INCOME LEVEL, ENERGY CONSUMPTION AND ENVIRONMENTAL QUALITY: AN APPLICATION OF EKC MODEL IN BRAZIL

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RESUMO

A capacidade do nosso planeta em suportar as externalidades negativas da atividade humana é de longa data tema central de discussões tanto no meio comum como no meio científico. O mesmo é válido para os economistas, desde os clássicos, como David Ricardo e Thomas Malthus, o meio-ambiente era fator determinante em seus modelos. Recentemente, um grupo especial de economistas vêm estudando a chamada EKC (Environmental Kuznets Curve). Segundo o seu conceito, a relação entre renda e degradação ambiental e consumo dos recursos naturais possui uma relação em “U” invertido. Significando que, ao contrário do postulado pelo ambientalistas, a relação entre o nível de renda e a degradação ambiental pode ser sustentável no longo-prazo. Mas, infelizmente apenas poucos deles foram aplicados para o caso específico de um país (a maioria dos estudos foram aplicados para um grupo de países em uma análise em cross-section). E especificidades dos países (como diferenças culturais e climática) podem prejudicar de forma considerável a análise. Dessa forma, no presente estudo, foi aplicado o modelo EKC para o caso específico do consumo per capita de energia no Brasil. A escolha de tal indicador foi feita pela simples razão de sua importância como fator de produção (assim, essencial no processo de acumulação de renda) e geradora de conforto, como também pelas externalidades negativas que surgem no seu processo de geração.

Palavras-chaves: EKC (Environmental Kuznets Curve), Consumo de Energia, Nível de Renda

ABSTRACT

In recent years, many studies of the Environmental Kuznets Curve (EKC) have been applied for several circumstances and indicators. Unfortunatelly, just some of then have been applied to the specific case of a single country, most of the studies are applied for a group of countries in a cross-section analysis. We found on literature that some country specifications (such as politics and polices, cultural issues and climate) can produce some bias on the function parameters estimation. So all the results that are found on other studies can not be usefull for police makers, once they are possible not showing a real situation. Thinking on this problem, in this paper, we explore the EKC for the specific case of Brazil. To achieve the objective, it has been used the anual total (all kind of energy sources that composes the Balanço Energético Nacional (BEN) – the brazilillian balance of energy consuption) energy consumption (in per capita terms) as our choosen indicator. The use of energy consumption as the indicator had been done due to the importance of energy as an essential input for the economy (so does a determinant of the income level) and also due to the negative externalities (such as the nocive gas emmitions) generated in the process of energy consume.

Key-words: EKC (Environmental Kuznets Curve), Energy Consumption, Income Level
1 INTRODUCTION

Energy is an essential input for most economic activities. All productive systems and the consumption activities somehow require energy in their processes. Energy is used to transform raw materials (such as iron ore and petroleum) into processed inputs (such as steel and gasoline), and it is also used to transform those inputs into other inputs that are used to produce final goods and services. In general, the amount of energy consumption is directly related to the level of production and consumption.

On Earth, there are different sources of energy. Some of them are more useful for specific need than others. In the case of biological needs, the main source of energy is food. For economic activities, other sources of energy (such as fossil fuels, wind and hydro power, nuclear energy etc.) are used (RAVEN ET AL., 1996). This study focus only on the sources of energy used for economic needs1.

Historically, after the Industrial Revolution, the main source of energy used by humans has been the energy provided by fossil fuels. In this case, the energy accumulated in a carbon chain is liberated through some kind of combustion process. Besides the energy, this process results in the emission of several potentially harmful gases (such as CO, CO₂, SO₂ and some other kinds of Suspended Particular Matter – SPM).

Those gases can negatively affect the environment and also human life. Sulphur dioxide (SO₂) may combine with rain water, resulting in sulphur acid (H₂SO₄), which may cause ‘acid rain’. There are evidences that ‘acid rain’ causes death of green life and micro organisms, accelerate the corrosion of buildings and contaminate water bodies (LOMBORG, 2001; FIELD, 1994). Carbon monoxide (CO) is a poisonous gas that may cause asphyxiation (LOMBORG, 2001).

On the other hand, carbon dioxide (CO₂), in the level found on our atmosphere, doesn’t affect human health directly. However, it has chemical and physical properties that trap heat in the atmosphere. Along with other gases (that have the similar properties), it may cause the ‘greenhouse effect’. In ‘normal’ levels, ‘greenhouse effect’ is a natural process that helps keep life on earth. But, emissions of large amounts of CO₂ (and other gases) may increase the amount of energy absorption in the atmosphere, causing a raise in the average temperature on the planet (LOMBORG, 2001; FIELD, 1994).

