On the Existence of a Sectoral Environmental Kuznets Curve for Portugal – A Nonlinear Cointegration Approach for CO_2 Emissions

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By

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Research goals

A sectoral approach of the EKC

- To provide new insights on the relationship between economic growth and CO_2 emissions.
- To examine if there is a EKC for both electricity generation, and transport sectors.
- To verify if the interaction between GDP and each of these sectors is similar.
- To assess the importance of each sector for Portugal's total carbon dioxide emissions.

Context

- Energy sector was responsible for 69.5 per cent of total emissions in 2011, and presenting an increase of 17 per cent over the 1990-2011 period.
- Two sectors stand out: Energy industries (23.6% of total GHG emissions) and transport (25.1% of total GHG emissions).
- CO_2 is the predominant GHG.
- In 2011 transport was the main emitter of CO_2 in Portugal, followed by energy industries.
- Transport sources, which are largely dominated by road traffic, are one of the sectors that have risen faster. In the period 1990-2011 these emissions increased 70%.

Environmental Kuznets Curve hypothesis

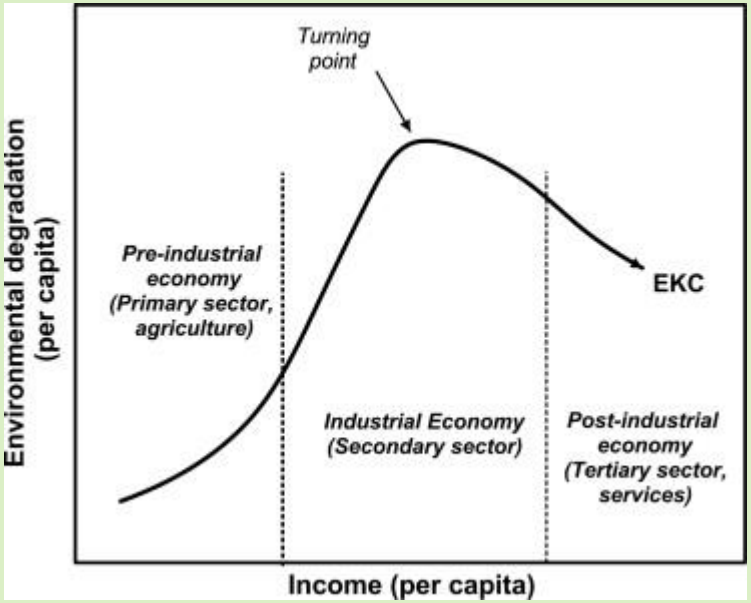

Figure 1: Example of an Environmental Kuznets Curve (Kaika and Zervas, 2013).

- Environmental quality changes over time, together with economic growth. The early stages of economic growth encompass the deterioration of environmental quality; however, beyond a certain level of income, the environmental degradation starts to decline.
- There is an EKC-turning point, after which economic growth has a positive impact on environmental quality.

Methodology

Data and unit root tests

Country: Portugal

Data range:1960 – 2010

Dependent Variables:

- Total CO_2 emissions (metric tons per capita)
- CO_2 emissions from electricity generation (metric tons per capita)
- CO_2 emissions from transport sector (metric tons per capita)

Explanatory Variable:

- Per capita real GDP (euros, base year=2006)

Table 1: Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
co2_elec_p~g	51	1138.621	866.5752	60.475 (1961)	2624.79 (2005)
co2_transp~g	51	944.8794	568.9812	199.826 (1960)	1889.17 (2004)
rgdp_pc	51	9587.527	4079.716	3135.87 (1960)	15521.8 (2007)

Methodology
Data and unit root tests

Unit root tests: ADF, DFGLS, PP, Ng-Perron and ERS

Dependent Variables:

- Total CO_2 emissions – I(1)
- CO_2 emissions from electricity generation – I(1)
- CO_2 emissions from transport sector – I(1)

Explanatory Variable:

- Per capita real GDP – I(1)

Engle and Granger cointegration technique: A first approach…

Preliminary results for electricity generation

- Evidences of a long-run relationship between CO_2 emissions and GDP.
- Inverted N-shape form.

