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Abstract

Given a panel of oil producing countries, we show that a higher oil concentration is associated with an increase in economic growth through capital efficiency in: (i) countries with medium and low income per head from East Asia & Pacific and Latin America & the Caribbean, classified as followers in terms of technology-convergence clubs; (ii) countries with high income inequality. In our view, the overall results reflect the broader scope for factor efficiency increases in less developed countries arising from the oil industry, which is characterised by a highly globalised know-how.

Keywords: Energy, Economic growth, Panel data

JEL classification: C23, O13, O47, O50

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1. Introduction

In this paper we examine the effect of geographic oil concentration on economic growth**,** bearing in mind the findings of Torres *et al*. (2009), who re-evaluate the impact of natural resources on growth through a panel-data analysis of the "resource curse"**.**

The afore-mentioned panel study dismisses the hypothesis of a "resource curse" proposed by a series of cross-section studies, initiated by Sachs and Warner (1995), as it shows a positive effect on growth, through capital efficiency, in the case of geographically-concentrated resources (such as oil and ores). This is exactly the type of resources that causes the curse, by hindering institutional quality, in recent cross-section studies (*e.g*., Sala-i-Martin and Subramanian, 2003; Isham *et al*., 2005). Thus, Torres *et al.* (2009) argue that geographic concentration of resources may favour growth.

Results in Torres *et al.* (2009) are in line with studies that explore the impact of more direct measures of mining production or reserves. Davis (1995), for example, showed that countries with a high share of minerals in exports and GDP performed relatively well from 1970 to 1989. The mining share in GDP is also a robust growth regressor 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 this paper, we disaggregate the proxy used in Torres *et al.* (2009) for geographically-concentrated natural-resource abundance and find that the positive effect on growth arises from mineral fuel abundance. However, the impact is no longer significant, narrowing the panel to oil producing countries. Therefore, we propose a more precise measure of geographic concentration to estimate the effect of oil on economic growth through factor efficiency. Due to data limitations, we focus on oil resources, for which we have a single reliable source

(OPEC). The geographic concentration of oil can be seen as a measure of its abundance, in line with Law (1957) and Grace (2005).

We must also consider that the geographic concentration of oil-proved reserves is fundamental in terms of investment flows. Much of the international investment in productive capacity has been undertaken in countries where foreign direct investment has serious restrictions or faces considerable political risk. In prospective terms, this means that, unless there is a full change in policies, political institutions and attitudes, a greater proportion of the cash flow of producing countries will be needed for oil re-investment (Greenspan, 2005).

During the last few years prior to the recent economic downturn, production among international oil (and gas) companies was stagnant**,** despite an increase in global energy demand, both in OECD and emerging economies. Political risk and serious concerns about security of supply are among the main causes of a lack of investment in oil (and gas) exploration and production recognized by the International Energy Agency (Osmundsen *et al*., 2006). While OPEC's market share and influence has been increasing, the production growth among major Western oil (and gas) companies has remained low. Since 1990 there has been a strong reduction in Exploration and Production (E&P) investments**,** and according to certain authors (Stein, 2003; Bertrand and Mullainathan, 2005; Dobbs *et al*., 2006), an increasing share of oil investment has been directed towards short and medium term development projects rather than long-term reserve development.

Therefore, poor institutional quality may reduce the flow of international oil investment and, indirectly, the total amount (and composition) of national investment, and this is especially relevant in the case of high oil concentration countries. The value of institutions and policies in growth is supported by a vast number of empirical studies (*e.g.*, Acemoglu and Robinson, 2006; Acemoglu *et al*., 2005), the same being the case with investment (*e.g.*, Englander and Gurney, 1994; Barro and Sala-i-Martin, 2004).

In this study, the effect of geographic oil concentration on growth is estimated and analyzed in a final panel of 21 countries from 1980 to 2003, taking into account national investment, institutional quality and other growth determinants, such as trade, infra-structures and R&D activities. We use panel analysis as it increases estimation efficiency and allows the control of unobserved country and time effects (which, if not considered, can lead to inconsistent estimates – *e.g.*, Wooldridge, 2002).

The oil concentration measure, our proxy for abundance, is crude oil production *per* rig (rig productivity). Our approach differs from the classic production function with exhaustible resources presented by Dasgupta and Heal (1980). Instead of proven reserves, we use production as a numerator to analyse the ratio's impact on factor efficiency. Since a single rig can explore more than one well, we prefer rigs as the denominator of the ratio.

The impact of oil concentration on growth is then analysed through the use of several dummy variables. In order to capture the most relevant aspects to explain the relationship, we separate countries according to income, technological-knowledge clubs, geographical areas and income inequality. Given our panel of oil producing countries, we would expect different impacts of oil concentration when comparing developed and developing countries, namely because of differences in economic structures.

The paper is structured as follows. In section 2, we derive and present the model specification, including the proposed variable of oil concentration. In section 3, we present and discuss the main results, analysing the oil concentration impact on economic growth through several multiplicative dummies, followed by estimated growth decompositions for some representative countries. Finally, concluding remarks are presented in section 4.

2. The effect of oil concentration on economic growth

This section presents the model specification used to estimate the impact of oil concentration on growth. The model is first derived for natural resources (subsection 2.1) and then modified to estimate and decompose the effect of oil concentration on growth (subsection 2.2).

2.1 Growth accounting model

Production function with factor efficiency

We consider the following Cobb-Douglas production function, at each time *t*:[1]

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

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

The Solow residual is decomposed in terms of improvements to the efficiency of inputs, which, in turn, are "explained" by a set of variables related to natural resources. This means that the contribution of natural resources to growth is measured through the estimation of labour and capital efficiency gains along with the most crucial growth determinants. To estimate the unobserved levels of efficiency, we use the duality qualities/prices of production factors, which, as stressed by Barro (1999), is also a vital growth accounting result.

Specification for labour efficiency

The functional form of constant elasticity for labour efficiency, at each time *t*, is:

$$f(t) = F\left(\frac{I(t)}{L(t)}\right)^{a_1} \left(\frac{T(t)}{L(t)}\right)^{a_2} e^{\int \left(a_3 IQ(t) + a_4 \frac{NresP(t)}{L(t)} + a_5 \frac{NresD(t)}{L(t)}\right) dt}, \text{ where:} \qquad (2)$$

[1] This is in line with Torres *et al.* (2009). We use their dataset starting in 1980, the first year for which we have information from OPEP, to calculate our oil concentration ratio (crude production *per* rig).

