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Economic Growth, Consumption and Oil Scarcity in Colombia: A Ramsey model, time series and panel data approach

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Este borrador es resultado de una investigación autónoma realizada con el apoyo del Grupo de Economía del Medio Ambiente —GEMA— del Centro de Investigaciones Económicas —CIE— de la Universidad de Antioquia. Constituye un primer acercamiento al tema de recursos naturales y las implicaciones económicas que su escasez o disponibilidad tiene para la economía colombiana.

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ECONOMIC GROWTH, CONSUMPTION AND OIL SCARCITY IN COLOMBIA: A RAMSEY MODEL, TIME SERIES AND PANEL DATA APPROACH

Danny García Callejas[1]

Resumen: este artículo muestra la relación que existe entre el crecimiento económico, del consumo y de la disponibilidad de petróleo en Colombia. Primero se realiza un análisis teórico modificando el modelo de crecimiento de Ramsey para incluir una variable que represente la disponibilidad de petróleo, llegando a la conclusión que la tasa de crecimiento del consumo está directamente relacionada con la tasa de crecimiento de la producción de petróleo. Luego, por medio de un modelo de series de tiempo y panel de datos se verifica este resultado teórico y se muestra que la disponibilidad de petróleo contribuye al menos en un 13% en la tasa de crecimiento económico de Colombia.

Palabras clave: consumo, crecimiento económico, escasez, reservas y producción de petróleo.

Abstract: this paper shows the existing relation between economic growth, consumption and oil availability growth rate in Colombia. Firstly a theoretical analysis using a modified Ramsey growth model in which a variable that represents oil availability is performed, concluding that consumption's growth rate is directly related with oil production growth rate. Later, this theoretical result is verified using a time series and panel data analysis which shows that oil availability provides at least a 13% of Colombia's economic growth.

Key words: consumption, economic growth, scarcity, oil production and reserves.

JEL classification: Q01, Q32, Q38, Q43.

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Introduction

The Ramsey (1928), Harrod (1939) Domar (1946) and Solow (1956) Swan growth models represent economist's concerns about economic growth and their possible determinants, however, new difficulties and the importance of natural resources on growth generate new questions that should be answered and that can still be analyzed using their theoretical approaches. This paper takes advantage of the Ramsey (1928) growth model and modifies it to include a non-renewable resource as oil. After solving the model an interpreting its outcomes, the main conclusion is that consumption growth rate is directly related with oil production growth rate or oil reserves, that is, if an economy has oil scarcity and cannot obtain it from other sources, for example imports or input substitution, then its future consumption can be jeopardized.

The economic data and statistics on oil, consumption and economic growth present a direct association that entails Latin America to have a constant source of this input. Even though this region possesses important reserves the amount they demand is also high and according to Jones (2003) this estimate of reserves could exceed the true available quantity. Such a situation would put Latin-American countries in a complicated position that would require, in order to surpass it, substitutes of this input or other energy sources different from those provided by oil. This paper evidences through a panel data and time series analysis that a reduction in oil availability could reduce Colombia's growth rate in at least 13%.

Developing countries have been demanding more oil and require it every time more and more. According to Gately and Streifel (1997) world oil demand in the 1971 – 1993 period has increased in 18.3 million barrels per day and for that increase developing countries are the most responsible since they participated with 14.2 million barrels per day from the quoted increase. Therefore, future research must not be disregarded because developing countries like Latin-American ones require more oil every year and the effects of oil shocks on these economies and the microeconomic effects and between sector impacts of this possible situation using a general equilibrium frame should be studied.

This paper is divided in three sections: firstly an interpretation of statistic and descriptive data using bar and time series graphs is made; secondly a modified Ramsey growth model that includes oil in which a mathematical approach and the model's economic interpretation will be encountered. Thirdly, an empirical approach using time series and panel data analysis that proves the theoretical and model's statements is presented. Finally, the most relevant conclusions and references used in this paper will be detailed.

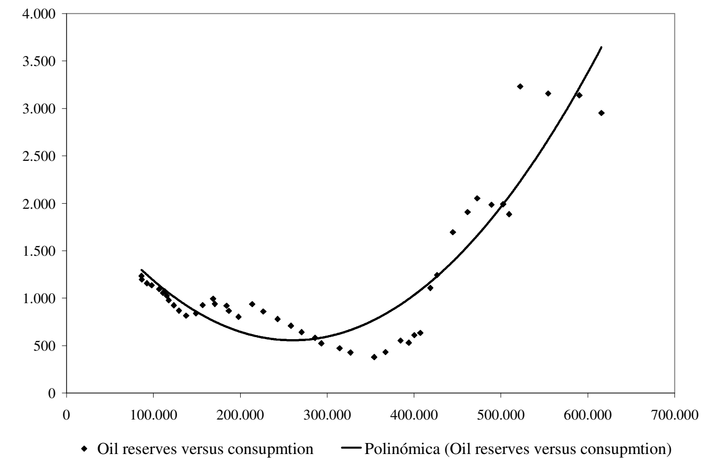
I. Oil as a Scarce Resource

The planet can run out of oil in any moment because the available quantity of oil on earth is practically fixed and reserves are lesser than expected (Jones, 2003). Oil is produced by the earth, but its renewal rate is very low and near to zero making it a non-renewable resource but current extraction levels will not allow oil to renew, therefore it will disappear. "As geologists make clear, there is an embarrassingly limited amount of conventional oil in the earth's crust, and it is *not* wise to suppose that these assets can be greatly augmented" (Banks, 1997, p. 2).

Even if it is thought that the fixed quantity is very big and high oil sector productivity will save us (Rauch, 2001), it can be quoted that "Although some economists still find it possible to claim that oil is inexhaustible, geological authorities are increasingly expressing the belief that this resource is painfully finite in an economic sense, because eventually it might become too costly to produce in amounts supplied earlier" (Banks, 1997, p. 1), and this shows how the production, of this resource, will have to decline in some moment of time.

