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Mishandling carbon intensities

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Abstract

The goal of this paper is to make clear cut reasoning for the ambiguous evidence in favour of the Environmental Kuznets Curve (EKC) hypothesis. The EKC for CO2 might be flawed with some sort of misconceptions thus providing misleading guidelines for policy makers. The main contribution of this paper (but not unique) is to provide original explanations to dismiss the EKC according to economic concepts. Thus it goes beyond the usual justification based mainly on inadequate use of econometric techniques. Actually, the controversy in the EKC literature may partially be the result of some kind of "monetary illusion" regarding the usual figures for carbon intensity trends. We may summarize the main policy implication of this paper as follows. Neglecting the EKC on CO2 suggests significant distributional consequences from any climate change policy that eventually put at risk any international climate change agreement.

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1. Introduction

Ehrlich and Holdren (1971) have suggested the IPAT framework as a way to analyse the determinants of environmental impacts from economic development. Accordingly, there is an important strand of the literature that aimed to relate CO_2 emissions with Gross Domestic Product (GDP), population growth, or both variables simultaneously. The underlying idea behind most papers is the Environmental Kuznets Curve (EKC)[1] hypothesis, a sort of inverted U-shape relationship relating pollution to development following the original novel laureate Simon Kuznet and his graphical representation for the inequality-development relationship.

The EKC hypothesis deserves a close scrutiny because it might legitimate strategies for no-action against climate change (mainly on Non-Annex I countries within the Kyoto Protocol) as long as it offers a solution to the medium and long term: reductions in CO2 emissions will occur during the normal course of development, so we just have to spur a faster economic development without need for more stringent political action and public interference. But the empirical facts may not be in accordance with such an optimistic perception. It is interesting to call into this introduction the analysis released in 2011 by the oil company BP in its Energy Outlook 2030. There are two powerful trends that might support the EKC tale: (i) "energy intensity[2] converges across countries at accelerating speed and to lower and lower levels" and (ii) there is an "equalisation of fuel shares"[3]. But, BP Energy Outlook alerts also that world primary energy is

[1] See also Dinda and Coondoo (2006), Dinda (2004) and Verbeke and De Clercq (2006) for discussions about the EKC topic.

[2] In the economic literature, the term energy intensity usually represents the ratio energy to GDP (i.e., Gj/€).

[3] These words come from an article by BP's group chief economist Christof Rühl published by the European Energy Review on the 19th of January, 2012: www.europeanenergyreview.eu

likely to grow by a 39% from 2010 to 2030. As a result, global CO_2 emissions might rise by 27% with an average annual growth rate equal to 1.2%[4]. These increases come mainly from economic development in less developed countries, i.e. China and India might account for "two thirds of global demand growth in 2030". And this growth in total emissions is not exclusively for developing countries but also for developed ones[5] as we will show later on through the paper.

The empirical literature about the EKC on CO_2, which will be surveyed in the next section, leads to inconclusive results. As pointed out by Stern (2004) "The only robust conclusions from the EKC literature appear to be that [...] emissions tend to be monotonic in income". Therefore there is an overwhelming empirical evidence of positive relationship between per capita income and emissions regardless of any indication in favor or against the EKC. And this finding should raise some concerns about the distributional consequences of policies to reduce emissions. Any policy aiming to control or even to reduce carbon emissions that eventually includes developing countries (and this is a precondition to get involved key countries like USA) will abate their legitimate aspirations for further economic development.

This paper contributes to the literature in twofold aspects. Firstly, it includes the energy prices into an econometric model in a proper way, something unusual in the literature. Our results indicate that energy prices and country-trends accounting for technological change are important explanatory variables. The findings reported in this piece of research confirm the suspicion raised

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[4] See Rühl and Giljum (2011).

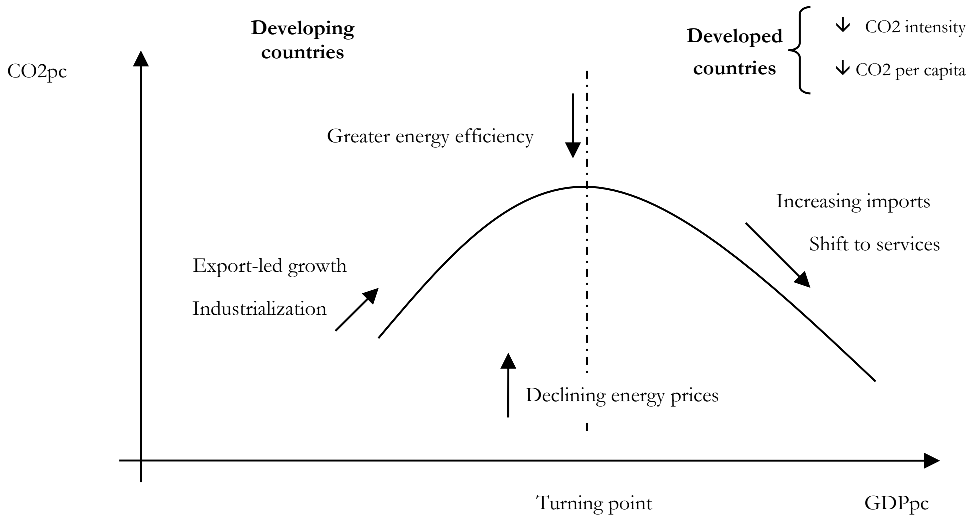
[5] For instance, Ailun and Yiyun (2012) reports that "483 power companies have proposed new coal-fired plants" across 59 countries and estimates that "1,199 new coal-fired [...] are being proposed globally"; the USA account for a number of 36 of them. The authors recognize that "not all of these projects will necessarily be approved and developed".

by some researches that the relationship among CO_2 emissions and GDP may be the result of omitted variables correlated both with GDP and CO_2. Secondly, it offers original explanations to dismiss the EKC based on economic concepts thus going beyond the usual justification based mainly on inadequate use of econometric techniques. The paper develops through the following sections. Section 2 summarizes the EKC hypothesis. In Section 3 we present a review of the literature. Section 4 presents the data base and some preliminary empirical evidence. Section 5 is concerned with the econometric methodology and results. Section 6 presents some in deep thoughts about the failure of the EKC hypothesis according to our empirical findings and literature survey. And finally section 7 summarizes conclusions and the main policy implications.