(i) F is a scale factor; (ii) I is the investment; (iii) T represents international trade;[2] (iv) IQ is the institutional-quality variable, evaluated by the budget balance as a percentage of GDP;[3] (v) $NresP$ conveys the geographically-concentrated natural-resource abundance; (vi) $NresD$ conveys the diffuse natural-resource abundance;[4] (vii) a_1 and a_2 are (constant) elasticities of f in relation to $\frac{I}{L}$ and $\frac{T}{L}$; and (viii) a_3, a_4 and a_5 are (constant) semi-elasticities of f in relation to IQ, $\frac{NresP}{L}$ and $\frac{OCR}{L}$, respectively. This set of variables is based on several studies (namely empirical) on the subject.[5]

Specification for capital efficiency

The functional form of constant elasticity for capital efficiency, at each time t, is:

$$g(t) = G\left(\frac{RD(t)}{K(t)}\right)^{b_1}\left(\frac{Inf(t)}{K(t)}\right)^{b_2} e^{\int\left(b_3\frac{NresP(t)}{K(t)}+b_4\frac{NresD(t)}{K(t)}\right)dt}, \text{ where:} \quad (3)$$

(i) G is a scale factor; (ii) RD stands for R&D;[6] (iii) Inf is the variable infra-structures;[7] (iv) b_1 and b_2 are (constant) elasticities of g in relation to RD and Inf, respectively; and (v) b_3 and

[2] This variable is measured by the sum of exports and imports (total trade).

[3] The budget balance is a proxy for the quality of fiscal policy (*e. g*., Easterly and Rebelo, 1993; Burnside and Dollar, 2000) and the quality of policies in general (the correlation between the quality of different policies is stressed, *e.g*., by Mauro, 1995, and Stein, 2005). Thus, the budget balance measures institutional quality over time**,** 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).

[4] Since f refers to the efficiency of each worker, the variables were divided by the number of workers, except in the case of *IQ*; *NresD* and *NresP* are measured by the weight of fuels, ores and metals in merchandise exports net of its proportion in imports.

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

[6] The *RD* variable is evaluated by the number of patent applications to national patent offices (*e.g*. Jaffe, 1989).

b_4 are (constant) semi-elasticities of g in relation to $\frac{NresP}{K}$ and $\frac{NresD}{K}$, respectively. This set of variables is also based on several (namely empirical) studies on growth.[8]

Expression (4) is derived from the first order condition for maximising profit in relation to *L*, where $\hat{w}$ represents real wage growth *per* worker and also productivity growth:[9]

$$\hat{w}(t) = (\alpha - 1)\,\hat{L}(t) + \alpha\,\hat{f}(t) + (1-\alpha)\,\hat{K}(t) + (1-\alpha)\,\hat{g}(t)\,, \tag{4}$$

resulting in the following estimation form after substituting $\hat{f}$ and $\hat{g}$:

$$\begin{aligned} \hat{w}(t) = {} & \delta_1\left[\hat{I}(t) - \hat{L}(t)\right] + \delta_2\left[\hat{T}(t) - \hat{L}(t)\right] + \delta_3 IQ(t) + \delta_4\,\frac{NresP(t)}{L(t)} + \delta_5\,\frac{NresD(t)}{L(t)} + \delta_6\left[\hat{K}(t) - \hat{L}(t)\right] + \\ & + \delta_7\left[R\hat{D}(t) - \hat{K}(t)\right] + \delta_8\left[In\hat{f}(t) - \hat{K}(t)\right] + \delta_9\,\frac{NresP(t)}{K(t)} + \delta_{10}\,\frac{NresD(t)}{K(t)} + u(t), \text{ where:} \end{aligned} \tag{5}$$

$\delta_j = \alpha\, a_j$ 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.

To some extent, wages reflect human-capital advances. Thus, the inclusion of wages through the use of the profit-maximising condition for *L* justifies the exclusion of human capital in determining *f*.[10] The capital elasticity is given by the coefficient of $\left[\hat{K} - \hat{L}\right]$ in (5), while the other coefficients represent the impact of the associated variables on growth.

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

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[7] This variable is measured by the number of telephone lines and subscriptions for mobile telephone services (*e.g.*, Roller and Waverman, 2001).

[8] Among these studies, we highlight for *RD* the seminal works of Coe and Helpman (1995) and Barro and Sala-i-Martin (2004), and for *Inf* the prominent works of Argimón *et al*. (1997) and Roller and Waverman (2001).

[9] The circumflex accent conveys the growth rate of the respective variable.

[10] This is in line with theoretical endogenous growth models (*e.g.*, Lucas, 1988, and Romer, 1990), and the empirical studies supported by these models (*e.g.*, Barro, 1991; Benhabib and Spiegel, 1994; Englander and Gurney, 1994).

$$\text{(i)} \quad \hat{w}_{it} = \delta_0 + \sum_{j=1}^{10} \delta_j \left(X_j\right)_{it} + \varphi_{it}, \tag{6}$$

for Pooled OLS and Random Effect Model (REM) with time and country effects, where $\varphi_{it} = c_i + d_t + \omega_{it}$ (i being the country, c_i the country effect, d_t the t effect and ω_{it} a white noise);

$$\text{(ii)} \quad \hat{w}_{it} = \rho_{it} + \sum_{j=1}^{10} \delta_j \left(X_j\right)_{it} + \omega_{it}, \tag{7}$$

for the Fixed Effects Model (FEM) with time and country effects, where $\rho_{it} = \delta_0 + c_i + d_t$.

Each of these models assumes a different hypothesis concerning the possibility of an unobserved element, which, in our case, can be a country effect and/or a time effect.

2.2 The impact of oil concentration

In order to determine the origin of the positive effect of concentrated resources on growth, by capital efficiency (Torres *et al.*, 2009), we decompose the variable $\frac{NresP}{K}$ between mineral fuels ($\frac{NresPF}{K}$) and ores/metals ($\frac{NresPM}{K}$) in (3), and thus in (6) and (7).

Using the variables $\frac{NresPF}{K}$ and $\frac{NresPM}{K}$ instead of $\frac{NresP}{K}$, we re-estimate (6) and (7)**,** and as will become clear in section 3 below, find that only $\frac{NresPF}{K}$ benefits growth. Since $\frac{NresPF}{K}$ is unexpectedly insignificant when the panel is narrowed to oil producers,[11] we build a more precise measure of geographic concentration of fuels. The measure is confined to oil resources due to data availability.

We have named the variable Oil Concentration Ratio (O*CR*), calculated as crude oil production *per* rig (rig productivity). In line with Law (1957) and Grace (2005), this can be seen as a proxy for oil abundance. As already mentioned, we choose oil production as a numerator, instead of proven reserves,[12] because we are explaining factor efficiency. This differs from the classic production function with exhaustible resources presented by Dasgupta

[11] These results are not shown in this paper, but they can be made available upon request.
[12] This has the advantage of allowing a higher number of observations.

and Heal (1980). The use of rigs as a denominator was preferred to wells since a single rig can explore several wells. The data used to build the ratio was obtained from a single source, OPEC, covering 46 countries since 1980 (OPEC, 2007).