As Graph 1 illustrates, the Colombian case will not be as different as the one predicted by the theory and the results of the modified Ramsey Model in section 2. This South American country might see its consumption possibilities reduced in the future if it does not search for a commodity that substitutes its oil needs or if new reserves are not discovered. Graph 1 warns on this possibility: there is a positive relation between consumption and oil reserves, therefore if oil reserves reduce consumption will follow the same pattern; this idea will be confirmed through the time series and panel data econometric models.

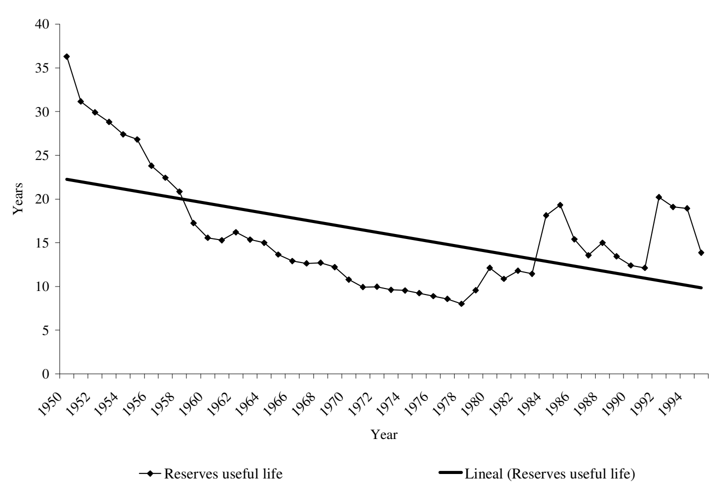
Graph 1. Colombia: Oil Reserves and Consumption, 1950-1995



Source: Autor's calculation. Ecopetrol (2004), DNP (2004) and Dane (2004).

The concerning problem is that duration of oil reserves in Colombia have been diminishing in an important way. Graph 2 shows this tendency that seems to sustain in the long run. This problem is not despicable since it could generate a consumption and production abridgement. As Halvorsen and Smith (1986) show, the possibility of reducing the effects that the scarcity of a natural resource can cause on the economy is through a substitute that does not have a high price. The problem is that a high price of a natural resource can be a signal of its depletion (Hotelling, 1931), nevertheless, this could appear only towards the end of its exhaustion what does not allow this variable to control demand and secure its future availability (Reynolds, 2004).

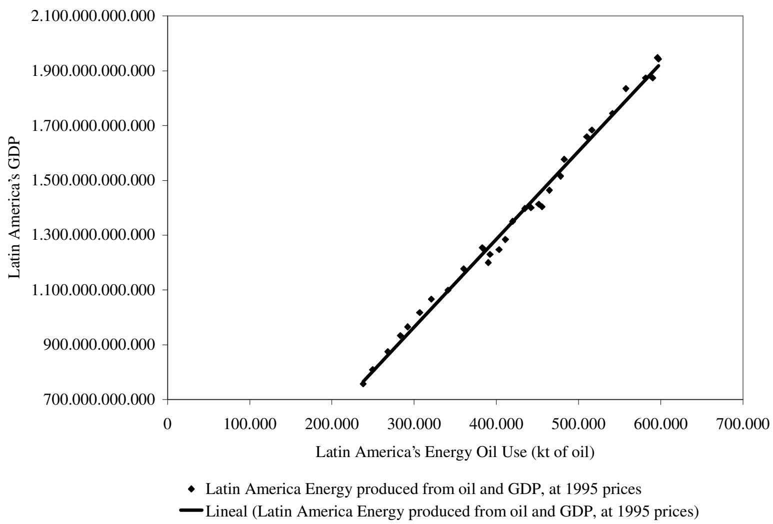
Graph 2. Colombia: Oil Reserves Useful Life



Source: Autor's calculation. Ecopetrol (2004), DNP (2004) and Dane (2004).

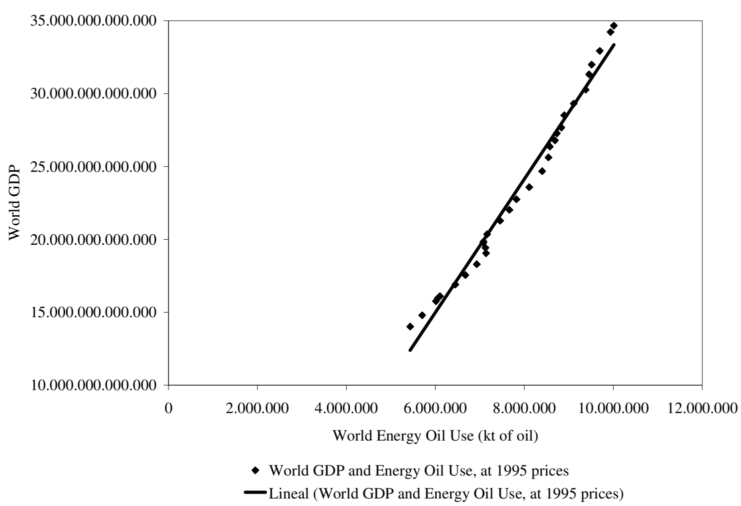
The Latin American and World economies are oil dependant. As graphs 3 and 4 present, there is a positive relation between production and oil energy use. Modern economies can not move without fuel that is why oil price increases affect economic growth and can even generate recessions, they are simple too oil dependant (Irons, 2000). Recessions will bring low income and thus will add consumption abridgement worsening the situation and obliging economies to find cheaper and more reliable energy alternatives.

Graph 3. Latin America: GDP at 1995 Prices and Energy produced from Oil (kt of oil), 1971-2001



Source: Author's calculations. World Bank (2004).

