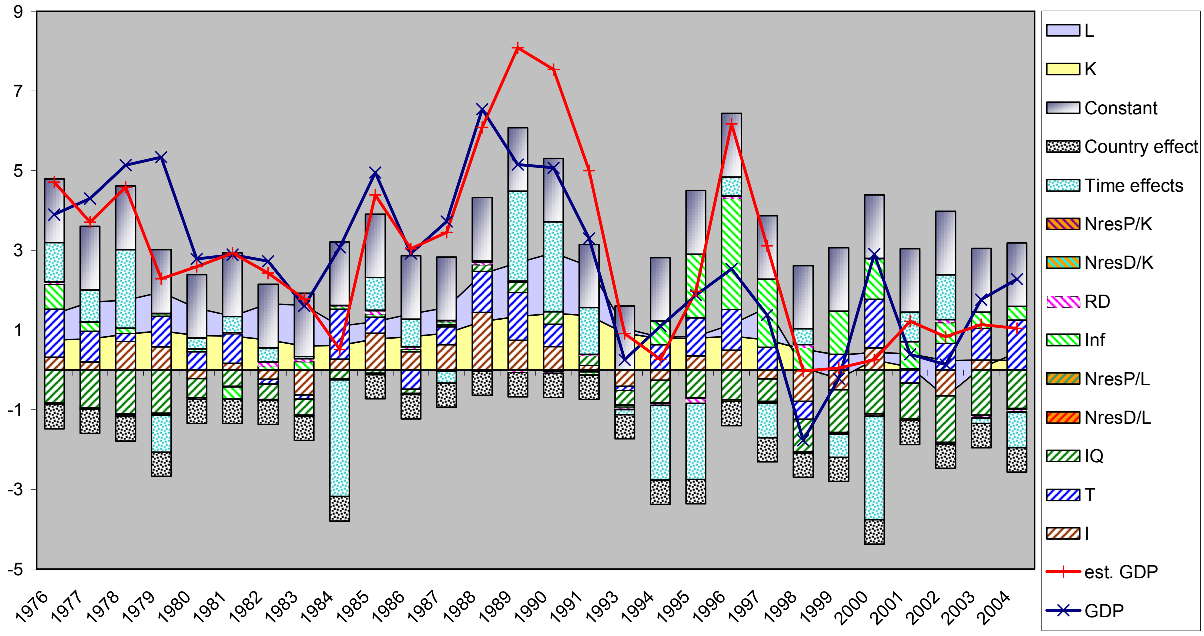
[29] Ignoring that the coefficients of $\frac{NresP}{L}$, $\frac{NresD}{L}$ and $\frac{NresD}{K}$ are all statistically non-significant, we find that the average negative effect in labour efficiency (-1.77 p.p. due to $\frac{NresP}{L}$ and 0.02 p.p. owing to $\frac{NresD}{L}$) more than offsets the average favourable effect in capital efficiency (1.50 p.p. due to $\frac{NresP}{K}$ plus -1.35 p.p. owing to $\frac{NresD}{K}$).

Figure 2 shows the estimated growth decomposition for Algeria in the period 1994-2002. In terms of the estimated growth factors, the most positive impacts come from labour and the effect of infrastructures and concentrated natural resources via capital efficiency. The most negative impact arises from the fixed-country effect, explaining the fall in estimated product in the majority of the period. We also find a negative influence of concentrated resources via labour efficiency, but, as already mentioned, this is statistically non-significant.

(ii) Low *NresD* adjusted measure and above average economic growth – The Japan case

Figure 3 - Japan real GDP growth and estimated growth decomposition



Japan has a relative scarcity of diffuse and concentrated natural resources, explaining the null related effects to estimated growth in Figure 3. The good economic performance up to the 1990s is mostly associated with the physical impacts of capital and labour, followed by the positive effect of trade and investment via labour efficiency. This is partially offset by the negative effect of institutional quality via labour efficiency, which increases after 2000, explaining the lower estimated growth along with the slowdown of labour and capital. From the mid 90s, there is also a positive impact of infrastructures through capital efficiency.