The variable *OCR* is introduced in both labour and capital efficiency specifications in the same way as the resource variables in the previous subsection;[13] thus, (6) and (7) become:

$$\text{(i)}\ \hat{w}_{it} = \delta_0 + \sum_{j=1}^{8} \delta_j \left(X_j \right)_{it} + \varphi_{it}\,, \qquad (8)$$

in the case of the Pooled OLS and the REM with time and country effects;

$$\text{(ii)}\ \hat{w}_{it} = \rho_{it} + \sum_{j=1}^{8} \delta_j \left(X_j \right)_{it} + \omega_{it}\,, \qquad (9)$$

for the FEM with time and country effects, with

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

Finally, we decompose the coefficient of $\frac{OCR}{K}$ using several multiplicative dummy variables to explain its significant positive impact on growth (see section 3):

– Income: *HIC*=1(0) and *LIC*=0(1) for High (Low and Middle) Income Countries (World Bank classification, 2007). This dummy evaluates whether the impact of oil concentration differs between rich and middle/low-income countries. We can expect a higher impact in less developed countries, where efficiency levels are lower;

– Technology Clubs: *A*=1(0) and *FM*=0(1) for Advanced (Follower/Marginalised) countries. The empirical analysis of Castelacci (2008) identifies the three technology clubs aforementioned, all showing markedly different levels of technological-knowledge development. The impact of oil concentration on capital efficiency should be higher in countries with low levels of technological-knowledge development;

[13] Since we are no longer analysing the “resource curse”, the natural-resource abundance variables are (now) left out. All the other growth determinants of the original model remain in the specification.

– Geographic groups: *EAP*/*ECA*/*LAC*/*MNA*/*SAS*/*SSA*= 1(0) if country *i* is from East Asia & Pacific/Europe & Central Asia/Latin America & the Caribbean/Middle East & North Africa/South Asia/Sub-Saharan Africa (otherwise). This dummy follows the World Bank (2007) geographic classification for *LIC*, but we also apply it to *FM* countries. Thus, our area dummies identify differences in oil concentration which can result from variations in income, technological-knowledge levels, and also distinct exploration conditions associated with varied local crude oil characteristics (*e.g.*, Law, 1957; Grace, 2005);

– Inequality: *GL*=1(0) and *GH*=0(1) if Gini Index$_i$ <(≥)40. We can expect a higher impact of oil concentration in countries where the oil sector can induce wage inequality due to a productivity advantage over the rest of the economy, typically in developing countries (*e.g.*, Sachs and Warner, 2001). We consider an usual threshold of 40 to separate high from low and medium inequality countries.[14]

Consequently, the vector X_j in our panel specification (8) and (9) is redefined to include the multiplicative dummy variables (which are combined as shown in section 3):

$$X_j = \left\{ \begin{array}{l} \left[\hat{I}-\hat{L}\right], \left[\hat{T}-\hat{L}\right], IQ, \frac{OCR}{L}, \left(\hat{K}-\hat{L}\right), \left[R\hat{D}-\hat{K}\right], \left[In\hat{f}-\hat{K}\right], \frac{OCR}{K}; HIC\times\frac{OCR}{K}, LIC\times\frac{OCR}{K}; A\times\frac{OCR}{K}, FM\times\frac{OCR}{K}; \\ HIC\times\frac{OCR}{K}, LIC\times\frac{OCR}{K}\times\left[EAP, ECA, LAC, MNA, SAS, SSA\right]; \\ HIC\times\frac{OCR}{K}, FM\times\frac{OCR}{K}\times\left[EAP, ECA, LAC, MNA, SAS, SSA\right]; GL\times\frac{OCR}{K}, GH\times\frac{OCR}{K} \end{array} \right\}.$$

3. Results

Table 1 presents the results of the panel estimation forms (6) and (7) with the disaggregated concentrated-resource variables. The estimates come from a FEM with Group and Time effects, chosen according to the test statistics. The insignificance of $\frac{NresPM}{K}$ (at 10%) and the positive estimate of $\frac{NresPF}{K}$ (significant at 5%) show that the effect of concentrated resources

[14] Data from the World Bank (2007).

on capital efficiency arises from mineral fuels.[15] Perhaps the average geographic concentration and economic impact of ore exploration is not high enough to justify a positive impact on growth. The other estimates are similar to Torres *et al.* (2009).

Table 1 – Wage equation with disaggregated concentrated-resource variables (1976-2005)

Panel model		FEM G&T [(a)]
Test Statistics	F [(b)]	3.851
	LM [(c)]	8.69
	Hausman [(d)]	60.24
Dependent variable, $\hat{w}$		
	Constant***	2.254*** (0.091)
	$(\hat{I} - \hat{L})$	0.118* (0.000)
	$(\hat{T} - \hat{L})$	0.117* (0.000)
	IQ	0.148** (0.012)
	$\frac{NresD}{L}$ (e)	-0.004 (0.791)
	$\frac{NresP}{L}$ (e)	-0.038 (0.224)
	$\frac{NresD}{K}$ (e)	0.042 (0.944)
	$\frac{NresPF}{K}$ (e)	1.590** (0.011)
	$\frac{NresPM}{K}$ (e)	-1.101 (0.350)
	$(\hat{K} - \hat{L})$	0.299* (0.000)
	$(\hat{Inf} - \hat{K})$	0.157* (0.000)
	$(\hat{RD} - \hat{K})$	-0.006 (0.389)
	$(\hat{RD} - \hat{K})_{-1}$	0.011*** (0.099)
	$(\hat{RD} - \hat{K})_{-2}$	0.003 (0.691)
	Observations	1005
	R^2	0.497
	Adjusted R^2	0.428

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; estimates obtained with Limdep 8.0 software.

In Table 2, we show some descriptive statistics of the data available for the main variables in our unbalanced panel of 46 oil producers from 1980 to 2005, using Torres *et al.* (2009) dataset and information from OPEC regarding crude production and rigs.[16]

[15] This effect is no longer significant when we narrow the panel to oil producers, as aforementioned, thus justifying the use of a more precise measure of geographic concentration of fuels (rig productivity).