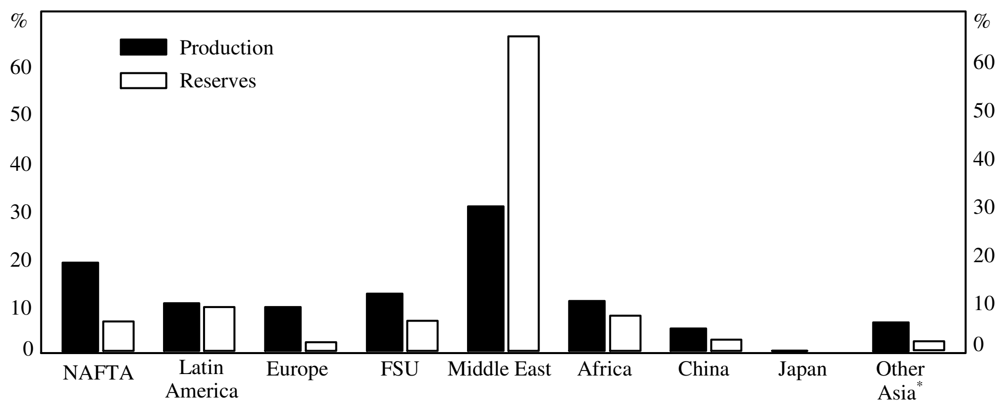
Graph 4. Earth: GDP at 1995 prices and Energy Oil Use (kt of oil), 1971-2001



Source: Author's calculations. World Bank (2004).

The Latin American case discloses a positive relation between GDP production and energy production since the later is an important input of the former. The outlook is far worse than expected. Latin-American reserves account for almost 10% of worldwide oil availability and according to a recent —2003— study made by Sweden's Uppsala University, oil reserves are at least 80% lesser than predicted and production levels will peak in the next ten years (Jones, 2003).

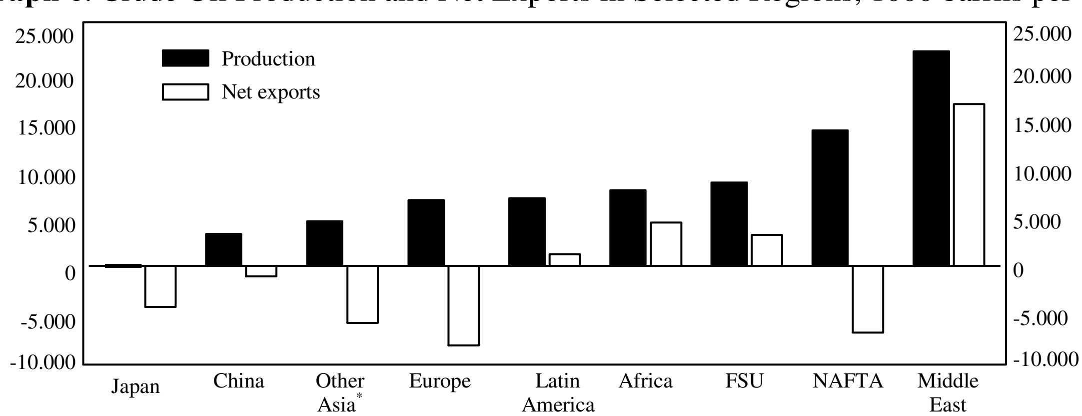
Graph 5. Share of World Crude Oil Reserves and Production by Region



Source: Carvahlo and Suni (2002, p. 56).

The Latin-American and Colombian scenario worsen when the net exports are examined in Graph 6, not only the region does not have a high reserve level but it is increasingly importing crude oil and in the near future will become a net importer that will depend directly on its international providers that do not have as much as it was thought (Jones, 2003). As Olson (1988) arguments, oil shocks can aggravate GDP recessions, contribute to diminish productivity and generate macroeconomic instability, problems that can exacerbate distribution and poverty problems in the region.

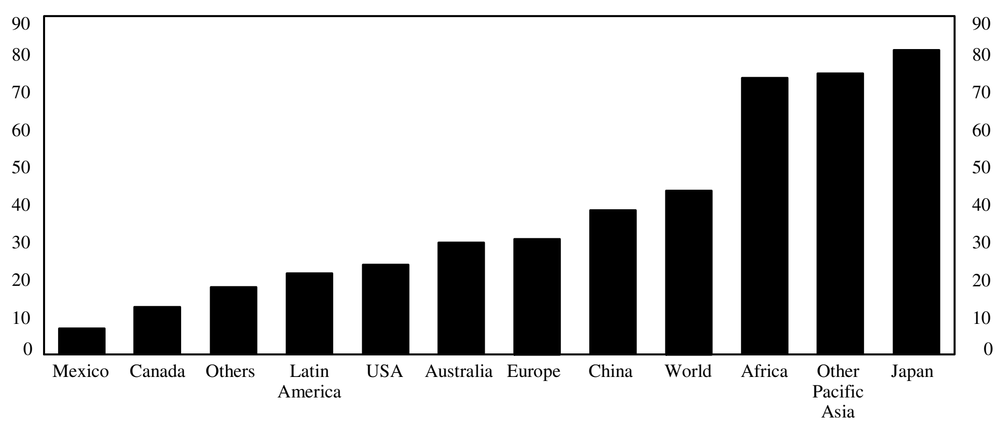
Graph 6. Crude Oil Production and Net Exports in Selected Regions, 1000 barrils per day



Source: Carvahlo and Suni (2002, p. 56).