(iii) High *NresD* adjusted measure and below average economic growth – The New Zealand case

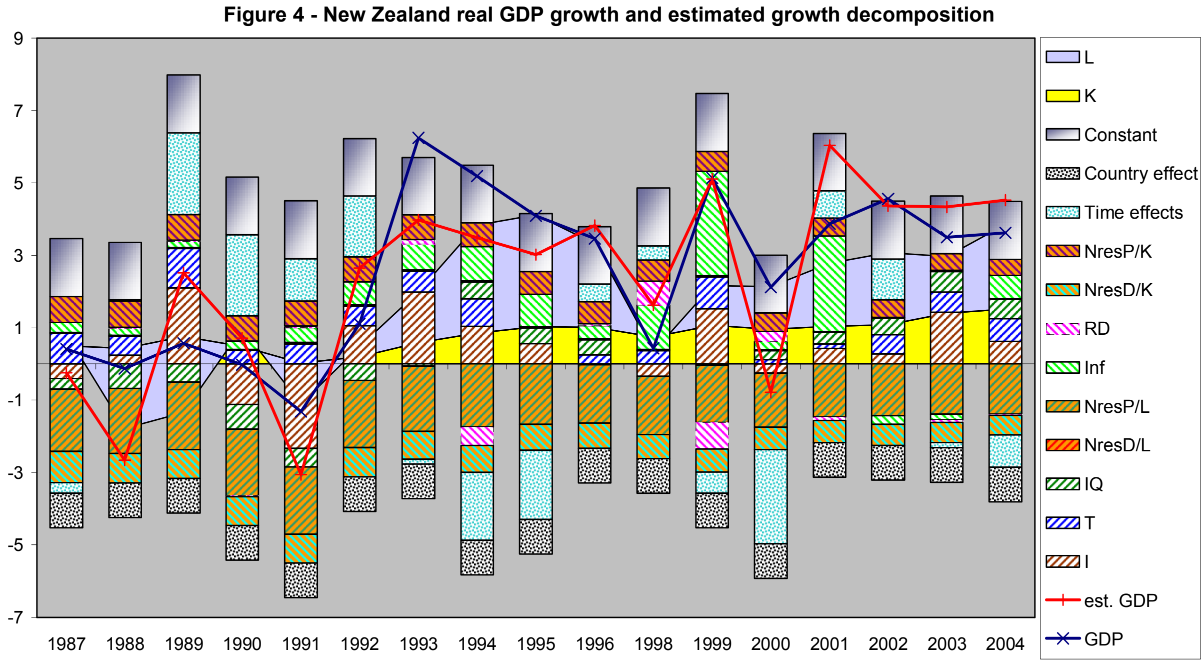


Figure 4 depicts the decomposition for New Zealand for 1987-2004.[30] Estimated growth is hindered up to 1992 by the drop of the labour stock, along with the negative impacts of investment and institutional quality via labour efficiency, which are positive in the following years. The better performance after 1992 is also associated with the capital growth and the strong effect of infrastructures via capital efficiency. In the whole period, we also find a stable positive effect of trade (via labour efficiency) and concentrated natural resources (via capital efficiency). Concentrated resources also have a negative effect via labour efficiency, which, as the negative effect of diffuse resources via capital efficiency, is statistically non-significant.

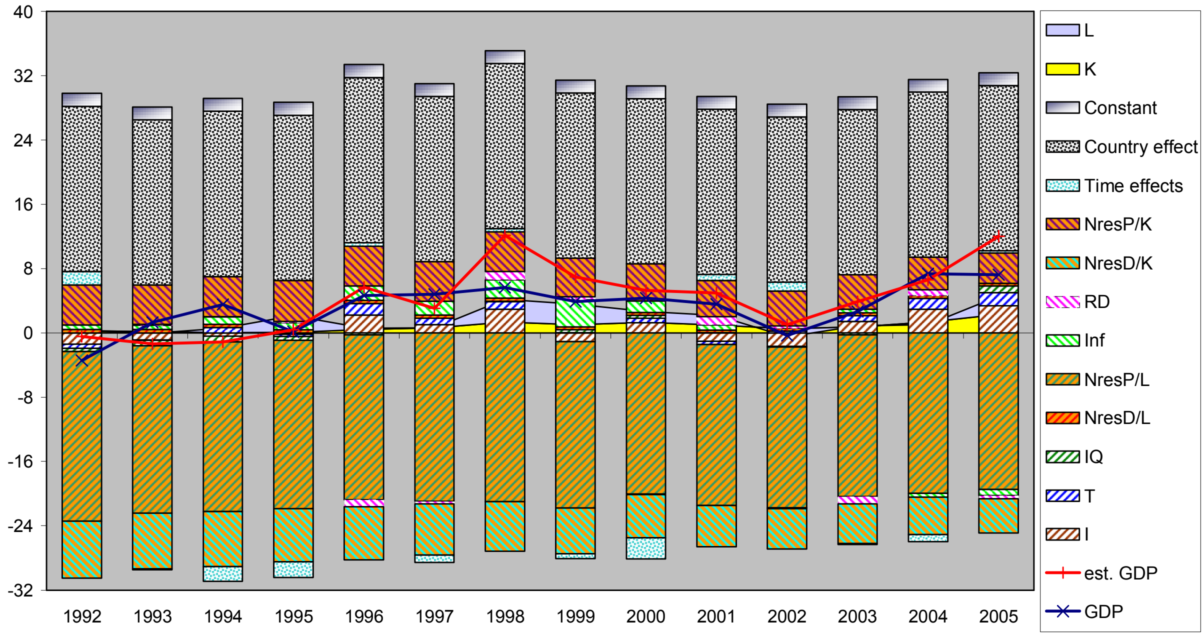
(iv) High *NresD* measure and above average economic growth – The Iceland case