Preliminary results for transport sector

- The results are inconclusive.

Econometric critique:

This empirical study is based on standard linear cointegration.

Nonlinear regressions exhibit a different behaviour and require an appropriate analysis.

The EKC model

$$CO_{2t} = \beta_0 + \beta_1 GDP_t + \beta_2 GDP_t^2 + \beta_3 GDP_t^3 + \varepsilon_t$$

Where:

- CO_{2t} $-$ *per capita carbon emissions at period t*
- GDP_t $-$ *per capita real GDP at period t*
- ε_t $-$ error term

Methodology
Nonlinear cointegration analysis

- Rank tests for cointegration (Breitung, 2001)
- Nonlinear cointegration test (Choi and Saikkonen, 2010)
- Rank test for neglected nonlinearity (Breitung, 2001)
- Test of linearity of the cointegrating relation(Choi and Saikkonen, 2004)
- Modified RESET test (Hong and Phillips, 2010)

Results
Total CO_2 emissions

$$CO_{2t} = 1.539 - 4.3566x10^{-4}GDP_t + 1.0228x10^{-7}GDP_t^2 \ -3.6138x10^{-12}\,GDP_t^3 + \varepsilon_t$$

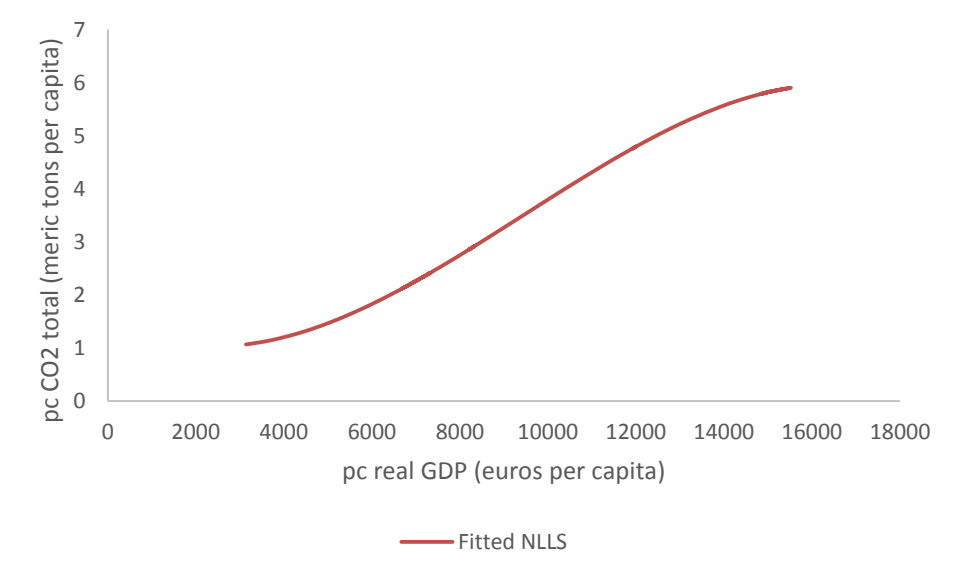

Figure 2: Per capita real GDP versus per capita total CO_2 emissions for Portugal (1960 to 2010).

- Nonlinear cointegrated relationship
- Inverted N-shape
- Minimum turning point: €2,447.00 (€3,135.87)
- Maximum turning point: €16,421.00 (€15,521.78)
- EKC holds
- Total CO_2 may be slowing down

Results

CO_2 emissions from electricity generation

$$CO_{2t} = 1.3826 - 6.8244x10^{-4}GDP_t + 1.0380x10^{-7}GDP_t^2 \; -3.6414x10^{-12}\, GDP_t^3 + \varepsilon_t$$