The dependency on Middle East Crude Oil is a key factor that can bring difficulties for all economies in the future. In 2000 40.2% of the World's total oil supply was met by the Organization of Petroleum Exporting Countries —OPEC— (Perry, 2001) and in 2003 the Middle East —which includes part of the OPEC members— produced 30% of the World's consumption (Esser, 2004). Graph 7 shows a difficult prospect for Japan which imports from the Middle East more than 80% of the oil it requires. Even though Latin America appears to be in the last places in this category, it does need to import at least 25% from this Arab region. The problem is that reserves are estimated to hold until 2050 or, in the best scenario, until 2080 (Vozza, 2003), situation that will bring yield complications and generate incentives to countries intensive in oil as an input to search for a substitute.

Graph 7. Dependency on Middle East crude oil in selected regions, share in total oil imports, in percentage



Source: Carvahlo and Suni (2002, p. 56).

Perhaps one of the alternatives is international commerce and the discovery of new reserves that will satisfy world oil demands —improbable according to Jones (2003)—. The first one will reduce recession possibilities of Developing countries only if they can trade with big oil producers and not find that these only sell to Developed countries as Lawrence and Levy (1982) show. If price does correct demand due to resource exhaustibility as Hotelling (1931) explains then the risk of a major crash appears to be real if there are no available substitutes. That impossibility of price to correct demand is more plausible than Hotelling's (1931) idea (Aldeman, 1990, p. 9) since price can rise at a high point when agents think that the resource is scarce but as it is exploited and demand increases its price elevates lesser. Krautkraemer (1998, pp. 2066) also exhibits how in the last 125 years there has not been a price that can control resource depletion.

II. Ramsey's Growth Model and Oil

Ramsey's growth model was developed in 1928 and, since then, it has been applied to different economical situations. In this case, we will apply such model to the oil sector in order to try to establish the theoretical relation between oil supply's growth and economical growth. The idea, then, is to see the long run consequences on growth of oil supply changes; for this a Ramsey model with oil as a natural resource that generates utility to economic agents will be introduced in order to determine the new variable's consequences to growth.

We will assume that this economy produces two goods: the first one is a "generic" good that can be consumed or saved and that only requires of capital (K) and labor (L) to be supplied; the second one will be oil (P) that is only available in a fixed quantity, therefore, it is treated as a non-renewable resource. We will also assume that economical agents have a utility function in which they include these two goods from which they obtain satisfaction when they are consumed (C). This economy's production pattern will be represented through a Cobb Douglas production function (1).[2]

$$Y = F(K, L) = Ak^{\beta} \qquad (1)$$

Utility hill have positive but diminishing marginal utility returns (2).

$$U'(c, p) > 0 \text{ y } U''(c, p) < 0. \qquad (2)$$

It will also be assumed that this economy has a population that represents entirely its labor force that grows at a fixed rate called *n*. We can describe the mass of workers at any moment in time by the equation $L = e^{nt}$, where *t* represents the different periods of this economy.

The agent's utility function in this economy will be the combination of the proposed function by Cash and Koopmans and the utility function that agents would have if the only good in the economy were oil. The latter is going to be an exponential function like this one: P^{α}, where $\alpha < 1$ is a parameter. Hence, supposing that these two functions can be united in one that is using the separability and adding-up properties, then the following expression can be obtained:

[2] To identify *per capita* variables, lowercase letters will be used.

$$U(c)=\frac{c^{1-\theta}-1}{1-\theta}+\mathrm{P}^{\alpha} \qquad (3)$$

In this way, the consumption side of this economy has been showed, however, agents can save their goods and this is essential in the economy's growth because it will be through savings that capital will grow and, therefore, production. This is observed in equation (1) where production has a positive relation with capital's per capita amount. In consequence, the condition for capital growth is given by:

$$\dot{K}(t)=F(K,L)-C-\delta K \qquad (4)$$

Thus, it is clear that the economy's problem is to maximize economical agent's utility subject to their saving capacity but —taking in account the depreciation rate (δ)— because the latter is the principal long run growth cause; and, they are aware, specially policymakers, of the positive capital growth influence and the initial capital stock k(0) > 0. Since these agents are rational, they will search to get the highest utility as possible so they solve the following problem:

$$\text{Max.}\, U(c,\mathrm{p})=\int_0^{\infty}\left[\left(\frac{c^{1-\theta}-1}{1-\theta}\right)+\mathrm{P}^{\alpha}\right]e^{-(\rho-n)t}dt$$

$$\text{r. t.}\, \dot{k}(t)=Ak^{\beta}-c-(n+\delta)k-\mathrm{p} \qquad (5)$$

As observed, this is a dynamical optimization problem; for solving it, Hamilton's maximizing method will be used in order to establish the optimum growth path. But that θ, the inverse intertemporal substitution elasticity, is greater than zero must be kept in mind and that ρ > n represents the temporal preference parameter. Thus, knowing the fixed values of equation (5), Hamilton's method in order to optimize utility is used; this is given by the following expression:

$$H(c,\mathrm{p},k,\lambda)=\left[\left(\frac{c^{1-\theta}-1}{1-\theta}\right)+\mathrm{P}^{\alpha}\right]e^{-(\rho-n)t}+\lambda(Ak^{\beta}-c-(n+\delta)k-\mathrm{p}) \qquad (6)$$

From equation (6) the equations for the maximum's principle that are key in determining the maximum values of the variables will be obtained; then following equations will appear:

$$\frac{\partial \mathrm{H}}{\partial \mathrm{c}}=c^{-\theta}e^{-(\rho-n)t}-\lambda(t)=0 \qquad (7)$$

$$\frac{\partial \mathrm{H}}{\partial \mathrm{p}}=\alpha\mathrm{P}^{\alpha\text{-}1}e^{-(\rho-n)t}-\lambda(t)=0 \qquad \mathbf{(8)}$$

$$\frac{\partial \mathrm{H}}{\partial \mathrm{k}} = \lambda(t)(\beta A k^{\beta-1} - (n+\delta)) = -\dot{\lambda}(t) \quad (9)$$