Unlike the previous cases, for Iceland the fixed-country effect is positive and explains most of the estimated GDP growth, but, as mentioned before, is non-significant. We stress the strong positive impact of concentrated resources via capital efficiency and, in some years, the

[30] We found other countries with lower adjusted *NresD* values and below average economic performance – Kenya, Guatemala and Uruguay –, but with only a few estimated years.

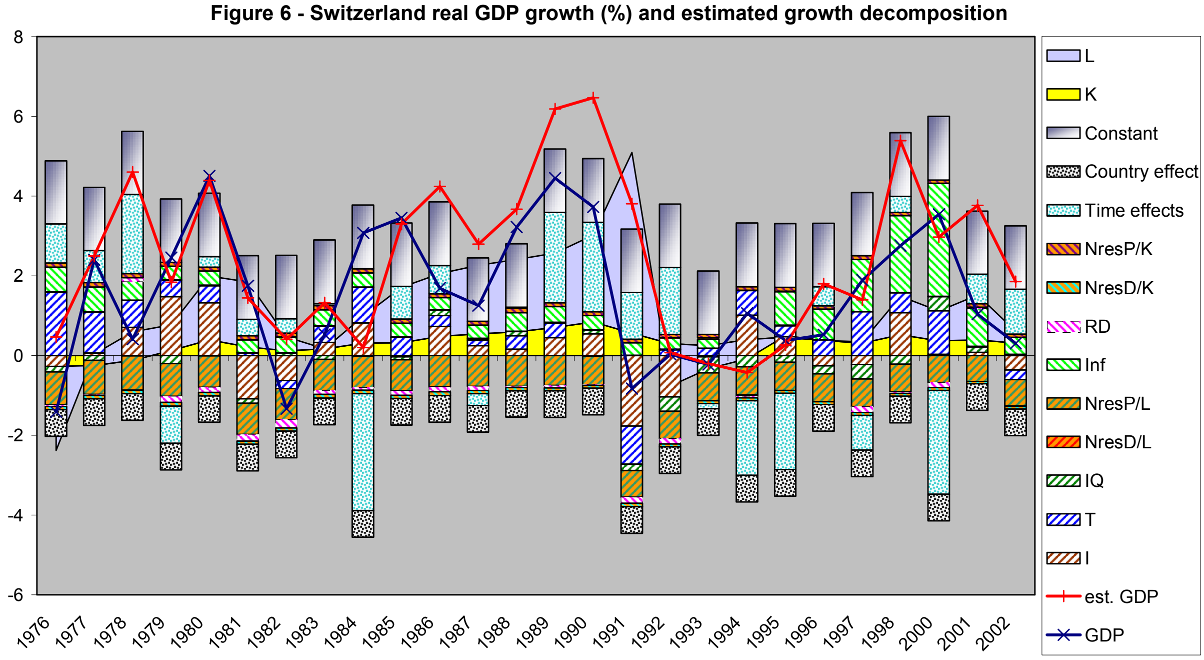
favourable effects coming from investment, trade (via labour efficiency), infrastructures or R&D (via capital efficiency). We also see negative impacts of concentrated resources via labour efficiency and of diffuse resources via capital efficiency, both non-significant.