2. The Environmental Kuznets Curve hypothesis

The theoretical explanations of the EKC hypothesis are based on three effects: the scale effect, the structure effect and the abatement effect (Grossman and Krueger, 1995; Islam et al., 1999; and more recently Vishal, 2011). Firstly, the greater is the scale of the economy (population, GDP), the greater will be pollution. Secondly, national economies will experience structural changes throughout the economic development processes, from agricultural based economies to industrial (thus increasing energy and carbon intensities) and later on knowledge based economies, leading to less energy and natural resources intensive nations. Thirdly, richer economies will invest more resources on environmental protection and cleaner technologies. As a result of these three effects, at some point during the economic development process, both the structure and the abatement effect could counterbalance the scale effect, as to depict the well-known inverted-U-shaped curve relating pollution and GDP represented by Figure 1.

Figure 1: A graphical representation of the ECK for CO2



Source: Own elaboration. Adapted from Agras and Chapman (1999).

Besides GDP there may be some other factors than impact on carbon emissions like trade liberalization level, the share of each fossil fuels on total energy demand, the sectoral composition and sectoral intensity (see for instance among others: Marrero, 2010; Friedl and Getzner, 2003; Cole et al., 1997; Panayotou et al., 2000; Harbaugh et al., 2000; Kahuthu, 2006; Martinez-Zarzoso et al., 2007). Some researches have also look for the impact of additional factors on pollution like policy and institutional variables (i.e., Torras and Boyce, 1998; Panayotou, 1997) and the patterns of urbanization and sub-urbanization (i.e., see for instance Martinez-Zarzoso, 2011; Parikh and Shukla, 1995).

Let us make some reflections about the impact of stricter environmental regulations and increased trade liberalization following the globalization process and socioeconomic and political developments in most OCDE countries during last decades. International trade may influence EKC when firms outsource the production of pollution intensive products (or semi-finished products) as a consequence of i) stricter environmental regulations in rich countries (see for instance He, 2007) and ii) other competitive disadvantages like labor costs. Hence a “rich” country may manage to keep unaffected the consumption of final goods and services (and therefore the social welfare net of environmental impacts) whilst experiencing a “greening” in its production structure (Vishal, 2011)[6].

This situation is illustrated by the so-called Pollution Haven Hypothesis (PHH). Thus the EKC for a developed country could be moving downwards (upwards for a developing country) as illustrated in Figure 1 as a result of greater awareness of environmental issues and international trade liberalization, ceteris paribus a given GDP and population level. Put in other words, the EKC may be not a “development path” but a “policy response” instead.[7] This observation will reinforce the EKC hypothesis by means of enlarging the breach on carbon and energy intensity ratios between developed and developing countries.

Let us summarize the main insights from this section. According to the EKC hypothesis we should expect (i) an increasing reduction in carbon intensity for developed countries the farther they are from the turning point on the right hand of the EKC (i.e. the stationary point where the slope is zero; the opposite stands for developing countries)[8], with (ii) greater energy and carbon

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[6] However, there is not full evidence about the impact of international trade on emissions (Stern, 2004)

[7] Note, changes in energy efficiency or energy prices would move the EKC and consequently, they would change the “development path”.

[8] For developing countries there will be a slowing down increase in carbon intensity the closer they are to the turning point.

efficiency[9] as the main contributors to that trend (i.e. lower carbon per capita as a result of technological development, stringent environmental policies and more structural change from industry to services).

3. A survey of the literature

Let us start the journey on the relationship among CO2 and GDP by the beginning of this story. Dietz and Rosa (1997) represent one of the pioneering papers developing the stochastic version of the IPAT framework for CO2. They found that there is a linear relationship between the size of population and CO_2 emissions for a cross section data on 111 countries. This should not be surprising as long as it is capturing a scale effect. Additionally they found a quadratic relationship among CO2 and per capita GDP where "this decline in impact only occurs when per capita affluence is above $10,000". They speculate it might be as a result of (i) structural changes and (ii) investments in energy efficiency by more developed economies.[10] They found also important deviations in the technological multiplier[11] even among industrial nations. The Spanish technological multiplier for instance represents one of the lowest values in world, so that the Norway multiplier is 3.8 times the Spanish one while it is more than double for the cases of Sweden and Switzerland.

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[9] We refer to physical or technical efficiency. See for instance OECD (2012) to know more about competing concepts about resource efficiency and resource productivity.

[10] This is not a proper validation procedure for the EKC in strictu sensu as long as they regress absolute CO2 emissions instead of the per capita counter part.

[11] Theoretically, it represents the CO2 to GDP ratio but is modeled as a residual term. It incorporates not only the state of the technology art but also "social organization, institutions, culture, and all other factors affecting human impact on the environment other than population and affluence".