Taking logarithm to equations (7) and (8), deriving respect to time and having in mind equation (9) the following two equations that solve this maximization problem will be acquired:[3]

$$\frac{\dot{c}(t)}{c(t)} = \frac{1}{\theta}(\beta A k^{\beta-1} - \rho - \delta) \qquad (10)$$

$$\frac{\dot{\mathrm{p}}(t)}{\mathrm{p}(t)} = -\frac{1}{\alpha - 1}(\beta A k^{\beta-1} - \rho - \delta) \quad (11)$$

But, it must be taken in account that in the long run the economy will tend to the steady state and in this period of time the aggregated variable's growth is fixed and per capita's variables growth is none, therefore, from equations (10) and (11) can be concluded that in such moment, the following must be true:

$$\frac{\dot{c}(t)}{c(t)} = \frac{\dot{\mathrm{p}}(t)}{\mathrm{p}(t)} \qquad (12)$$

Equation (12) shows a direct relation between consumption growth rate and oil production growth rate or reserves. An economy that does not have the sufficient oil to attend its needs and to use as an input in its production process will have difficulties in increasing its consumption patterns because production will be jeopardize due to the unavailability of an important resource —oil— and due to this income will not grow and therefore consumption possibilities will be abridged.

III. Data and results

Using information gathered by Dane (2004), DNP (2004) and Ecopetrol (2004),[4] a time series and panel data analysis was performed in order to establish the veracity of the conclusions proposed by the theoretical model in Section II and described through statistical indicators in Section I, that is, it will be shown that growth and consumption have a direct pattern with oil availability and production.

[3] For more details on the model's mathematical development please refer to Appendix A.
[4] Descriptive statistics on the data used in this paper is available in Appendix B.

Firstly, a time series analysis will be developed. In order to do such analysis the first step according to Enders (1995) is to check if the variables are stationary, that is if they do not have a unit root. In doing so, two unit root tests are applied for the logarithmic variables. The statistics of the Philips Perron and Augmented Dickey Fuller tests are shown in Table 1.

Table 1. Colombia: Augmented Dickey Fuller and Philips Perron Unit Root Tests, 1950 – 1995

Variable	**Augmented Dickey Fuller**		**Philips Perron**		
	Statistic	Critical Value	Statistic	Critical Value	
GDP at 1975 price level					**I(1)**
Level	0.569881	-3.5162^{b}	0.812558	-3.1854^{c}	
1st Difference	-3.784810	-3.5189^{b}	-3.266357	-3.1868^{c}	
Consumption at 1975					**I(1)**
price level	-0.545829	-3.1868^{c}	-0.745764	-4.1728^{a}	
Level	-3.237905	-3.1898^{c}	-5.248398	-4.1781^{a}	
1st Difference					
Capital at 1975 price level					**I(1)**
Level	-0.882294	-1.9483^{b}	6.666018	-3.5814^{a}	
1st Difference	2.026386	-1.9486^{b}			
Economically active					**I(1)**
population	1.967797	-2.6182^{a}	29.27399	-2.6143^{a}	
Level	3.082803	-2.6196^{a}			
1st Difference					
Accumulated oil					**I(1)**
production	1.881455	-1.9514^{b}	12.28847	-2.6143^{a}	
Level	2.009950	-1.9492^{b}			
1st Difference					
Annual oil production					**I(1)**
Level	-0.387507	-3.5348^{b}	0.063431	-3.5112^{b}	
1st Difference	-3.677514	-3.5162^{b}	-4.191675	-3.5136^{b}	
Annual oil reserves					**I(1)**
Level	-0.502108	-4.1781^{a}	-0.532772	-4.1728^{a}	
1st Difference	-4.551428	-4.1837^{a}	-7.270790	-4.1781^{a}	
Reserves useful life					**I(1)**
Level	-2.073557	-4.1781^{a}	-2.679154	-4.1728^{a}	
1st Difference	-4.870828	-4.1837^{a}	-6.019963	-4.1781^{a}	

For the Augmented Dickey Fuller test, the Durbin Watson was always near or equal to two as the test requires it.
a, b, c correspond to 1%, 5% and 10% rejection levels.

The theoretical model analyzed in Section I, specifically in Equation 12, proposes a direct relation between consumption and oil production growth rates indicating that the econometric model should not be estimated in level but using a differenced form. This conclusion was also verified by the empirical data that shows the rejection of a unit root for the differenced variables —first difference. Consequently a differenced translog model was estimated including capital, labor force and accumulated oil production as a proxy of oil exhaustibility. Since the differenced variables did not have a unit root, a cointegration analysis was not required nor using second difference variables. The theoretical model pointed a direct relation between differenced variables, therefore, if a cointegration analysis would be to be met the differenced variables —first difference— must have a unit root recommending as shown by Enders (1995, p. 219) an estimation of a second difference model or a cointegration process.

Most papers that have estimated production functions use Cobb-Douglas functional forms,[5] however, as Greene (2000, p. 217) points out this is a nested model that should be estimated only after proving a hypothesis test that sustains that the Translog model can be reduced to a Cobb-Douglas form. The Translog functional form relating GDP growth —Y, labor —L— and accumulated production of oil or oil exhaustibility —P— and including a constant term — α_0— and a proxy for technological progress or time trend —T— can be expressed econometrically as:

$$\ln Y = \alpha_0 + \alpha_1 \ln K + \alpha_2 \ln L + \alpha_3 \ln P + \alpha_4(\ln K)^2 + \alpha_5(\ln L)^2 + \alpha_6(\ln P)^2 + \alpha_7(\ln K)(\ln L) + \alpha_8(\ln K)(\ln P) + \alpha_9(\ln L)(\ln P) + \alpha_{10}T + \varepsilon_t \quad (13)$$

The results of estimating the Differenced Translog model using data for the period 1951-1995 —45 observations— and performed through Least Squares is presented in Table 2. However estimation results were not satisfactory since capital presented a negative relation with GDP growth which is against neoclassical growth functions theoretical proposition but resulted to be not significant indicating that it is highly probable that its value is zero. Oil exhaustibility did not result significant nor two of the three interactions involved in the regression. These outcomes can be evidence of an inadequate functional form advising that the Cobb-Douglas model could be an admissible form.