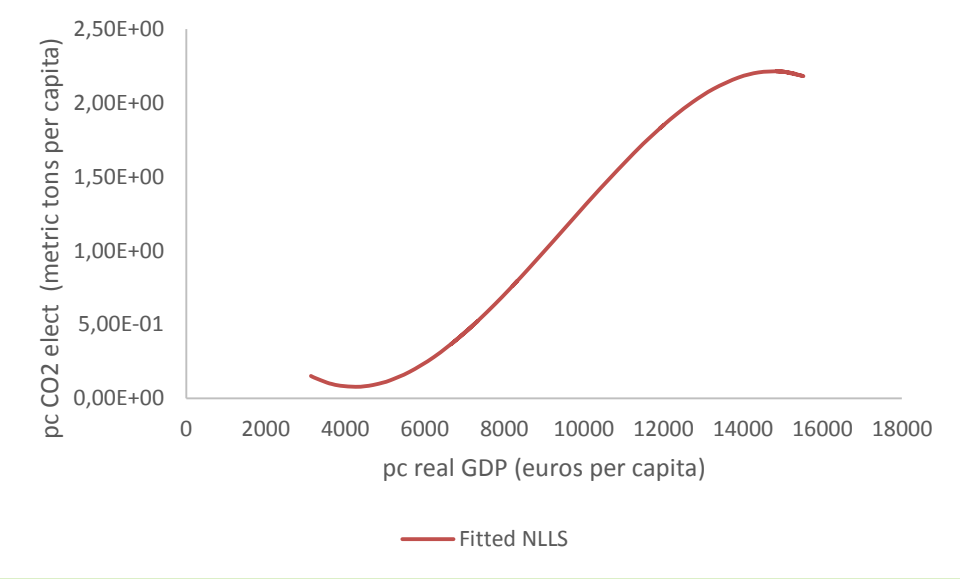

Figure 3: Per capita real GDP versus per capita CO_2 emissions from electricity generation sector for Portugal (1960 to 2010).

- Nonlinear cointegrated relationship
- Inverted N-shape
- Minimum turning point: €4227,90 (€3,135.87)
- Maximum turning point: €14775,78 (€15,521.78)
- EKC holds
- CO_2elect show a downward-sloping trend

Results

CO_2 emissions from transport sector

$$CO_{2t} = -8.4559x10^{-2} + 9.1985x10^{-5}GDP_t - 2.1738x10^{-9}GDP_t^2 + 2.8239x10^{-13}\,GDP_t^3 + \varepsilon_t$$

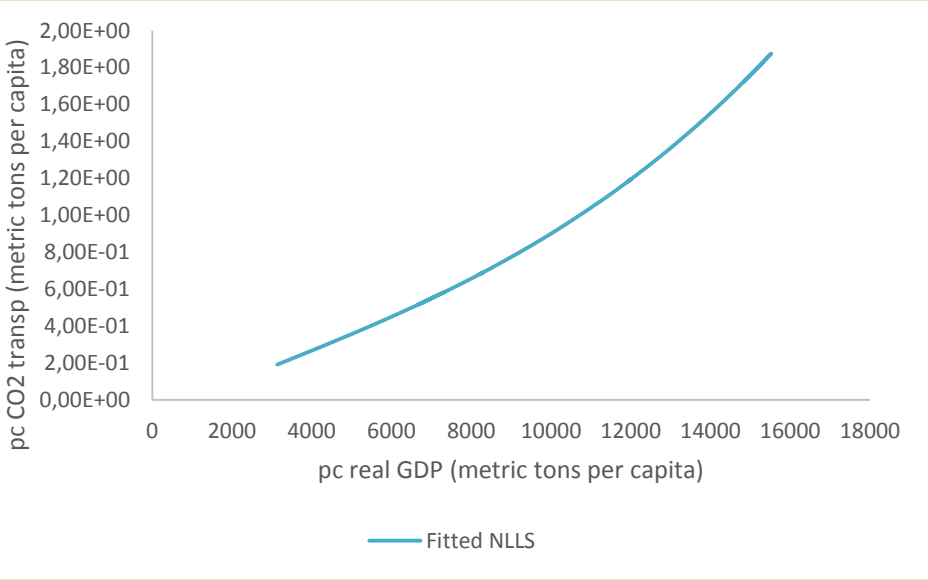

Figure 4: Per capita real GDP versus per capita CO_2 emissions from transport sector for Portugal (1960 to 2010).