Following the previous framework Bengonchea-Morancho et al. (2001) reached different patterns for old and new EU members by applying panel data econometrics. They found that a 1% GDP growth in countries above average income will increase CO2 emissions by 0.18% whereas it will reach a 0.97% rise in below-average income countries. In other words, there is a greater elasticity of CO2 to changes on GDP for the poorest than for the richer. They developed their analysis further in Martínez-Zarzoso et al. (2007) by considering additionally population and the energy intensity as a proxy variable to measuring the level of environmentally damaging technology[12]. Again, they reached different patterns for old and new EU members. For instance, the elasticity emission-population is lower than unity for the former, whereas for the later is 2.73, which is in accordance with the higher marginal propensity to emit in less developed regions as reported in this literature review.

Let us now turn our attention to those papers focused on the EKC for per capita CO_2 emissions. The vast majority of investigations regarding this issue concentrate on cross-section and panel data. See for instance, among many others, Müller-Fürstenberger and Wagner (2007), Aldy (2007), Friedl and Getzner (2003), Holtz-Eakin and Selden (1995), Shafik and Bandyopadhyay (1992), Shafik (1994), Tucker (1995), Cole et al., (1997), Roberts and Grimes (1997), Dijkgraaf and Vollebergh (1998), Galeotti and Lanza (1999), Kahuthu (2006), Halkos and Tsionas (2001), Bertinelli and Strobl (2004), Martinez-Zarzoso and Bengochea-Morancho (2004), Bradford *et al.* (2005), Liu (2005), Vollebergh *et al.* (2005), Galeotti *et al.* (2006), Aldy (2005), Moomaw and Unruh (1997), Schmalensee et al. (1998), Vincent (1997).

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[12] They developed their analysis further in Martínez-Zarzoso et al. (2011) by considering additionally the urbanization level.

There are also in the literature studies for single economies. They usually address developing countries (i.e. Patel et al., 1995; Vincent, 1997) even though there are some exceptions for industrialized countries like Löfgren and Muller (2010), Moomaw and Unruh (1997) and Friedl and Getzner (2003). A good example of that sort of exceptions for industrialized countries is De Bruyn et al. (1998) who concluded that their results are consistent with the notion that an EKC estimated from pooled data (from cross-section and panel data) need not hold for specific individual countries. Furthermore, some papers like Dijkraaf and Vollebergh (1998) indicate that the relationship between income and carbon emissions varies among nations. Inside this longitudinal analysis, some researches conduct them for a very long period (around 100 years). This has been done for USA (Tol et al., 2009), Sweden (Lindmark, 2002; Kriström and Lundgren, 2005), UK (Fosten et al., 2012), and even for a large number of countries (Lindmark, 2004). All of them found strong evidence in favor of EKC.

We already acknowledged in the introduction to this paper that the EKC literature leads to inconclusive results. In fact there are many examples against this hypothesis[13]. But generally speaking papers that did not find evidence of EKC do find a positive relationship between per capita income and emissions. For instance, Holtz-Eakin and Selden (1995) suggest a diminishing marginal propensity to emit carbon dioxide as GDP per capita rises[14]. This result is "consistent with the left-hand side of an inverted U-shaped parabola" for the relationship between per capita GDP and several air pollutants found in Grossman and Krueger (1991) and Selden and Song (1994). Despite this feature, Holtz-Eakin and Selden conclude that emissions will keep increasing

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[13] For instance, Holtz-Eakin and Selden (1995), Huang et al. (2008), Brock and Taylor (2004, 2005), Galeotti et al. (2009), Wagner (2008), Marrero (2010), Martinez-Zarzoso and Maruotti (2011).

[14] The same kind of result reported in the IPAT literature surveyed previously.

with growth because output and population will expand faster in lower-income nations[15] (with their high marginal propensity to emit) than higher ones (which eventually passed the turning point). Put in other words, economic growth in itself does not offer a solution to environmental problems as long as reductions in CO_2 emissions will not occur during the normal course of development. Besides, the reader should note that an EKC for CO_2 emissions *per capita* does not imply an EKC for total CO_2 emissions, as showed in York et al. (2003).

As a result of such unconvincing literature there is not clear and unambiguous evidence that income gains will reduce CO2 emissions once attained a high enough income level. As a consequence of no homogeneous results in the EKC literature, the validity of this hypothesis has been questioned in some literature surveys (e.g. Stern 1998, 2004). Besides some authors point out there are some technical weakness in some analysis as well as the presence of omitted variables bias (for an exposition on these issues see for instance Perman and Stern 2003, and Stern 2004). The existence of omitted variables correlated with per capita GDP will result in inconsistent and biased estimates (Mundlak, 1978; Hsiao, 1986). As a consequence, Borghesi and Vercelli (2003) and Stern (2004) concluded that the EKC hypothesis cannot be generally accepted for the case of carbon emissions whereas it may be correct for those studies based on local emissions. Thus as long as the evidence is rather diverse for panel data, and the studies on single countries are rather rare, additional research is called for.

Regarding to the issue of omitted variables, it is surprising that nearly all of the studies surveyed omit energy prices. There is not doubt that marginal costs will affect energy consumption for a given end-use service where the energy price is one of its main variables. Thus the energy price

[15] The same results as reported by BP energy Outlook 2030.

elasticity will have an important effect on the energy intensity and carbon intensity of any economy[16]. There may be different channels for that causality. On the one hand, an increase on energy prices may cause substitution effects (among different energy sources; between energy and other final goods; between energy and other intermediate inputs or primary factors; etc.). On the other hand, it may boost investments on energy efficiency (by households; by firms on their production processes; by firms on the energy efficiency incorporated to the final goods offered to the households or any other economic agent; etc.). Additionally, there may be indirect effects caused by the income elasticity of energy consumption through changes on real income.