Table 2 – descriptive statistics of main variables for oil producers (1980-2005)

	Mean	S.D.
GDPpc growth	1.587	7.483
$\hat{w}$	0.783	7.971
$(\hat{I} - \hat{L})$	1.994	15.084
$(\hat{T} - \hat{L})$	4.256	12.022
IQ	-2.282	5.749
OCR	139.523	366.807
$\hat{L}$	1.876	4.329
$\hat{K}$	3.861	4.223
$(In\hat{f} - \hat{K})$	8.879	13.093
$(R\hat{D} - \hat{K})$	-2.725	24.541

Notes: percent values (of growth rates and ratios) except in the case of OCR, which conveys thousands of barrels of crude oil a day *per* rig; results based on non-missing observations.

We stress the high standard deviations of the several variables, namely *OCR*, expressing a variety of situations among oil producers. In comparison with the full dataset of 208 countries, we observe smaller average values for $\hat{w}$ and $(In\hat{f} - \hat{K})$, and higher values for the rest of the variables (apart from *OCR*) in oil producers. The average *GDP pc* growth is only slightly higher (1.587% and 1.491%, respectively), but the average $\hat{w}$ is much smaller (0.783% and 1.379%), reflecting a higher progression of other income sources.

The estimation results are shown in Table 3. To take into account the deferred impact of policies on growth and avoid potential endogeneity problems, we first instrument our *IQ* proxy with a two-period lag of the variable and then run the main regressions using a 2SLS approach, which means that the years 2004 and 2005 are not estimated.[17] Since the panel estimation only considers the years with data for all variables in each country, we obtained just over 280 observations in the regressions with all variables, corresponding to 21 countries from 1980 to 2003. In Appendix 1, we present the number of years with complete data for each of the 46 oil producing countries together with the corresponding categories**,** in view of

[16] Our panel excludes oil producers from former USSR and Yugoslavia because they are aggregated in OPEC data, and the same does not happen in the remaining data.

[17] The instrumentation results are not shown here, but they can be made available upon request.

our dummy variables. An inspection of the estimation panel shows enough variability to carry our estimation and exclude selectivity bias problems in most cases.[18]

Table 3 – Wage equations (1980-2003)

Regressions		1	2	3	4	5	6	7
Dummies		None	None	Income	Income; Geogr.(LIC)	Tech. Clubs	T.Clubs; Geogr.(FM)	Inequality
IQ		Present	Absent	Present	Present	Present	Present	Present
Model		REM G&T						
Test Statistics	Hausman	5.55	7.94	5.76	9.73	6.53	10.81	5.91
	LM	15.29	21.19	15.44	15.08	15.12	14.94	15.58
	F	2.883	2.598	2.869	3.036	2.916	3.097	2.861
Dependent variable		$\hat{w}$						
Constant		0.405	1.000	0.443	0.173	0.272	-0.079	0.459
		(0.343)	(0.094)	(0.376)	(0.100)	(0.223)	(-0.046)	(0.389)
$(\hat{I} - \hat{L})$		0.064**	0.071**	0.063**	0.067**	0.065**	0.069*	0.063**
		(2.353)	(3.154)	(2.314)	(2.493)	(2.399)	(2.587)	(2.311)
$(\hat{T} - \hat{L})$		0.069	-0.009	0.070	0.075	0.070	0.075	0.070
		(0.991)	(-0.166)	(1.000)	(1.076)	(1.002)	(1.081)	(1.000)
IQ		0.420***		0.431**	0.417***	0.402***	0.401***	0.432**
		(1.944)		(1.983)	(1.866)	(1.845)	(1.785)	(1.989)
$\frac{OCR}{L}$ (b)		-0.006	-0.017	-0.002	-0.001	0.034	0.046	-0.001
		(-0.355)	(-1.138)	(-0.090)	(-0.078)	(0.754)	(0.977)	(-0.070)
$\frac{OCR}{K}$ (b)		0.142***	0.168**					
		(1.833)	(2.277)					
Income Dummies	$HIC \times \frac{OCR}{K}$			0.105	0.138			
				(1.089)	(1.228)			
	$LIC \times \frac{OCR}{K}$			0.192***				
				(1.771)				
Tech.Clubs Dummies	$A \times \frac{OCR}{K}$					-0.230	-0.306	
						(-0.572)	(-0.731)	
	$FM \times \frac{OCR}{K}$					0.091		
						0.948)		
Geogr. Dummies for LIC; FM	$EAP \times \frac{OCR}{K}$				32.758*		32.906*	
					(3.097)		(3.116)	
	$LAC \times \frac{OCR}{K}$				0.193***		0.103	
					(1.731)		(1.012)	
	$MNA \times \frac{OCR}{K}$				-0.461		-0.416	
					(-0.228)		(-0.205)	
	$SAS \times \frac{OCR}{K}$				6.271		7.511	
					(0.204)		(0.244)	

[18] Considering our dummies, only Sub-Saharan countries (SSA) are not estimated in our regressions due to data constraints. Middle East countries are also clearly misrepresented in our dummy MNA (only one observation from Iraq) due to data availability.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$ECA \times \frac{OCR}{K}$						11.253 (0.399)	
Inequality Dummies: $GL \times \frac{OCR}{K}$							0.101 (1.051)
Inequality Dummies: $GH \times \frac{OCR}{K}$							0.197*** (1.815)
$(\hat{K} - \hat{L})$	0.304* (5.855)	0.317* (6.433)	0.302* (5.799)	0.300* (5.841)	0.303* (5.845)	0.302* (5.892)	0.302* (5.795)
$(\hat{Inf} - \hat{K})$	0.143* (2.803)	0.040 (1.008)	0.135* (2.588)	0.127** (2.423)	0.146* (2.851)	0.135* (2.634)	0.134** (2.567)
$(\hat{RD} - \hat{K})$	0.022 (1.550)	0.019 (1.409)	0.023 (1.623)	0.023 (1.575)	0.021 (1.514)	0.022 (1.524)	0.023 (1.627)
$(\hat{RD} - \hat{K})_{-1}$	0.014 (1.001)	0.004 (0.336)	0.017 (1.121)	0.017 (1.146)	0.014 (0.989)	0.015 (1.047)	0.017 (1.138)
$(\hat{RD} - \hat{K})_{-2}$	-0.014 (-0.864)	-0.016 (-1.078)	-0.013 (-0.829)	-0.014 (-0.891)	-0.013 (-0.832)	-0.015 (-0.913)	-0.013 (-0.821)
Observations	284	327	284	284	284	284	284
$R^{2\,(a)}$	0.518	0.466	0.518	0.546	0.522	0.551	0.518
Adjusted $R^{2\,(a)}$	0.407	0.353	0.404	0.432	0.409	0.435	0.404

Notes: the estimation period was determined by available data for the oil concentration proxy (from 1980 to 2006) and for the remaining variables (from 1976 to 2003 with uninstrumented *IQ*); see notes in Table 1; (a) From the FEM G&T; (b) To avoid values close to zero, the ratio of *OCR* to *L* was multiplied by 10^3 and the ratio of *OCR* to *K* by 10^{10}, expressing indices of oil concentration *per* unit of factor; see notes in Table 1.