- Nonlinear cointegrated relationship
- N-shape with complex roots
- CO_2transp – GDP evidence a monotonically increasing relationship

Conclusions
Electricity generation sector

- The economic growth promoted the technological effect. Renewable electricity production, mainly hydro and wind, overlapped the effect of electricity demand on CO_2 emissions, which justifies the descendent trajectory.

- The support policies applied so far proved to be effective. Now, Portugal ought to take full advantage of existing infrastructures. Renewable power plants and hydropower stations should give priority whenever is possible in order to maintain the decline of per capita CO_2 emissions.

Conclusions
Transport sector

- Higher income associated behaviours such as car ownership and distance-travelled per car per year, the purchase of more potent vehicles with higher energy consumption, tend to overlap the advantages of more efficient technologies.

- Transport sector has been insufficiently targeted in existing policies. The regulatory framework should be improved to be capable of reversing the progression of CO_2 emissions in transport.

Conclusions
Total CO_2 emissions

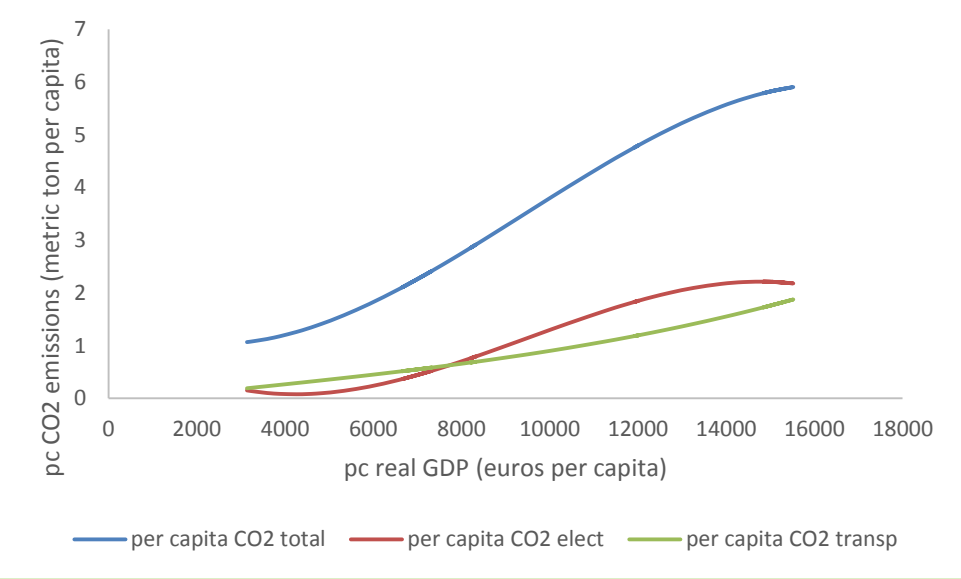

Figure : Long-run relationship between per capita real GDP and per capita CO2 emissions for Portugal (1960 to 2010).

- The impact of each sector on the performance of total CO_2 emissions can be drawn from the curves plotted in figure.
- The split of the total CO_2 emissions' curve enlightens the slowing down trend of emissions' increase. As the decrease of CO_2 from electricity generation is hindering emissions growth, the transport sector is pushing up the CO_2 emissions at nationwide.

Conclusions

- If Portugal wants to fulfil the international commitments in terms of greenhouse gases, it has to be aware of the different stages of emissions development of these two sectors, which calls for distinct policies.

- Policy-makers should handle these strategic sectors with differentiated measures and goals.

Future research directions

- Extend the model to other independent variables, such as temperature and precipitation.

- Apply the cointegration with unknown structural breaks methodology.

Thank you for your attention!

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