The first attempt to our knowledge to study EKC for CO2 emissions including energy prices as an explicative variable is Agras and Chapman (1999). Their results may be subject to criticism as long as they use the same variable (real gasoline prices in the US) for all countries in the sample. Even if we could assume that the oil market have a reference price, this is not the reference price to undertake any decision by the industry and household in each country, since the tax burden may rise important differences (and any other political regulation or intervention that deviates final prices from the producer costs). The same sort of weakness might be found in Heil and Selden (2001) and Fosten et al. (2012). The former use the price of crude oil delivered to US refiners in each year measured in 1994 US dollars[17], whereas the later uses gas prices to represent energy prices when analysing the ECK for CO2 in the UK. In the particular case of Richmond and Kaufmann (2006a), they arrived to similar results as presented in Agras and Chapman (1999) against the EKC hypothesis. In this case, the authors use the price of light fuel oil for industry.

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[16] Energy intensity and carbon intensity of one economy refers to the energy to GDP ratio and Carbon to GDP ratio respectively.

[17] They believe that the US oil price is a reliable proxy for the world oil price.

They have been playing around with different functional forms and specifications. They found a positive relationship between per capita GDP and CO2 emissions even though it exhibits diminishing returns which are consistent with the "inverted U-shaped parabola".

Finally, since last decade there is a growing literature dealing with the dynamic causal relationships between pollutant emissions, energy consumption and output. This literature examines the time series dynamics (i.e. through Granger causality test) between income and emissions in order to infer the direction of causality among variables. As a general conclusion it could be said that there is evidence of an inverted U-shape pattern associated with the EKC in Hsiao-Tien and Chung-Ming (2010), Apergis and Payne (2009), Ang (2007), Coondoo and Dinda (2002), Dinda and Coondoo (2006), Akbostanci et al. (2009), Niu et al. (2011), and Lee and Lee (2009). However Vishal (2011) does not provide such evidence of an EKC.

4. The data base and some preliminary empirical evidence

Our sample is a balanced panel for 15 OECD countries[18] during the period 1980 to 2004. We have excluded previous years in order to avoid (i) the structural changes taking place in the 70's in response to the energy crisis and also (ii) any distortions related to the financial crisis in more recent years. The data sample has been published by the "Energy Statistics of OECD countries, 2007 edition" and the "Energy Prices & Taxes 2nd Quarter 2007" both published by International Energy Agency (IEA) and the OECD.

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[18] Countries included are Austria, Belgium, Check Republic, Denmark, Finland, France, Hungary, Italy, Japan, Poland, Slovak Republic, Switzerland, Turkey, United Kingdom, United States.

Table 1 summarise the main descriptive statistics.[19] Our data database includes several OECD countries at very different stages (i) on their development process and (ii) CO2 per capita levels (most developed EU countries, former soviet federation European republics, USA, Australia, Turkey). In addition to GDP and CO2 emissions, energy prices represent also key variables in our database. Average coal and gas final prices (150.71 $/t and 425.54 $/m3 using ppp, respectively) are lower than average oil prices (935.56 $/kl using ppp), particularly coal prices are less than a quarter and gas less than the half of oil prices on average. Finally we attempt to capture the national endowment on energy resources by the domestic primary energy production relative to total primary energy consumption. As it is shown by table 1, our data base contains a sample of countries showing high energy dependence from abroad and consequently low energy security.

[insert Table 1 here]

In advance to our econometric study let us proceed with some descriptive analysis of the data. Let us bear in mind at this point that according to the EKC hypothesis we should expect (i) an increasing reduction in carbon intensity for developed countries the farther they are of the turning point on the right hand of the EKC in Figure 1, with (ii) greater energy and carbon efficiency as the main contributors to that trend (i.e. lower energy and carbon per capita as a proxy for efficiency). However a close inspection of the data does not provide empirical evidence in support of the EKC hypothesis. Let us identify the following trends for most of the countries in our database over the period 1980–2004. There is on average (i) a rise on per capita CO2 and

[19] Details about the variables definitions are showed in the Appendix.

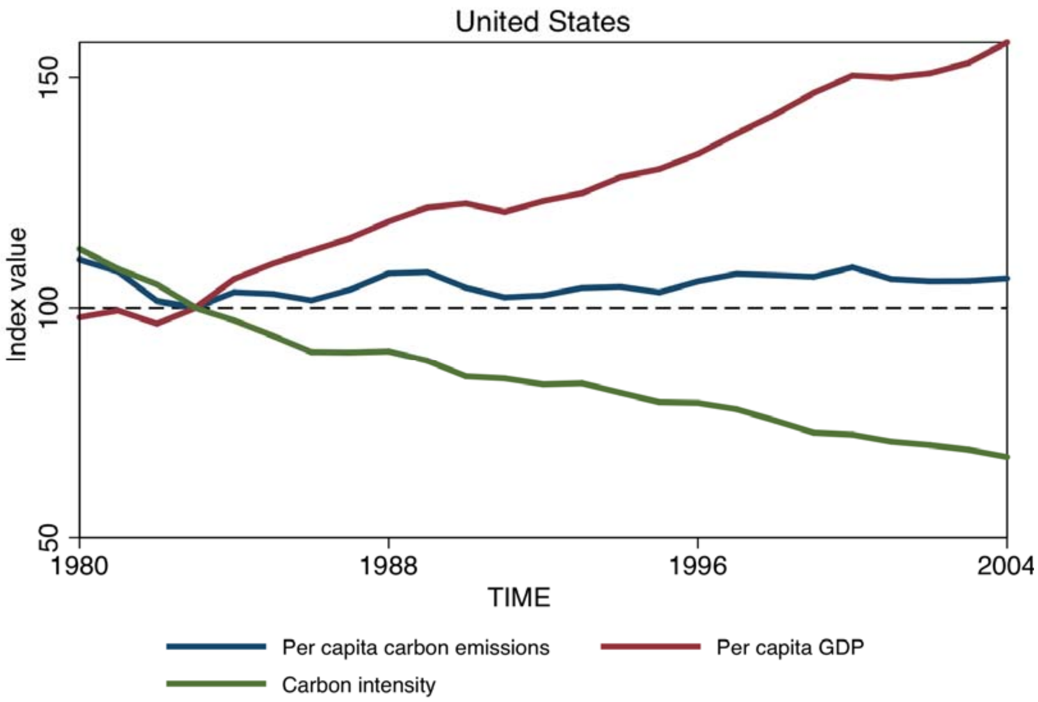
simultaneously (ii) an improvement on carbon intensity[20]. The Figure 2 for USA bellow might provide a flavour of the sort of processes going on in our data base for most of the countries[21].