According to test statistics, the REM with Group and Time Effects is the adequate model for all regressions in Table 3 – estimation form (8).

In the first regression, we can see a positive impact of oil concentration on *g* (coefficient of $\frac{OCR}{K}$), significant at 10%, and a negative but not significant effect through *f*. The variables *I*, *IQ* and *Inf* also benefit growth in oil producers, with significance levels of 10%, 5% and 1% respectively, while *T* and *RD* are not significant at 10%.[19] The estimate of capital elasticity is 30.4% (significant at 1%), slightly below the usual reference of one third.

In the second regression, we show that the impact of oil concentration on growth is higher (and significant at 5%) when we exclude the *IQ* variable. Thus, it seems that a higher

[19] As in Torres *et al.* (2009), we also add the first two lags of *RD* to capture a (deferred) positive impact of R&D. However, neither of the associated coefficients was significant at 10% in our regressions, maybe due to some limitations of our proxy (number of patent applications to national patent offices), namely the exclusion of applications to regional patent offices, which confer protection in the respective areas.

budget balance reduces the effect of oil concentration on growth, perhaps because of less public re-investment in the oil sector, although one should expect higher foreign investment in risky countries associated with the corresponding increase in institutional quality.

The other regressions in Table 3 decompose the impact of $\frac{OCR}{K}$ using the multiplicative dummy variables selected in section 2. Regression 3 shows that a higher oil concentration increases growth by *g*, only in low and middle income countries (the coefficient of $LIC \times \frac{OCR}{K}$ is positive and significant at 10%, while the estimate for $GL \times \frac{OCR}{K}$ is insignificant), as expected. This positive effect originates in East Asia & Pacific and Latin America & low and middle-income Caribbean countries, as we can see in the fourth regression (the coefficients for *EAP* and *LAC* are significant at 1% and 10%, respectively). In the case of *EAP*, the only country represented is Malaysia, which presents the highest contribution of oil concentration to growth in the estimated panel (an average of 52.3%) despite the low levels of *OCR* (an average of 4.374 in the estimated period, much smaller than sample value) and $\frac{OCR}{K}$.[20]

In regression 5, the impact of $\frac{OCR}{K}$ is decomposed between technological-knowledge clubs, but neither *A* nor *FM* groups are significant. When we apply the geographical dummies to *FM* countries in regression 6, we find that only *EAP* is significant (again, only Malaysia is represented), at 1%. The *LAC* group is not significant for *FM* countries**,** due to the inclusion of Trinidad and Tobago, a high income country. All estimated countries in these two area groups are followers in terms of technological-knowledge convergence.[21]

Finally, in regression 7 we find that an increase in oil concentration benefits growth by *g* only in countries with high inequality (the coefficient of $GH \times \frac{OCR}{K}$ is positive and significant

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[20] We found a mild positive correlation between the series *OCR* (and also $\frac{OCR}{K}$) and oil concentration estimated growth contribution.

[21] Algeria, Egypt (*MNA*) and India (*SAS*) are the only marginalized countries included in our estimated panel.

at 10%, while the estimate of $GL \times \frac{OCR}{K}$ is insignificant). We stress that all high inequality countries in our estimated panel belong to the *LIC* group**,** with the notable exception of the United States, which probably reduces the significance of $GH \times \frac{OCR}{K}$. The decomposition of $GH \times \frac{OCR}{K}$ according to area groups did not produce significant results.[22]

No major differences were found concerning the estimates of the other growth determinants in comparison with the first regression.

Estimated growth decomposition

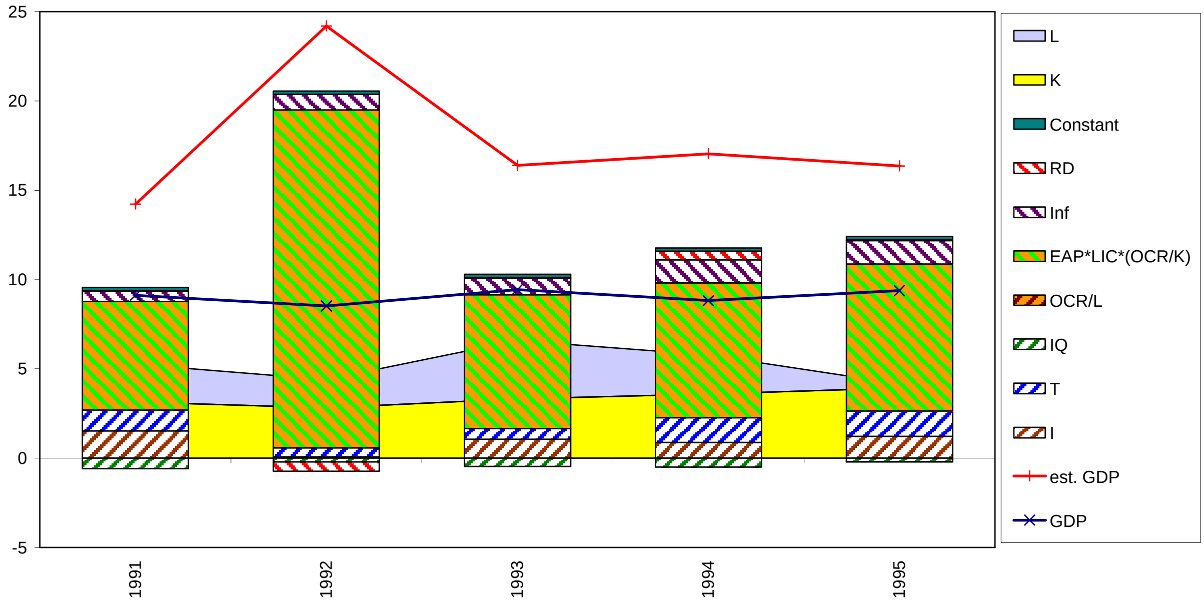
Based on the fourth regression in Table 2, where two area dummies are significant, we now analyse the evolution of real GDP growth and the estimated GDP growth decomposition for some representative countries, taking into account the highest contributions arising from *OCR*. We chose Malaysia and Colombia because they show the highest contributions in *EAP* and *LAC*, the two significant *LIC* area groups, respectively. Despite the insignificant coefficients associated with *OCR* in *HIC*, we also found important contributions in New Zealand and Norway**.** Thus we included these countries in our growth decompositions. In Appendix 2, we explain in detail how the first decomposition chart is interpreted.