[5] For example: Azofeifa and Villanueva (1996).

Table 2. Colombia: Estimating a Differenced Translog Model with Stationary Variables, 1950 – 1995

Dependant variable: Colombia's GDP growth rate

Variable	Coefficient	Variable	Coefficient
Capital growth rate	-0.232667 (-0.101589)	0.5 * Capital growth rate * Accumulated oil production growth rate	54.15918 (1.084017)
Capital growth rate squared	-11.64963 (-0.967802)	0.5 * Capital growth rate * Economically active population growth rate	40.74926 (0.355626)
Accumulated oil production growth rate	6.836699 (1.363128)	0.5 * Accumulated oil production growth rate * Economically active population growth rate[b]	-390.5678 (-1.984131)
Accumulated oil production growth rate squared	-14.47131 (-0.563804)	Constant[b]	-0.567482 (-1.847754)
Economically active population growth rate[a]	26.42297 (2.220786)	Trend[b]	-0.000668 (-1.961823)
Economically active population growth rate squared[a]	-248.9895 (-2.247359)		
R-squared	0.485404	Durbin-Watson statistic	1.841908
Adjusted R-squared	0.334052	F-statistic	3.207126

a, b are significant at 5% and 10% respectively.
T-Statistics in parenthesis.

Due to the results in Table 1 and the suspicion of a nested model, specifically a Cobb-Douglas, a Wald Coefficient test was performed. The results are presented in Table 3 and clearly show the viability and adequacy of estimating a Cobb-Douglas with the variables included in the prior econometric analysis. Its functional form would be:

$$\ln Y = \alpha_0 + \alpha_1 \ln K + \alpha_2 \ln L + \alpha_3 \ln P + \alpha_{10} T + \varepsilon_t \quad (14)$$

Table 3. Wald Test for Coefficient Equality: Proving if the Translog Model can be treated as a Cobb-Douglas

Null Hypothesis	$\alpha_4 = 0$ $\alpha_5 = 0$ $\alpha_6 = 0$ $\alpha_7 = 0$ $\alpha_8 = 0$ $\alpha_9 = 0$		
F-statistic	1.118729	Probability	0.372226
Chi-square	6.712373	Probability	0.348268

Thanks to the results achieved with the Wald coefficient test in Table 2, the Cobb-Douglas functional form is validated and estimated in Table 3. Outcomes are satisfactory and predicted by theory and other growth production related papers like Douglas (1976). Dornbusch, Fisher and Startz (2002, p. 47) find that labor is three times more important than capital in U. S. production after estimating a Cobb-Douglas. In this case —Table 4— labor force growth rate represents almost five times the growth rate that capital can experiment and which would contribute to GDP growth, nevertheless, a oil exhaustibility is a variable that is not included in regular production function analysis subtracting weight or importance to capital since oil can be accounted as an input required by capital goods in tasks such as the production of energy for the economy or in industrial processes. So if capital growth rate and accumulated oil production growth rate are united labor force growth rate will answer for more than double of the GDP's growth rate adjusting more to other papers conclusions.

Table 4. Colombia: Cobb Douglas Model, 1950 – 1995

Dependant variable: Colombia's GDP growth rate

Variable	Coefficient
Capital growth rate	0.461745 (2.643312)
Accumulated oil production growth rate	0.551862 (2.905878)
Economically active population growth rate	2.391183 (4.211328)
Constant	-0.053178 (-2.360238)
Trend	-0.000805 (-3.234322)
R-squared	0.383811
Adjusted R-squared	0.322192
Durbin-Watson statistic	1.854780
F-statistic	6.228790

T-Statistics in parenthesis.

All variables in Table 4 are significant and additional tests that are presented in Appendix 3 show the model's reliability. But, what does this result mean? Firstly it shows that GDP growth is positively impacted by oil availability so if oil exhaustibility comes to happen the economy would reduce its growth rate at least in 0.5%. This would entail the economy to import oil and search for energy substitutes and the former will only be possible if there are still world reserves or if those reserves where to be sold to Colombia because developed nations would compete for this input and would have the upper hand card in the deal; the latter, a technological improvement or substitute, would be possible if enough research and development is done by private and public entities but this requires a state policy for this matter that is not available in Colombia because government and private resource must be dedicated to more important and urgent issues; therefore the only possibility is that such technology or oil substitutes becomes available on the world market and Colombia has the resources for buying it. This important resource and its availability should not be despised since it accounts for 13% or more Colombia's growth rate, according to the econometric model and by adding up all the other effects and dividing the impact of oil by this sum.

The reduction in oil availability clearly affects an oil dependant economy like Colombia, but would this affect consumption as predicted by the theoretical model proposed in Section 1? The answer is yes and this should be clear theoretically. If production reduces so does income and if that happens consumption will be abridged also due to lower revenue. Empirically, a differenced Cobb-Douglas is estimated having as dependant variable consumption growth rate and including oil exhaustibility and a proxy of technology. The signs and results that appear in Table 5 are as expected and show the direct relation between oil accumulated production growth rate and technology; indeed, if technology improves then the possibility of oil substitutes is more possible, however, the first impact caused by oil is much higher than technology specially when no research and development are made in this field.

Table 5. Colombia: Consumption and Resource Availability estimated with a Differenced Cobb Douglas, 1950 – 1995

Dependant variable: Colombia's consumption growth rate

Variable	Coefficient
Oil accumulated production growth rate[a]	0.713802 (5.887904)
Trend[b]	0.000380 (1.706178)
R-squared	0.154518
Adjusted R-squared	0.116150
Durbin-Watson statistic	1.760608
F-statistic	59.17940

a, b significant at 1% and 10%.
T-Statistics in parenthesis.