The Figure 2 for USA below might provide a flavour of the sort of processes going on in our data base for most of the countries. It shows the path followed for the three main variables of interest in this piece of research: per capita CO2 and GDP and carbon intensity. For easiest of exposition they are represented as an index for the period 1980-2004 with the year 1983 as the base year. The main facts illustrated by Figure 2 are the following: between 1983-2004 there was (1) a +36% increase in per capita GDP which resulted in (2) a -37% reduction on carbon intensity as a result of (3) a moderate +6% increase in per capita CO2.

[20] A simple arithmetic calculus for the whole sample will tell us that per capita CO2 has increased on average by a 0.4% annually whereas carbon intensity dropped by a 1.7% annually.

[21] Following the energy crisis in the 70's there was a correction on per capita carbon emissions until early 80's. After that we may observe graphically that per capita carbon emissions were rising smoothly. That is the reason we conduct our analysis for the period 1983-2004. See Tol (2006) figure 1 for another example for the USA showing the same sort of graphical representation but for a very long time period (1850-2004).

Figure 2: Per capita Carbon emissions and GDP plus Carbon intensity for the USA



Source: own elaboration. The figure represents the index for each variable (1983 base year).

The observation of higher carbon per capita and lower CO2 intensity all together might represent a paradox[22] and the main source of interpretative distortions in the EKC literature. An analyst might point out that the reason for such a paradox is that the scale effect from economic growth is strong enough so as to outweigh both the composition effect (the structural change of the economy) and improvements on productive efficiency (the technological effect). That reasoning might jeopardize the EKC hypothesis as long as the US symbolizes one of the most developed economies in the world leading the structural and technological change during this century. Let

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[22] As noted previously, there should be a reduction on per capita energy and CO2 (greater efficiency) on the right hand side of the EKC.

us say, the US economy should behave “like if” standing at the left hand side of the turning point on the EKC.

Actually those trends should not be taken as a proper novelty. They are embedded in some publications like BP Energy Outlook 2030 and Jones (2002) for instance. Let us take just the findings raised by Jones (2002) for the US example in the period 1950–1998: (i) per capita energy use has increased at an average annual rate of about 1% and simultaneously (ii) energy efficiency (GDP per unit of energy input; so it actually refers to energy intensity) improved at an annual rate of 1.4% on average. But further economic development in a rich country like the US should be the result of a structural change towards a knowledge based economy (structure effect), where a fraction of GDP gains should be devoted to stimulate further investment on environmental protection (abatement effect). Both effects will improve energy efficiency and reduce per capita energy consumption (lower per capita environmental impacts). However Jones (2002) presents an US economy where lower energy intensity does not result on lower energy per capita. The preliminary results raised in this section represent indeed a serious handicap for the EKC hypothesis and it should be refuted by robust empirical evidence.

5. Econometric methodology and results

In this section we present an in deep econometric analysis of our data base in order to validate the EKC hypothesis for CO2 emissions. First of all, we outline the econometric methodology. We express the model as following:

$$d_{it} = \beta_1 y_{it} + \beta_2 y_{it}^2 + \beta X_{it} + u_{it}; \quad i = 1,...,N; t = 1,...,T$$

We will assume that the fixed effect u_{it} follows a one-way error component model[23],

$$u_{it} = \mu_i + \nu_{it}$$

where $\mu_i \sim$ IID $(0,\sigma_\mu^2)$ and $\upsilon_{it} \sim$ IID $(0,\sigma_\upsilon^2)$, independent of each other and among themselves.

In this model, d_{it} is CO_2 per capita discharged on the environment, y_{it} is the Gross Domestic Product per capita and X_{it} is the set of the additional explanatory variables. We perform different specifications in order to assess the robustness of the results. First of all, we estimate a basic Environmental Kuznet Curve (EKC) including (y_{it}) and its square in order to control for the possible inverted U-shape of the curve. This specification will allow us to compare our results

[23] Within this class of models, the fixed effects specification is a common choice for macroeconomic analysis and it is believed to be more appropriate than a random effects model for two reasons. First, if the individual effect represents omitted variables, it is likely that these country-specific characteristics are correlated with the other regressors. Second, a typical macro panel is not likely to be a random sample from a larger universe of countries. Moreover, we have tested for fixed effects using Hausman test in all specifications and fixed effects are preferable to random effects.

with previous studies and to get a reference point for comparison purposes with alternative specifications.