Figure 5 - Iceland real GDP growth (%) and estimated growth decomposition



(v) Low *NresP* adjusted measure and below average economic growth – The Switzerland case

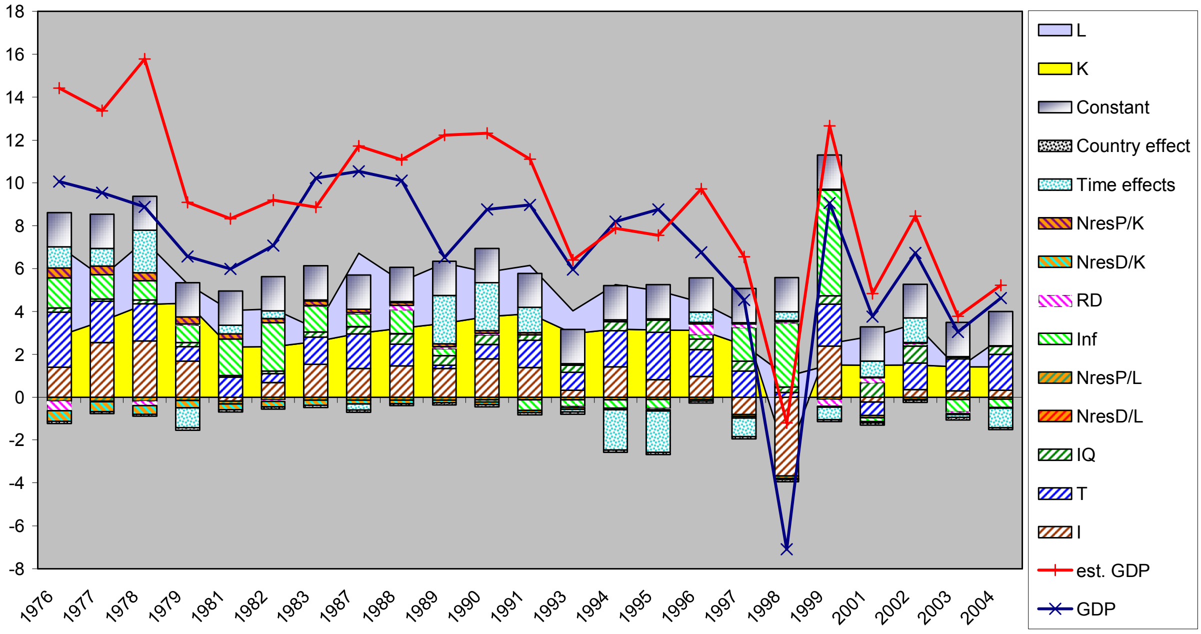
Figure 6 - Switzerland real GDP growth (%) and estimated growth decomposition



In this case we show the estimated growth decomposition for Switzerland.[31] The high impact of labour to estimated growth was replaced after 1992 by the growing effect of infrastructures via capital efficiency. Even though we chose a country with a below average adjusted measure of concentrated natural resources, we have a negative impact associated with this kind of resource via labour efficiency. This seems stronger than the positive effect via capital efficiency, but, as already stated, only this last impact is statistically significant.

(vi) Low *NresP* adjusted measure and above average economic growth – The South Korea case

Figure 7 - Republic of Korea real GDP growth (%) and estimated growth decomposition



Besides the high impact of both labour and capital stocks on estimated South Korean growth, we stress the positive impact coming from trade, investment and institutional quality via labour efficiency for most years. We also find an important effect of infrastructures up to 1988 and from 1997 to 1999. The effect of natural resources is small and only visible up to the early 90s, where the positive impact of concentrated resources via capital efficiency is similar to the negative effect via labour efficiency, which is, however, non-significant.