Brazil is an exception in the world, due to the characteristics of its hydrological basin, there is a great participation of the energy provided by hydroelectric power plants (especially for residential use). It’s estimated that 10% of all 2001 supply of energy is provided by hydroelectricity (but the main source is still the petroleum –corresponding to 42% of all 2001 country’s supply of energy) (Fig. 1) (MME, 2003). Although this source of energy is considered to be clean, due to small charge of pollutants generated on its generation, its uses also generate some externalities. The most evident is the extension of land that is covered by water to create the reservoir that will originate the hydroelectric power plant, leading to loss of productive areas, death of plants and animals and change of natural habitats (PRYOR, 1981).

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1 All the sources of energy present on BEN (Balanço Energético Nacional) (MINISTÉRIO DE MINAS E ENERGIA-MME, 2003).
2 THE EKC (ENVIRONMENTAL KUZNETS CURVE) HYPOTHESES

For a long time, people have been concerned about the capacity of human to keep its process of income accumulation, without affecting the habitat, and maintaining the environmental sustainability. The study of those relationships can be divided in two distinguished groups. One group, more pessimists, predicts that the process of income accumulation in long-run will be unsustainable and all the environmental system will get into chaos (CLUB OF ROME, 2004). A second group, more optimistic, believes that the economical system will find alternatives to overcome the environmental problems. Within this group, the Environmental Kuznets Curve (EKC) was developed.

EKC was proposed in the beginning of the 90’s (e.g. SHAFIK & BANDYOPHADYAY, 1992; GROSSMAN & KRUEGER, 1993; and SELDEN & SONG, 1994). According to this theory, the relationship between income level and environmental quality can be represented by an inverted U-shaped curve (Fig. 2). This implies that, in lower levels of income, economic growth is positively related to the use of resources and/or environmental pressure. But, at certain level of income there is a turning-point. Beyond this point, further increase in income is associated to abatement in the level of environmental pressure (SHAFIK & BANDYOPHADYAY, 1992; WORLD BANK, 1992; GROSSMAN & KRUEGER, 1993; SELDEN & SONG, 1994).

![Fig. 2. The Environmental Kuznets Curve.](image)
Theoretically, this results from interactions of several factors, such as: changes in the structure of preferences of the consumers (SHAFIK, 1994; SELDEN & SONG, 1994; GAWANDE, 2000; GAWANDE ET AL., 2001); development of new and more efficient technologies (BRUYN ET AL., 1998; UNRUH & MOOMAW, 1998; JOHN & PECCHENINO, 1994); changes in the structure of production \(^2\) (SHAFIK, 1994; SELDEN & SONG, 1994); and, influences from international commerce \(^3\) (GROSSMAN & KRUEGER, 1993; JAYADEVAPPA & CHHATRE, 2000).

Although, some consistent arguments have been presented in the literature to explain this inverted U-shaped relationship, there are other strong arguments suggesting different shapes for this relationship (such as, linear with negative or positive slope, and the N-shaped). Furthermore, there are many variables that may bias the EKS. Excess of civil rights, problems related to the definitions of property rights, market failures, country specific politics and policies and, geographical and climate characteristics of the chosen region and country are few examples (SHAFIK & BANDYOPHADYAY, 1992; SHAFIK, 1994; SELDEN & SONG, 1994).

3 THE METHODOLOGY AND MODEL

EKC (in the specific case of per capita energy consume on Brazil) is estimated by Generalized Least Square (GLS) using energy consumption as dependent variable. It is measured in terms of per capita tEP (tons of equivalent petroleum).

The explanatory variables are: real per capita GDP \((Y)\) (on 2001 R$\(^4\) terms), as indicator of income; the Energy Intensity \((INT)\), measured by the ratio between total energy consumption and total GDP (a proxy for technology / energy efficiency); energy price indicator \((P)\), since the demand for energy seems to be price-elastic (AGRAS & CHAPMAN, 1999); population density \((d)\), due to the possible scale effect of energy consumption resulting from the process of urbanization (SELDEN & SONG, 1994).

A measure of economy’s openness to the international commerce (suggested by GROSSMAN & KRUEGER, 1993) has been suggested as a variable. However, in the case of Brazil, during the period studied, since this indicator had only a small variation (variance of 0.001 of openness measured by the ratio between the sum of exportation and importation and the total GDP) the variable has not been accepted in the final model.