But economic development is not the unique important variable for explaining CO_2 discharge on the environment. The energy mix has been used in recent decompositions of the Carbon emission changes (Ang, 2005; Wang, et al. 2005; Liu et al, 2007 among others) and even it have been included in some estimations (i.e., Marrero, 2010). Nevertheless, the energy mix is not the primary tool for basing policy-makers decisions. In fact, the energy mix is driven by energy prices and production capacities. From a methodological point of view, adoption of energy shares to account for some kind of composition and structural effects may be subject to some criticism. That sort of fuel-mix regression model might be better suited to maximise the goodness of fit to the data (higher r-square). But this is only because the specification might be flavored by some sort of accounting identity.[24] Besides it is unclear the usefulness of such fuel-mix model. It could not say anything about future carbon emissions without meaningful projections for the demand of each fuel type. In that case (if the researcher has those projections) she does not longer need a statistical model to predict carbon emissions (it will just be enough to compute them with some simple mathematical equations or a simple "accountability" method). Furthermore she will need to know future income and relative price movements for instance in order to obtain demand projections by fuel type.

[24] Carbon emissions are calculated by statistical agencies precisely as a weighted sum of the different fuel consumptions, using fixed coefficients reflecting the carbon content of the energy units in each type of fossil fuel (i.e., ac*COAL+ ag*GAS+ ao*OIL). Once you have in your model both energy shares and total energy you will reach to that original identity.

As pointed out in the introduction to this paper, one contribution of this piece of research is to incorporate energy prices. Very few papers have included energy prices for explaining the EKC hypothesis. One of the main reasons might be data availability. It is difficult to build an energy index due to the difficulties to get data for some energy sources (i.e. coal) and also to the changes in the energy mix along the time. As a result, some authors use the oil price as a proxy. Nevertheless, the researcher will be unable to take into account energy substitution effects driven by relative price changes when using just one price as a reference. That might be the reason why some authors do not get significant prices effects on carbon emissions (Richmond and Kaufmann, 2006b). To include several prices for competing energies is a complicated task due to the lack of data for many countries and sources. Nonetheless prices are certainly important governing the energy levels, energy mix and therefore pollution levels so we should include it in our model.

Accordingly energies prices (p_{it}) have been included as additional explicative variables in our empirical model instead of individual energy shares on final consumption (refined oil products, coal and gas)[25]. We use the end user prices for industry and household, thus including taxes and also many other policy decisions impacting on the price levels and the energy mix (i.e., environmental regulations, price controls, indicative planning on production capacity, "feed in" tariffs for renewables). Renewable energies provide an additional empirical trouble since there is

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[25] We have excluded electricity because of two main reasons: (1) it is a tradition in developed countries that electricity prices have been highly regulated through public tariffs with almost no intra year variations which render less explicative value in our empirical purposes, and (2) other energies like coal, oil products and natural gas may act as fuels for the production of electricity and thus the double counting should be avoided by consolidating those values. Besides we control for the production of renewable electricity in our empirical model.

not a reference price for them. But they are certainly important in order to reduce pollution so we should account for them in some way. Since it is not possible to calculate a price for renewable energy we include its production (toe) in per capita terms.[26] Finally, we also include the domestic production of different energies (their share on total energy) in an attempt to account for structural energy constrains.

Many papers have explored the contribution of sector's shares on total energy consumption in order to explain carbon emissions and the EKC (mainly within the decomposition analysis literature addressing the EKC hypothesis but also by some econometric modelers like for instance Marrero, 2010). However, we consider that the shares of each economic sector on total energy consumption do not represent a good proxy for technological changes (efficiency) between sectors. They could account instead for changes in sector composition (intra and between changes) due to other supply-side and demand-side reasons. In its place we include the country-trend to account for changes such as technological ones during the period 1980-2004 for each country.[27] We also incorporated year dummies accounting for common economic shocks for all countries. Furthermore, results reported by Holtz-Eakin and Selden (1995) disclose the importance for controlling for year and country effects. They emphasize the role of those variables to account for time varying omitted variables and also stochastic shocks common to all

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[26] Note, we assume that all renewable energy available is consumed.

[27] Country trends allow for different country levels on CO_2 emissions at any particular income level (we captured this effect in a dynamic fashion, in contrast to invariable country dummies as it is usual in the literature). Besides the inclusion of a country specific trend allows the same income elasticity along the income distribution from a cross section point of view.

countries which could be correlated with GDPpc, i.e. the omission of these variables would bias the results.

To assess the robustness of the results, we also incorporate the lag CO_2 per capita discharged on the environment in order to control for dynamics. Nevertheless, the inclusion of a lagged dependent variable in the model (1) renders the OLS estimator biased and inconsistent.[28] Soto (2007) analysed through Monte Carlo simulations the properties of various GMM and other estimators when the number of individuals is small, as typical in country studies. He found that the system GMM estimator has a lower bias and higher efficiency than all the other estimators being analysed.[29] Consequently, the best available estimator for our equation is the one-step system-GMM estimator by Blundell and Bond (1998).

The validity of the assumptions used to obtain the moment conditions of System GMM can be assessed using a Sargan overidentification test under the null that these moment conditions are valid. Nevertheless, too many instruments generated system GMM can lead to a problem of overfitting, reducing the power of the Sargan test (Roodman 2009a, 2009b).[30] There are two main techniques to limit the number of instruments: to use only certain lags instead of all available lags

[28] See Sevestre and Trognon (1985) for the magnitude of this asymptotic bias in dynamic error component

[29] Blundell et al. (2001) provide Monte Carlo simulation comparison between one-step difference and the System GMM estimator. They show that system GMM has substantial asymptotic efficiency gains, as it not only greatly improves the precision but also greatly reduces the finite sample bias compared to poor performance of the standard one-step difference GMM estimator for highly autoregressive panel series

[30] Instrument can overfit endogenous variables, failing to expunge their endogenous components and biasing coefficients estimates.

or to combine instruments through addition into smaller sets. We will apply both techniques in order to avoid overidentification.