Even though the prior analysis satisfies the theoretical backgrounds from which it is taken, the data availability on oil production and consumption in each region —state— is sufficient for a panel data approach. Can there be differences among states and time that cannot be perceived with the time series analysis and that can affect seriously our conclusions? The best way to answer this question is through panel data. This methodology gives the possibility of controlling non-observed heterogeneity invariant in time. In this case we cannot observe the efficiency with which each region produces, its need for oil and machines that work with this input, their substitution capacity between resources and their geographical conditions for obtaining oil from their terrain or producing energy by means different to oil sources. These reasons entice a panel data analysis specified as follows:

$$c_{it} = x_{it}^{T}\beta + \eta_i + \nu_{it},\ i = 1, \ldots, 16 \text{ and } t = 1, \ldots, 10 \quad (15)$$

Where c_{it} represents consumption growth rate, GDP growth rate or GDP per capita growth rate; xit constitute the characteristics of each region —state— that can include invariant columns in time, and specifically, will be composed by oil production growth rate and oil production growth rate squared or oil accumulated production growth rate and oil accumulated production growth rate squared and a time trend that represents technology —a proxy of technology.

In order to avoid panel data spurious regressions in the above suggested model, Baltagi (2001) suggests applying at least one panel data unit root test. In this case, the variables included in the panel data will be tested with the Im Pesaran Shin (1997) and Levin Lin Chu (2002) tests. The null hypothesis in these tests is that each series in the panel contains a unit root (H_0: $\rho_i = 1$, for all i) and the alternative is that at least one of the series is stationary (H_1: $\rho_i < 1$, for at least one i); the results, that all variables are stationary or that reject the null hypothesis, are presented in Table 6.

Table 6. Colombia: Im Pesaran Shin and Levin Lin Chu Unit Root Tests
for variables from 16 regions, 1991 – 2001

Variable	Im Pesaran Shin (1997)		Levin Lin Chu (2002)	
	T-statisitic for testing H_0: $\rho_i = 1$	*Conclusion*	*T-statisitic for testing H_0: $\rho_i = 1$*	*Conclusion*
Accumulated oil production growth rate	-3.367	Reject H_0	-12.181	Reject H_0
Annual oil production growth rate	-3.247	Reject H_0	-10.980	Reject H_0
Consumption growth rate	-2.822	Reject H_0	-10.865	Reject H_0
GDP growth rate	-2.790	Reject H_0	-10.908	Reject H_0
GDP *per capita* growth rate	-2.565	Reject H_0	-10.515	Reject H_0

After confirming that all variables are stationary, a panel data analysis was made and presented in Table 7. Four fixed effects models were estimated, after making checking with different panel data models —between, population averaged and random effects, the best results are presented only. Different intercepts were dealt with and in the four cases a marginal decreasing returns of scale are encountered showing that oil exhaustibility has an important impact at the beginning but the effect's growth diminishes each time allowing to infer that even though this energy resource is important its losing relevance in the long run. This could be related with additional energy resources that these regions possess like hydroelectric plants, coal plants and the use of other inputs different from oil or the possibility of substituting this need with other resources or having the advantage of producing good and services that do not heavily require oil and its derivatives.

Table 7. Colombia: Panel data estimations with different intercepts relating GDP and per capita's growth rate and consumption's growth rate with oil exhaustibility for 16 regions, 1991 – 2001

Independent Variable	**Dependant Variable**			
	GDP per capita growth rate	*GDP growth rate*	*Consumption growth rate*	*Consumption growth rate*
Oil production growth rate	0.007647	0.007535	0.014411	
	(2.855567)	(2.889703)	(7.781553)	
Oil production growth rate squared	-0.007484	-0.007439	-0.006375	
	(-6.721441)	(-6.866420)	(-8.793490)	
Oil accumulated production growth rate				0.070753
				(4.470829)
Oil accumulated production growth rate squared				-0.026411
				(-1.951681)
Trend	-0.003868	-0.003992	-0.005024	
	-7.025059	(-7.424381)	(-8.020817)	
Fixed effects intercept				
Antioquia	0.027089[a]	0.042990[a]	0.058192[a]	0.017080[a]
Arauca	-0.061275	-0.019235	-0.003735	-0.046722
Bolívar	0.029242[b]	0.054374[a]	0.069226[a]	0.027042[a]
Boyacá	0.025892[b]	0.033391[a]	0.048251[a]	0.006712
Casanaré	0.078392	0.112935	0.125805	0.075841
Cauca	0.035992[b]	0.053935[a]	0.069007[a]	0.013475
Cesar	0.044416[a]	0.063775[a]	0.078110[a]	0.033104[a]
Cundimarca	0.050936[a]	0.072843[a]	0.087824[a]	-9.19E-05
Huila	0.020582[a]	0.036562[a]	0.051113[a]	0.008675
Meta	0.037910[a]	0.057835[a]	0.072163[a]	0.027937[a]
Nariño	0.041020[a]	0.061444[a]	0.074719[a]	0.024371[b]
Norte de Santander	0.031227[a]	0.054473[a]	0.069431[a]	0.027376[a]
Putumayo	0.083762	0.114355	0.129138	0.085991
Santander	0.058520[a]	0.072734[a]	0.087798[a]	0.046580[a]
Sucre	0.033968[a]	0.054090[a]	0.072215[a]	0.016000[b]
Tolima	0.041967[a]	0.045675[a]	0.058927[a]	0.011917
Adjusted R^2	0.172788	0.207721	0.191719	0.097258

a, b, c represent intercepts significant at a 1%, 5% and 10% respectively.
T-Statistics in parenthesis.