(i) Malaysia

Figure 1 shows the decomposition for Malaysia from 1991 to 1995. The impact of *OCR* by *g* in the column of Total Factor productivity (TFP) explains most estimated growth, followed by *K* and *L* contributions. We also stress the positive impact of *T* and *I* (by *f*), and *Inf* (by *g*). Apart from the year 1992, estimated GDP growth captures relatively well the magnitude and evolution of actual product growth.

[22] This is why we don't present these results in Table 3, but they can be made available upon request.

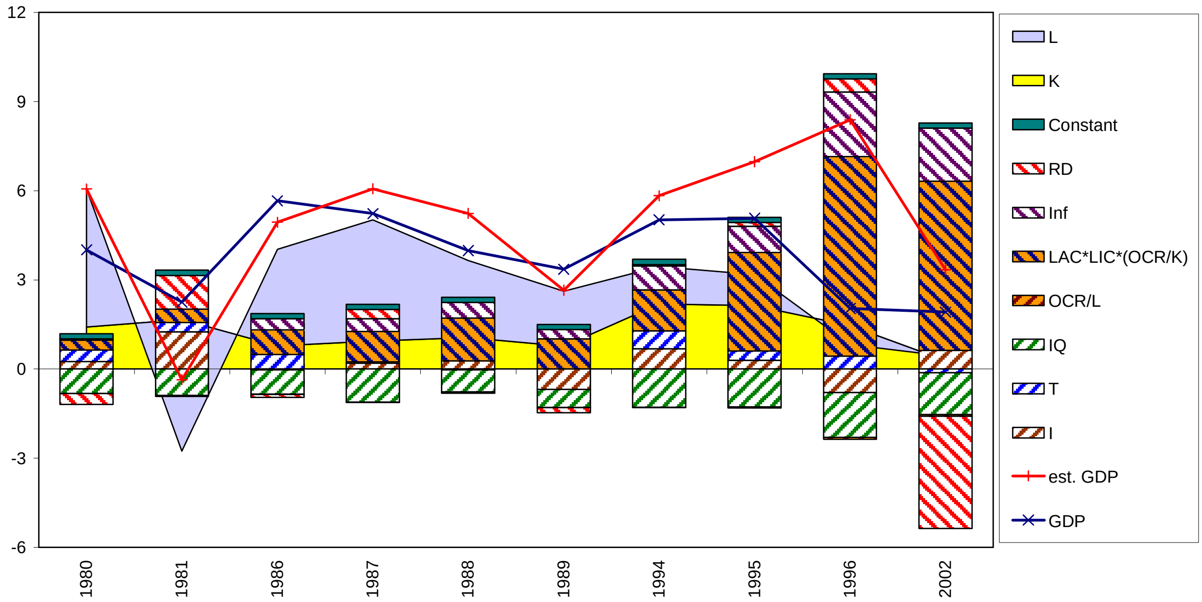
Figure 1 - Malaysia real GDP growth (%) and estimated growth decomposition



(ii) Colombia

In Figure 2, we can see that *L* and *K* are gradually replaced by $\frac{OCR}{K}$ as the most important growth factors of Colombia during the estimation period (1980-2002). The contribution of *Inf*, by *g*, is also important and contrasts with the negative effect of *IQ*.

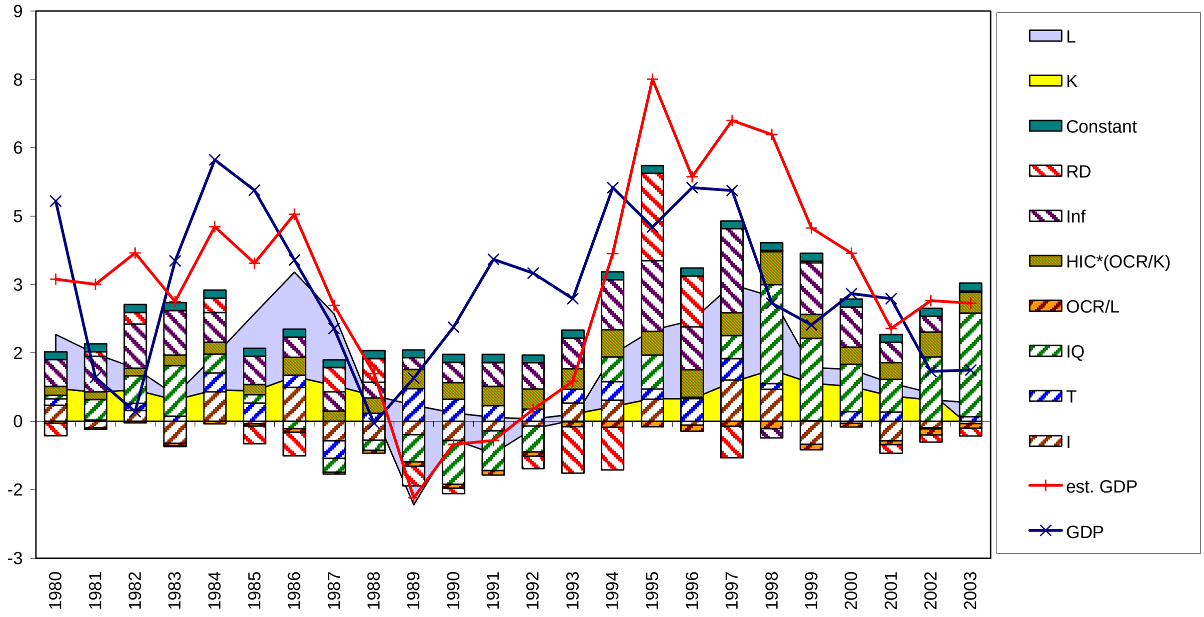
Figure 2 - Colombia GDP growth (%) and estimated growth decomposition



(iii) Norway

In the case of Norway, we have a more balanced decomposition (from 1980 to 2003), with varied contributions in TFP. We stress the positive stable contributions of *Inf* and *OCR* (by *g*), and also the important impacts of *IQ*, *T* and *RD*, despite negative values in some years.