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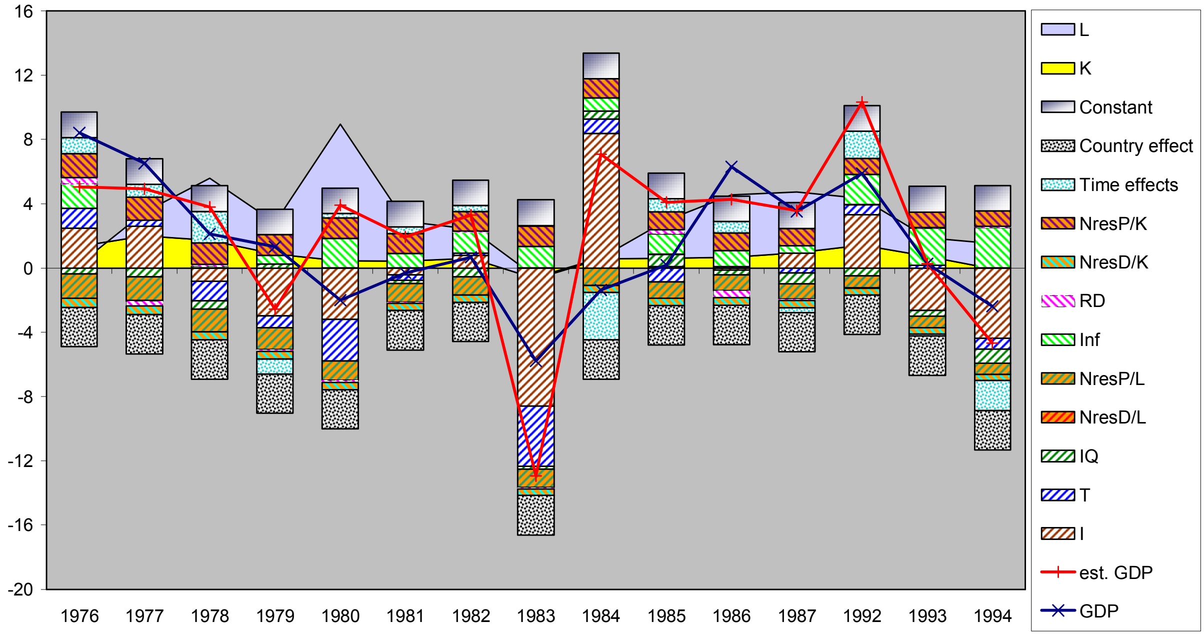
[31] Guatemala has lower adjusted *NresP* values, but it only has a few estimated years.

(vii) High *NresP* adjusted measure and below average economic growth – The Venezuela case

Figure 7 - Venezuela real GDP growth (%) and estimated growth decomposition



The most positive effect to Venezuela's growth comes from labour, followed by capital, and the effect of infrastructures and concentrated natural resources via capital efficiency.[32] In addition, we find negative effects of concentrated resources via labour efficiency and also of diffuse resources via capital efficiency, but they are non-significant. Moreover, trade, investment and institutional quality hinder economic growth via labour efficiency in several years. The negative fixed-country effect also penalises growth.

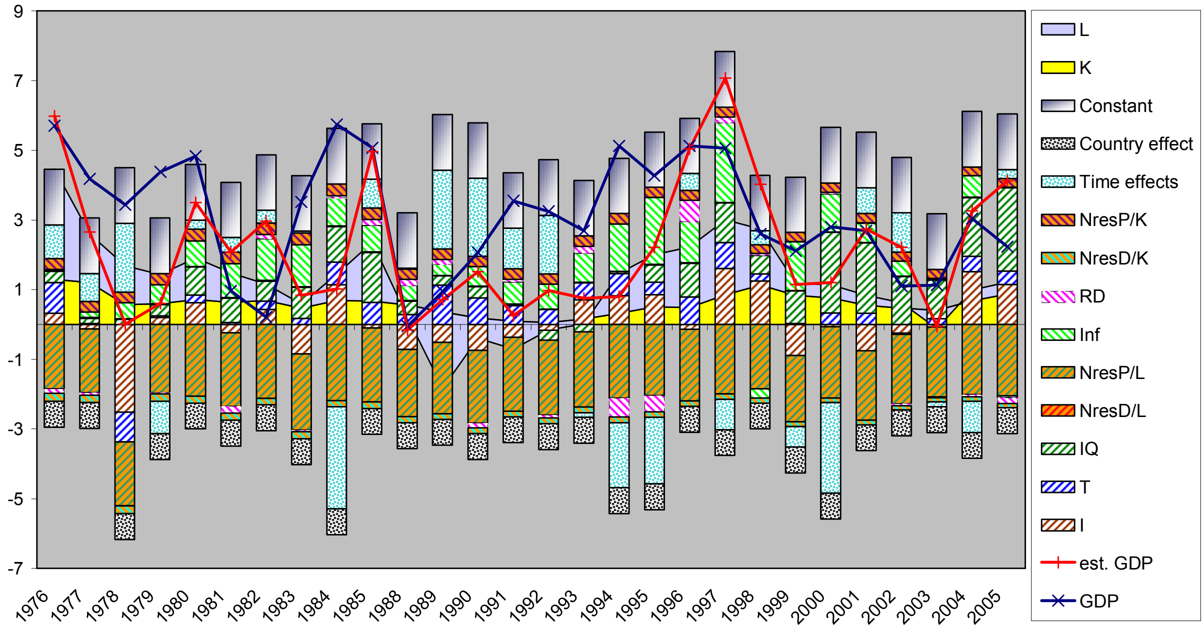
(viii) High *NresP* adjusted measure and above average economic growth – The Norway case