5.1. The Results

The standard EKC regression model (Stern, 2004) will render the reference point in order to compare our results with previous studies establishing also a benchmark for different alternative specifications. As showed in the first column in Table 2 there is not evidence in favor of the EKC as long as GDP and its square are both not significant. Hence validating our intuitive conclusions from the preliminary data inspection provided previously. Actually we only found a monotonic relationship among CO_2 and GDP for the last two columns (but still weak evidence according to p-values), once included both energy prices and domestic production of primary energies.

[insert Table 2 here]

As expected the results in Table 2 highlight the important role of energy prices in order to explain the path followed by per capita CO_2 emissions. The next two columns offer a counter intuitive result suggesting that a rise in the price of oil products may increase CO_2 emissions. We wonder whether that outcome might be a sign of the substitution effects among energy sources; an intuition being corroborated by the forth and fifth columns where the price of coal (relative to oil) become now a significant variable to explain CO_2 emissions. In absence of a price for renewables, their production in per capita terms turn out to be a significant variable when including absolute price indexes only (i.e. compare column 3 and 4). As a result an increase in per capita renewable production will render lower CO2 emissions per capita.

Finally the inclusion of primary energy production levels offers a mixed picture. As expected the greater the production of renewable energies the lower CO_2 emissions. A similar result was reported for oil and coal production (but for the case of coal is not significant at 1% confidence level). These values might be capturing some idiosyncratic element for some countries. That may be the rational explanation according to the estrange change on the value of the constant term and the very suspicious conversion to an insignificant variable.

The results from our preferred specification (column 7) are surprisingly similar[31] to that published in the pioneering paper made by Holtz-Eakin and Selden (1995). Those authors acknowledged a diminishing marginal propensity to emit (MPE) carbon dioxide as GDP rises (on relative per capita values). Their results reveal also that using the "appropriate statistical technique also alters dramatically the implications for the distribution of emissions" in such a way that "using the cross-section, the richest countries appear to have the greatest MPE; whereas the fixed effects estimates suggest that the reverse is true".

There are in the literature many papers that turn our attention to dynamic models. For instance, in order to take into account any structural element affecting changes or adjustments in the evolution of CO2 emissions. Martínez-Zarzoso et al. (2007, 2011), Friedl and Getzner (2003), Marrero (2010), Agras and Chapman (1999), among others included CO2 lags in their models. This will allow controlling for short-term dynamics and conditional convergence. Furthermore Agras and Chapman (1999) included also a lag for GDP. As a consequence and to assess the robustness of our results in the static specification we would rewrite our model as a dynamic specification.

As we have explained in the previous section, the suitable estimator for our model is Blundell and Bond's (1998) system-GMM estimator. We have applied some robustness test for all

[31] For the variables which are common for both studies (GDP and its square, constant term, r-square).

specifications. We have examined the behavior of the coefficients and the over identification test when we reduce the number of included instruments. For all specifications we get the same results independent of the number of the instruments being used. Moreover, all estimations have been checked using estimates based on OLS and within transformation procedures in order to appraise the robustness of the results. Additionally we report the number of observations and instruments being used and the p-values of the Arellano-Bond AR(1), Arellano-Bond AR(2)[32] and Sargan tests.

The main lessons from Table A1 are the following. Neither the GDP per capita nor its square appears to be significant, i.e. we do not find evidence for the EKC on CO2. Prices are important variables for some specifications (columns). Coal prices in absolute terms turn now to be significant instead of oil prices (whereas for the static model as in Table 2 coal was significant only in relative terms with respect to oil) and it is consistent with what we found in relative terms. It may be concluded from these results for prices that their main effect on CO2 emissions is on the medium and long term instead of the short term (the last effect being captured by the dynamic model). This conclusion should be expected according to the low price elasticity of energy consumption as reported usually in the energy economics literature. Finally the production of renewable energy seems to be negatively correlated with CO2 emissions and significant in all specification, i.e. the possibility of using renewable energy is an important tool

[32] Within the Arellano and Bond (1991) procedure, AR(1) residuals are not detrimental to estimation, while AR(2) residuals are. Another further feature of our results is the importance of allowing for an AR(1) component in equation function error term. We need to allow for this serial correlation in order to obtain any valid lagged internal instruments in first-differenced or equations in levels. The estimations for our model do not show autocorrelation of second order and Sargan test performed well, too.

to decrease the CO_2 emissions. Thus we may conclude that results from the dynamic econometric model are similar in qualitative terms to the within estimator (the static econometric model) where the last one being our preferred specification.

6. In deep thoughts about the failure of the EKC hypothesis

In this section we will try to add some light in order to found any rationality for the conclusions raised in previous sections: (1) the forces behind those disturbing data trends of higher CO_2 per capita and lower CO_2 intensity all together, (2) the contradictory results in the empirical literature with respect to rejecting or acceptance of the EKC hypothesis, (3) the overwhelming evidence against EKC from simple graphical analysis and corroborated by the empirical analysis both in the static and dynamic specification, (4) the effect of energy prices on per capita carbon emissions.

Some of our thoughts are firmly rooted into well established elements sometimes dismissed by researchers. Our literature survey and empirical exercise showed that there are some difficulties for the EKC hypothesis to conform to the empirical evidence. Or rather the empirical evidence is rather mixed or subject to alternative interpretations. Some researches argue that the functional form of EKC may be conditioned by policy decisions (environmental regulations, electoral processes, level of democracy, enhanced trade liberalization, etc.)[33]. This section renders some

[33] See for instance Barrett and Graddy (2000); Magnani (2001); Grossman and Krueger (1995). As noted in our survey some of these variables may act to reinforce the EKC empirical evidence.