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

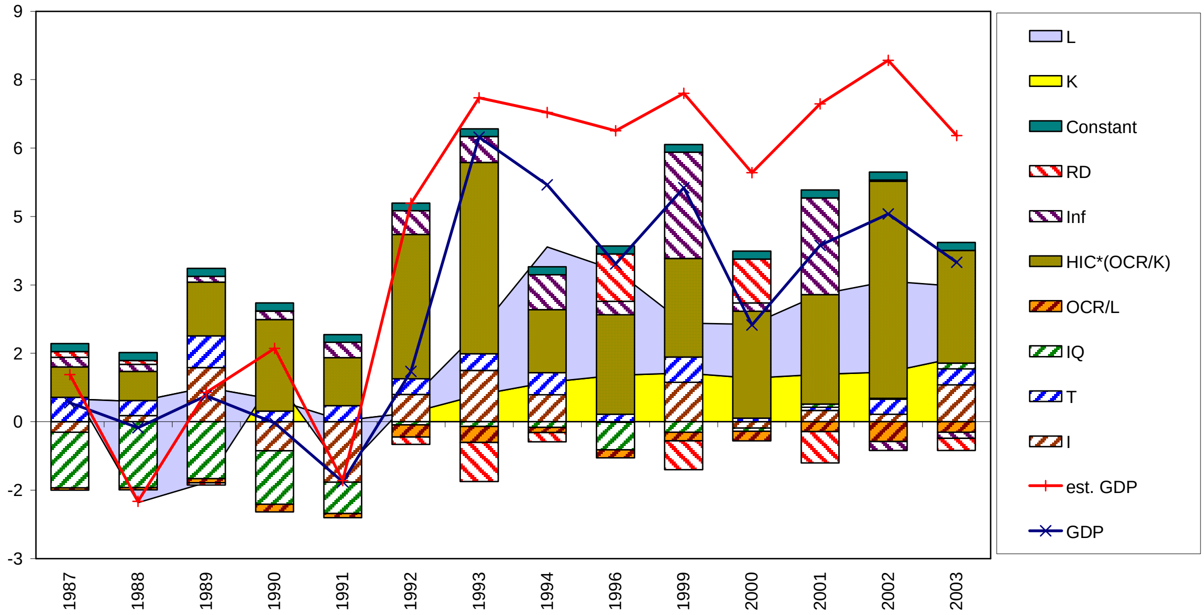


(iv) New Zealand

We also find varied contributions in the case of New Zealand, but the impact of $\frac{OCR}{K}$ is much more predominant than in the previous case, explaining most of the estimated growth, especially before 1993, when *L*, *K* and *IQ* showed negative contributions.[23] We also observe a steady positive impact of *T*, and in some years, good contributions from *RD* and *Inf*.

[23] Notice that Norway and New Zealand belong to the advanced technological-knowledge club, which is reflected in *RD* contribution. The *RD* effect is less visible in the case of Malaysia and Colombia, both follower countries.

Figure 4 - New Zealand real GDP growth (%) and estimated growth decomposition



4. Concluding remarks

In this study, we have examined the impact of geographic concentration of oil on economic growth through panel analysis, taking into consideration the positive effect of geographically-concentrated natural-resource abundance found in Torres *et al.* (2009).

We show that the above-mentioned positive effect originates in mineral fuels, justifying a deeper analysis in a panel of oil producing countries, but this could only be done with a refined measure of geographic concentration and abundance of oil. The choice was crude oil production *per* rig. We then estimated the impact of oil concentration on growth through labour and capital efficiency and decomposed the latter effect using an original combination of dummies.

Our results show that an increase in geographic oil concentration benefits growth through capital efficiency. However, this only happens in countries with low and middle incomes (from East Asia & the Pacific and Latin America & the Caribbean, all followers in terms of technological-knowledge convergence), and showing high-income inequality. This happens because only in developing countries can the oil sector induce a productivity advantage over the rest of the economy, driving growth and inducing wage inequality (*e.g.*, Sachs and Warner, 2001). Distinct oil exploration conditions may explain why only two of our area groups for low and middle-income countries show significant impacts of oil concentration by capital efficiency. In our view, the overall results reflect the broader scope for factor-efficiency increases in less-developed countries arising from the oil industry, which is characterised by a highly globalised know-how.

Finally, we present the estimated growth decompositions for countries with the highest oil concentrations in view of our income/area categories. We stress the high importance of the oil concentration effect in Malaysia (the country with the highest contribution of oil concentration to growth in the estimated panel despite the low levels of concentration) and Colombia decompositions, in contrast to the balanced decomposition of Norway, where we also find impacts from important growth factors such as trade, institutional quality and R&D, as expected in a high-income and advanced technological-knowledge country. New Zealand, however, is also an advanced high-income and technological-knowledge country, and shows a high predominance of oil concentration contribution, followed by trade and, in some years, R&D and Infrastructures, highlighting the diversity of situations among oil producers.

It is expected that future research will attempt to overcome data constraints and include data regarding natural gas and more countries. Despite this, we believe the above-mentioned constraints are not crucial enough to alter the major conclusions of this study.

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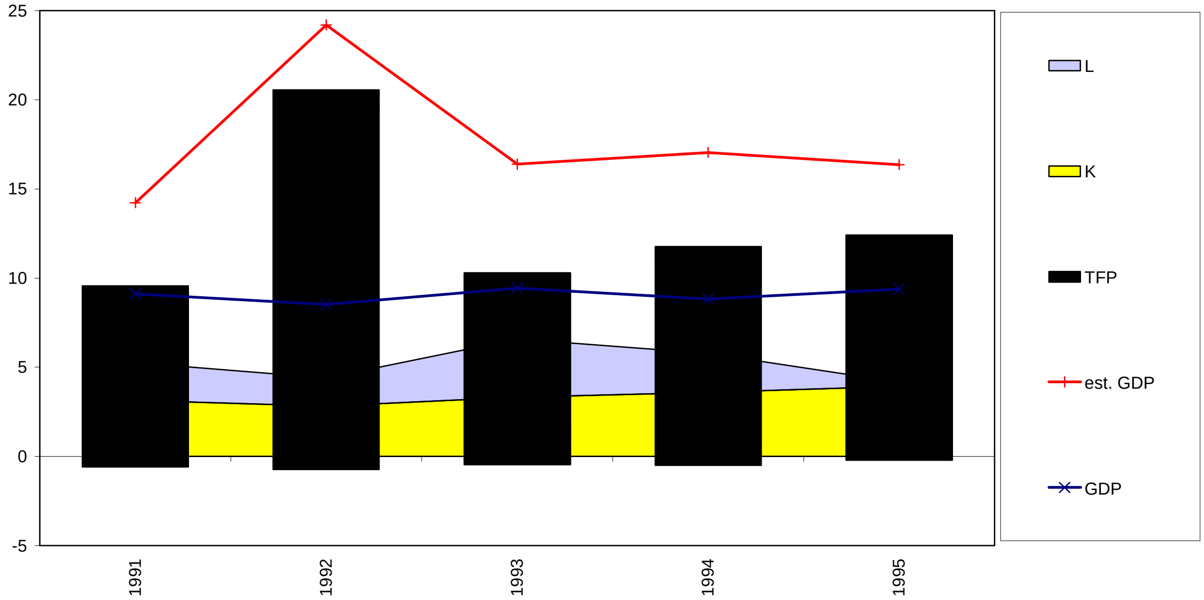
APPENDIX 1 – Estimated panel data