Moreover the positive contribution of labour and capital to Norway's growth, we stress the favourable impacts of institutional quality and trade via labour efficiency and also of infrastructure and concentrated natural resources via capital efficiency.[33] Concentrated natural resources also have a negative effect via labour efficiency, but this is non-significant.

[32] Similar values for adjusted *NresP* are presented in other countries, which also have low economic performance (*e.g.*, Saudi Arabia and Algeria) but with fewer estimated years.

[33] Similar adjusted *NresP* values are presented by Trinidad and Tobago, but only a few years are estimated.

Figure 7 - Norway real GDP growth (%) and estimated growth decomposition



4. Concluding remarks

In this study we re-evaluated the impact of natural resources on economic growth. Having realised that the physical restrictions related to natural resources are not decisive to economic growth, 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 'resource curse' by the negative effect of geographically concentrated resources on institutional quality, which in turn favours economic growth.

Bearing in mind these results, we developed a growth model to estimate the contribution of natural resources in a panel data analysis (which allows an increased estimation efficiency and the control of unobserved individual heterogeneity) and found no evidence of a 'resource curse'. In our model, the natural-resource variables (geographically diffused and concentrated) affect the efficiency gains of labour and capital in production. The Solow residual is 'explained' in terms of improvements to the efficiency of inputs, which depend on a set of variables also related to natural resources. In order to estimate the unobserved levels of efficiency, we used the duality qualities/prices of production factors.

If the natural resource proxies are unadjusted for the re-exportation distortion, as in most cross-section studies, we find in a fixed effect model that the negative impact of both geographically diffused and concentrated resources on labour efficiency (this last impact endures with a constant institutional quality, contrary to the recent cross-section studies) is overcome by the positive effect on capital efficiency coming from concentrated resources.

Using the adjusted resource proxies in the fixed effects model there is no significant impact of natural resources on labour efficiency. There is also a smaller positive effect of concentrated resources on capital efficiency but greater than the negative one issued from diffuse resources, which is non-significant under a fixed institutional quality. This last variable has a positive and significant (at 5%) effect on growth. Comparing these results with the inconsistent pooled OLS estimates, fixed country and time effects dismiss the significant negative effect of diffuse resources on capital efficiency and the impacts of resources on labour efficiency, which are negative if they are concentrated and positive if they are diffuse.

We conclude that natural resources have a positive impact on economic growth through the increased capital efficiency of concentrated resources, thus dismissing the hypothesis of a resource curse. The positive effect seems to reflect the capital and technological intensity usually associated with the exploration of those resources, in addition to economies of scale.

In the final FEM regression, the product elasticity in relation to capital has a value slightly below the reference level of one third. The contributions of investment and trade to real wage and product growth *per* worker are similar and slightly smaller than the estimate for infrastructures. All these coefficients have a significance level of 1%. The positive impact of R&D only occurs with a one year lag (significance level of 10%) and is much smaller than anticipated due to the limitations of the available proxies.

We also tested and rejected the hypothesis of conditional convergence, but this could not be done appropriately due to the presence of fixed-country effects.

Finally, we decomposed the estimated economic growth for eight selected countries in terms of resource abundance and growth. Even though only concentrated natural resources have a significant and positive effect on growth via capital efficiency, we also measured the other contributions of natural resources to growth. Among the selected countries, Iceland presented the highest impact of concentrated resources via capital efficiency (4.66 p.p., on average), contributing to its good economic performance from 1992 to 2005. Venezuela and Norway, which were selected for their abundance in this type of resource, presented smaller ratios in relation to capital and thus lower contributions of concentrated resources (1.2 p.p. and 0.3 p.p. on average, respectively) in comparison with Iceland – other not selected countries, such as Malta, presented even higher impacts associated with this type of resource. From the growth decompositions of Venezuela and Norway we conclude that concentrated resources can benefit growth through capital efficiency, but this may 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.

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