Three different shapes for EKC is tested: linear (eq. 1); quadratic (the traditional EKC, eq. 2); and, cubic (the N-shaped model, eq. 3). The choice between them was decided according to statistical tests \(^5\).

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\(^2\) Specially changes in the composition of goods and services produced in the economy.

\(^3\) This is the case when, in a open economy, environmental regulation begins to affect a given country’s competitiveness in the production of some goods (e.g., that are intensive in the use of natural resources and/or in the production of some negative externalities).

\(^4\) The Brazilian currency, the real (R$) – 2.90 R$ = 1 US$ (on January 2004).

\(^5\) 1)\(F\)-statistic, 2)\(t\)-statistic and 3) \(R^2\).
\[ ENE_t = \alpha_1 + \alpha_2(Y_t) + \alpha_3 INT_t + \alpha_4 P_t + \alpha_5 d_t + e_t \] (1)

\[ ENE_t = \beta_1 + \beta_2(Y_t) + \beta_3(Y_t)^2 + \beta_4 INT_t + \beta_5 P_t + \beta_6 d_t + e_t \] (2)

\[ ENE_t = \Phi_1 + \Phi_2(Y_t) + \Phi_3(Y_t)^2 + \Phi_4(Y_t)^3 + \Phi_5 INT_t + \Phi_6 P_t + \Phi_7 d_t + e_t \] (3)

Where:

- \( ENE_t \) is the per capita energy consume on the period of time \( t \);
- \( \alpha, \beta \) and \( \Phi \) are the parameters to be estimated;
- \( Y_t \) is the per capita GDP (2001 R$) on the period of time \( t \);
- \( INT_t \) is the energy intensity (a proxy for technology) on the period of time \( t \);
- \( P_t \) is the energy price indicator on the period of time \( t \);
- \( d_t \) is the population density on the period of time \( t \); and,
- \( e_t \) is the aleatory error on the period of time \( t \).

The data were: per capita energy consume (\( ENE \)), from Balanço Energético Nacional - BEN / Ministério de Minas e Energia (MME, 2003); real per capita GDP, from IPEA Instituto de Pesquisa em Economia Avançada (IPEA, 2003), deflated by IGP-DI (CONJUNTURA ECONÔMICA, 1970-2002); energy price indicator (KAMOGAWA, 2004); and, population density, (ANUÁRIO ESTATÍSTICO DO BRASIL, 1970-2002).

4 RESULTS

All standard statistical test procedures (multicolineariety, autocorrelation and heteroscedasticity) were estimated and proper correcting action taken where problems were found. Goldfeld-Quandt test, indicated the presence of heteroscedasticity on income (GDP) (the value of test was 7.91, significant at 5%). Generalized Least Squares (GLS) was used to correct for heteroscedasticity.

According to the chosen statistical parameters, the model with best fit was the cubic (tab. 1). However, it does not have a turning-point, despite the fact that is has two changes of slope (tab. 1). The estimated function implies that further increase in per capita income in Brazil will result in larger energy consumption (fig. 3).

The energy intensity (\( INT \)) and the density of population (\( d \)), were not statistically significant (tab. 1). Thus, it seems that there aren’t gains or losses of scale in energy consumption, due to larger population density. The same implication may be extended to per capita energy consumption resulting from changes in the efficiency of energy use in Brazil. An interesting result found is the presence of price inelasticity for energy consumption. In 2001, with a price index of 165, elasticity for annual per capita energy consumption was about –0.901. Aggregating all the effects of the other explanatory variables on a single time effect, a small reduction of energy consumption happened between 1970 and 2001 (fig. 3).
Fig. 3. Estimated relationship between annual energy per capita consumption (on tEP) and per capita GDP (on 2001 RS), 1970-2001.

Tab. 1. Econometrical results for the relationship between per energy consumption (tEP/person), per capita income (2001 RS), and the following explanatory variables, 1970-2001a.