	Oil producer	t=t0	t=T	N	Dummies			
					Geog.(for LIC; FM)	Income	Tech.Clubs	Inequality
1	Algeria	1994	2000	7	MNA	LIC	FM	GL40
2	Argentina			0	LAC	LIC	FM	GH40
3	Australia	1980	2003	24		HIC	A	GL40
4	Bahrain			0	MNA	HIC	FM	n/a
5	Brazil			0	LAC	LIC	FM	GH40
6	Brunei			0		HIC	n/a	n/a
7	Cameroon			0	SSA	LIC	FM	GH40
8	Canada	1980	2003	24		HIC	A	GL40
9	Chile	1980	2003	21	LAC	LIC	FM	GH40
10	China			0	EAP	LIC	FM	GH40
11	Colombia	1980	2002	10	LAC	LIC	FM	GH40
12	Congo, Dem. Rep.			0	SSA	LIC	FM	n/a
13	Denmark			0		HIC	A	GL40
14	Ecuador	1989	1994	2	LAC	LIC	FM	GH40
15	Egypt, Arab Rep.	1991	2001	5	MNA	LIC	FM	GL40
16	France	1980	2003	21		HIC	A	GL40
17	Gabon			0	SSA	LIC	FM	n/a
18	Germany	1980	2003	24		HIC	A	GL40
19	Hungary			0	ECA	LIC	FM	GL40
20	India	1995	1998	4	SAS	LIC	FM	GL40
21	Indonesia			0	EAP	LIC	FM	GL40
22	Iran, Islamic Rep.	2001	2001	1	MNA	LIC	FM	GH40
23	Iraq			0	MNA	LIC	n/a	n/a
24	Italy	1980	1985	6		HIC	FM	GL40
25	Kuwait			0	MNA	HIC	FM	n/a
26	Libya			0	MNA	LIC	n/a	n/a
27	Malaysia	1991	1995	5	EAP	LIC	FM	GH40
28	Mexico	1992	2003	12	LAC	LIC	FM	GH40
29	Netherlands	1980	2003	22		HIC	A	GL40
30	New Zealand	1987	2003	14		HIC	A	GL40
31	Nigeria			0	SSA	LIC	FM	GH40
32	Norway	1980	2003	24		HIC	A	GL40
33	Oman			0	MNA	LIC	FM	n/a
34	Peru			0	LAC	LIC	FM	GH40
35	Qatar			0		HIC	n/a	n/a
36	Romania			0	ECA	LIC	FM	GL40
37	Saudi Arabia			0	MNA	HIC	FM	n/a
38	Syrian Arab Republic			0	MNA	LIC	FM	n/a
39	Trinidad and Tobago	1980	2002	3	LAC	HIC	FM	GL40
40	Tunisia			0	MNA	LIC	FM	GL40
41	Turkey			0	ECA	LIC	FM	GH40
42	United Arab Emirates			0	MNA	HIC	FM	n/a
43	United Kingdom	1980	2003	24		HIC	A	GL40
44	United States	1980	2003	20		HIC	A	GH40
45	Venezuela, RB	1980	1994	11	LAC	LIC	FM	GH40
46	Yemen, Rep.			0	MNA	LIC	FM	GL40
# =21	Estimation Panel	1980	2003	284		N=284	N=284	N=284

Data based on authors' own estimations. Notes: we exclude oil producers from the former USSR and Yugoslavia because they are aggregated in OPEC data, and the same does not happen in the remaining data; $t = t_0$ and $t = T$ indicate the initial and final years with information for all variables, respectively; and N corresponds to the number of years with complete data for each oil producer; n/a stands for non available data.

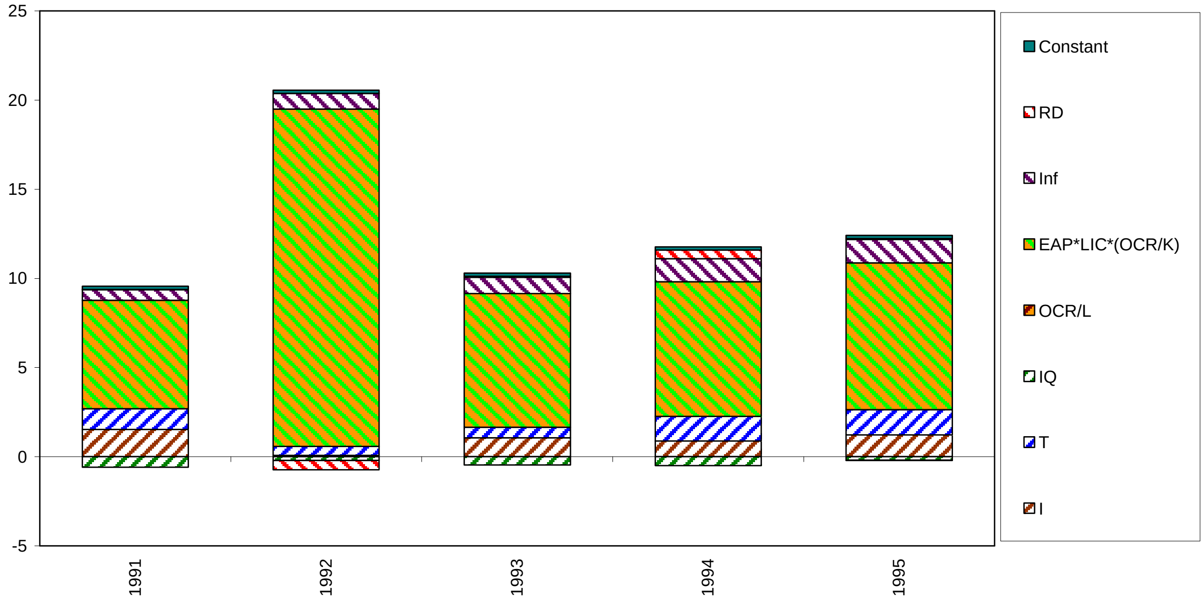
APPENDIX 2 – Malaysia growth decomposition explained in detail

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



In Figure 5, the blue line represents actual real GDP growth and the red line shows estimated growth, which results from the sum of the other components in the graph. The blue and yellow areas represent the physical contributions of labour and capital stocks to estimated GDP growth in each year, respectively, while the columns' net value constitutes the TFP impact.

Figure 6 - Malaysia estimated TFP decomposition



In Figure 6, we show in detail the estimated TFP growth decomposition: the rectangles in green, 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 oil concentration ratio through labour and capital efficiency are highlighted by an orange background.

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