Table 8 presents the result of estimating the fixed effects model with a common intercept providing similar outcomes to the ones appearing in Table 7. A positive but marginal decreasing relation is disclosed as in the above estimation, nevertheless, the positive relation between GDP growth rate, GDP per capita growth rate and consumption growth rate and oil exhaustibility concerns since reserves might disappear before than expected (Jones, 2003); regions, therefore, should entice policies that orient their economy towards new energy resources and incentives that make companies use inputs different from oil and its derivates. Public transport and private car owners should use and adopt more efficient vehicles that require less gallons of fuel per mile or that run on fuels not derived from oil.

Table 8. Colombia: Panel data estimations with common intercept relating GDP and per capita's growth rate and consumption's growth rate with oil exhaustibility for 16 regions, 1991 – 2001

Independent Variable	Dependant variable: GDP per capita growth rate	GDP growth rate	Consumption growth rate	Consumption growth rate
Oil production growth rate	0.008240 (3.185754)	0.007355 (2.983831)	0.014453 (7.047456)	
Oil production growth rate squared	-0.005865 (-6.103572)	-0.005345 (-5.861186)	-0.004453 (-6.754321)	
Oil accumulated production growth rate				0.082945 (3.977070)
Oil accumulated production growth rate squared				-0.042468 (-2.244263)
Trend	-0.003789 (-6.910835)	-0.003956 (-7.327766)	-0.004678 (-7.653015)	
Common intercept	0.034304 (10.31101)	0.053362 (16.41124)	0.066629 (16.25258)	0.021169 (5.408523)
Adjusted R^2	0.127140	0.187675	0.197181	0.126222

T-Statistics in parenthesis.

Conclusions

Oil is a scarce resource that will last shorter than expected (Jones, 2003) and Colombia, as many other countries, depends on this resource as an input, energy source and export product. Such is the dependency that production and energy provided by oil are directly related and output requires the latter in order to yield goods and services. The problem is that the region consumes a great part of its oil production but, in the future, will have to import from other countries specially those from the Middle East because Latin America's reserves are below this regions amount.

Scarcity becomes a problem because the whole world depends on oil in order to move and generate energy and high prices do not appear as constraints for oil consumption as Hotelling (1931) predicted because the uncertainty in the exact reserves amount and the need to export by nation's with high oil reserves due to their economical dependency on oil exports show a difficult scenario for Latin American countries. Also if the impossibility to pay as much for oil as developed nations and their negotiation power is added, it will be found, as shown by Lawrence and Levy (1982) that developed countries have the upper hand and first option for buying this scarce resource so countries as Colombia will have to wait and see if they can import at least a fraction of this black gold.

The econometric analysis using a time series and panel data approach both confirm for Colombia a positive relation between GDP growth, consumption growth and oil exhaustibility. The first method uses the idea of a neoclassical production function that allows encountering the importance of oil in production, concluding that this scarce resource contributes for at least 13% of output growth. Therefore, if Colombia's oil reserves do not satisfy national demand and imports become difficult to obtain, growth will be affected and production and energy generation through this fossil fuel will be at risk. This problem might be met in the near future because Colombia's reserves useful life present a diminishing tendency. The second approach confirms this result for Colombian regions but conveys a better scenario where oil dependency, in the long run, is abridged and its impact is lesser every time.

Future research should be oriented to determine the impact of oil scarcity at a microeconomic level and determining the best market organization and produce output that gives the optimum response to oil shocks and that allows the economy to minimize oil shocks. This would require analyzing specific sectors and their interrelations, ideas that would be better treated with a general equilibrium model for the regional and national economy.

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Appendix A. Expansion of the Theoretical Model

Below the necessary steps for obtaining equation 10 will be described. For this purpose, equations 7 and 9 will be used.

$$\frac{\partial \mathrm{H}}{\partial \mathrm{c}} = c^{-\theta} e^{-(\rho - n)t} - \lambda(t) = 0$$

$$\ln(c^{-\theta} e^{-(\rho - n)t} = \ln(\lambda (t))$$

$$-\theta \ln c - (\rho - n)\, t = \ln(\lambda (t))$$

$$\frac{\partial\, ((-\theta \ln \mathrm{c}) - (\rho - \mathrm{n}))\, \mathrm{t})}{\partial\, \mathrm{t}} = \frac{\partial\, (\ln \lambda(t))}{\partial\, \mathrm{t}}$$

$$-\theta \frac{\dot{\mathrm{c}}(\mathrm{t})}{\mathrm{c}(\mathrm{t})} - \rho + \mathrm{n} = \frac{\dot{\lambda}(t)}{\lambda}$$

$$\frac{\dot{\mathrm{c}}(\mathrm{t})}{\mathrm{c}(\mathrm{t})} = -\frac{1}{\theta} \frac{\dot{\lambda}(t)}{\lambda} + \rho + \mathrm{n}$$

And from 9, λ(t)/λ can be obtained and replacing it in the above equation and adding up terms it can be disclosed:

$$\frac{\dot{\mathrm{c}}(\mathrm{t})}{\mathrm{c}(\mathrm{t})} = \frac{1}{\theta} (\beta A k^{\beta - 1} - (n + \delta))$$

In a similar way equation 11 can be demonstrated but, for doing so, equations 8 and 9 are used.

Appendix B. Descriptive Statistics of the Variables Used in the Econometric Analysis

Table B1. Descriptive Statistics

Variable	Mean	Standard Deviation
GDP at 1975 constant prices	405,228.53	233,742.87
Consumption at 1975 constant prices	288,656.70	158,806.70
Capital at 1975 constant prices	1,162,072.77	684,607.80
Economically active population	8,004,960.23	3,363,439.44
Accumulated oil production	1,834.27	959.63
Annual oil production	77.14	44.73
Oil reserves	1,179.76	741.80
Reserves useful life	16.05	6.74

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