<table>
<thead>
<tr>
<th>Intercept</th>
<th>Y</th>
<th>(Y)²</th>
<th>(Y)³</th>
<th>d</th>
<th>INT</th>
<th>P</th>
<th>F</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>-4.93E-5</td>
<td>1.57E-7</td>
<td>-7.46E-6</td>
<td>1470.33</td>
<td>-4.31E-7</td>
<td>1591.57</td>
<td>0.996</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(-2.26)**</td>
<td>(12.26)**</td>
<td>(-1.35)</td>
<td>(10.13)***</td>
<td>(-2.44)**</td>
<td>***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-5.85E-6</td>
<td>2.06E-7</td>
<td>-1.12E-11</td>
<td>4.84E-6</td>
<td>394.78</td>
<td>-5.58E-7</td>
<td>3581.28</td>
<td>0.999</td>
<td></td>
</tr>
<tr>
<td>(-0.40)</td>
<td>(19.85)***</td>
<td>(-9.92)***</td>
<td>(1.29)</td>
<td>(2.22)**</td>
<td>(-5.22)***</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-2.47E-5</td>
<td>3.43E-7</td>
<td>-5.82E-11</td>
<td>4.42E-15</td>
<td>2.78E-6</td>
<td>30.86</td>
<td>-5.10E-7</td>
<td>4806.44</td>
<td>0.999</td>
</tr>
<tr>
<td>(-2.00)*</td>
<td>(9.82)***</td>
<td>(-4.96)***</td>
<td>(4.03)***</td>
<td>(0.93)</td>
<td>(0.19)</td>
<td>(-5.98)***</td>
<td>***</td>
<td></td>
</tr>
</tbody>
</table>

*a The student-t test is on parenthesis.
* significative on 10%
** significative on 5%
*** significative on 1%

5 PROJECTIONS

Using the cubic model, energy consumption projections were estimated for a period of 15 years. Different scenarios were considered: one, using an increment of annual per capita GDP in the level of 1%, and, the other using an increment of 2%. The population projection is from IBGE. The others explanatory variables were maintained constant at mean value.

According to the results, energy consumption (on per capita terms and also on absolute terms) will increase on both economical growth projections. For 1% increase in per capita GDP, energy consumption will expand, annually, 1.46% in per capita terms and 2.58% in total terms. In 15 years, this is going to represent 47% expansion in total energy consumption. For 2% increment in income, it is estimated an annual growth of energy consumption of 3.50% in per capita terms; and 4.52% in total terms. In 15 years, this will represent an increase of 94% on total energy consumption (fig. 4).
On quantitative terms those numbers represents an additional 81,319,625 tEP per year (1% per capita GDP growth) which is equivalent to the annual energy production of 26.5 *Itaipu’s* hydroelectric power plants\(^6\), or 93% of all the energy from petroleum in Brazil, in 2001\(^7\). And, in a 2% projection, it is estimated an increase of 170,165,050 tEP per year in the total Brazilian energy consumption.

### 6 CONCLUSIONS

The results show that, in Brazil, the turning point predicted by EKC is not going to happen in the near future. On other words, an inverted U-shaped relationship is not expected any time soon. Instead, the relationship found was non-linear but positive. If this is to hold, there are two alternatives to support the process of economical growth: increase the efficiency energy use and/or find alternative sources to supply the increase of energy consumption. Such evidences are enforced by the fact that per capita energy consumption in Japan and US are, respectively, 3.4 and 6.7 times bigger than in Brazil, with incomes seven (US) and ten (Japan) times larger (ENERGY INFORMATION ASSOCIATION, 2003). Empirical evidences show that turning-points on energy consumption only occur in high levels of income (RICHMOND & KAUFFMAN, 2003).

Furthermore, reduction of energy consumption, according to the economic analysis, is not easily obtained. On production side, technology changes quite slowly and the process may take a long time. In particular, Brazil has a great dependence on the industry (intensive on energy use), and on agriculture (highly intensive in goods and services that demands large amounts of energy). In fact, the recent expansion in energy consumption in Brazil has been generated by transportation and industrial sectors (fig 5).

On the consumer side, decrease may not be possible either. As income grows, energy consumption will expand resulting from larger consumption of industrialized goods, food, house wares, automobiles, air conditioners, electronic devices etc.

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\(^6\) The annual energy production of the plant is estimated on 90,000 GWh (ITAIPU, 2003).

\(^7\) In 2001 the energy provided by petroleum was estimated on 87,833,376 tEP (MME, 2003).
An option, in this scenario, is to search for new and cleaner sources of energy, which generates less negative externalities and uses smaller amounts of natural resources. Some alternatives sources have already been used on Brazil, such as the biological energy from agriculture (such as the alcohol), and the solar and wind power plants. But, unfortunately, those alternative sources of energy are more expensive than the energy from fossil fuel, and their overall capacity of energy generation is too small, compared to all energy consumption in the country.

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