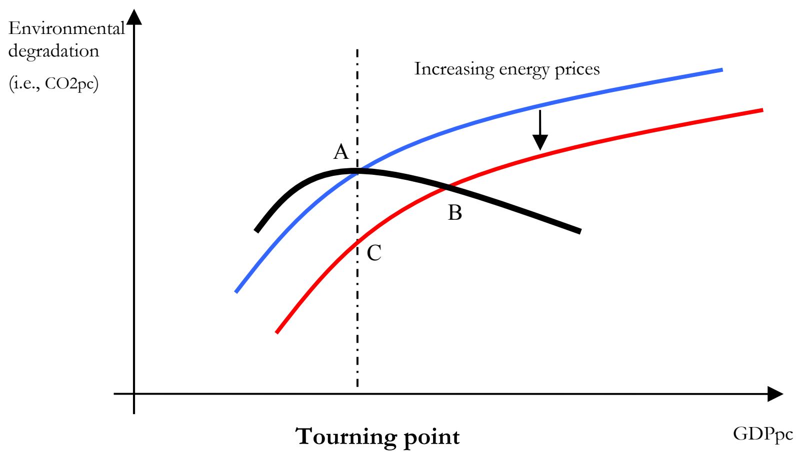
additional reasons to doubt the empirical support on the EKC hypothesis which may be disturbing the empirical assessments[34].

The controversy in the EKC literature may partially be the result of three main elements: (i) the lack of empirical researches to control for energy prices, (ii) the diminishing marginal propensity to emit carbon dioxide as per capita GDP rises, and more important (iii) the fact that diminishing carbon intensity trends (GDP ratios) might be the consequence of some kind of "monetary illusion".

According to section 2 in this paper there may be different channels for energy prices to impact on the economy. They will move downwards the EKC whatever the channel of any price increase. Figure 3 shows a hypothetical representation of the GDP-CO2 relationship for a particular country before (blue line) and after (red line) a significant rise on energy prices. Let us assume that along the price change there is a sustained rise on per capita GDP (there is not truncation on the development process; so point A takes places earlier in time that point B; otherwise the final point will be C following a price increase without a rise on per capita GDP). Thus an empirical assessment on the data generated by this graphical representation (black line) might provide evidence in favour of the EKC despite each single coloured line represents the true relationship between GDP and CO2 emissions. Thus we may reach to our first conclusion: researches lacking to include energy prices may be jeopardizing their empirical evidence in favor of the EKC hypothesis.

[34] See for instance Stern (2004) for a good survey on both issues: the theoretical and empirical support for the EKC hypothesis.

Figure 3: Per capita Carbon emissions and GDP



Source: own elaboration.

Holtz-Eakin and Selden (1995) acknowledged a diminishing marginal propensity to emit carbon dioxide as GDP rises (on relative per capita values) where marginal propensity to emit is closely related to income elasticity. More recently Bengonchea-Morancho et al. (2001) and Martínez-Zarzoso et al. (2007) found that there is a greater elasticity of CO2 to changes on GDP for the poorest than for the richer countries for a panel of old and new EU members. They found that a 1% GDP growth in countries above average income will increase CO2 emissions by 0.18% whereas it will reach a 0.97% rise in below-average income countries.

From a dynamic perspective Vishal (2011) finds that a 1% increase in GDP generates an increase of 0.68% in CO2 emissions in the short-run and 0.22% in the long run for 36 high-income countries for the period 1980–2005. This behavior “does indicate that, over time, CO2 emissions are stabilising in the rich countries" but in general Vishal (2011) rejects the EKC[35]. Some authors took a step forward on this evidence and reached misleading interpretations. For instance Narayan et al. (2010) "suggest examining the EKC hypothesis based on the short- and long-run income elasticities; that is, if the long-run income elasticity is smaller than the short-run income elasticity then it is evident that a country has reduced carbon dioxide emissions as its income has increased"[36]. Thus they might come to the erroneous conclusion that there is a rise on energy efficiency. But there may be indeed a rise in CO2 emissions in absolute and per capita terms. Therefore increasing energy efficiency is not a conceivable explanation for smaller long-run income elasticity and marginal propensity to emit. Jones (2002) provides convincing evidence as outlined previously.

A similar conclusion has been found also within a country like the US where the richer states present lower income elasticities for CO2 (Aldy, 2007) but still with a positive sign. The Aldy paper is certainly very insightful as departs from the main strand of the literature by analyzing a data base for different states within a federal country where (i) you could find a sort of regulations and institutions common for all states and (ii) similar economic development levels but (iii) still with some heterogeneity.

Thus we may reach to our second conclusion. Coupled lower CO2 intensity and greater CO2 emissions should be an expected result as long as we regard energy as a primary good (what will be consistent with diminishing both marginal propensity to emit and income elasticity with

[35] Income elasticity remain positive and therefore against the EKC hypothesis (which otherwise will predict negative values at the right hand of the turning point). This phenomenon has been identified by several authors, i.e. York, Rosa and Dietz (2003).

[36] Similar interpretations could be found in Narayan and Popp (2012) and Arouri et al. (2012).

regard to GDP). Accordingly CO2 should reduce its share on GDP as a country develops economically and CO2 becomes more income inelastic. Then CO2 per capita might be growing but at lower rates than those values for GDP (as usually showed in the literature, i.e. Figure 2 in section 4).

Households behave in a similar way with respect to carbon emission along the income distribution. That sort of features has been found for urban household data across different regions in China. Golley and Meng (2012) found an increasing marginal propensity to emit over the income range in such a way that a growing carbon per capita across the income ranges was joined with decreasing carbon intensities (in terms of household expenditure)[37]. The same sort of patterns has been reported by Gough (2011) for the UK where the highest decile present a GHG per capita twice the median decile whereas the reserve stands for emission intensity values.

Let us turn now our attention to carbon intensity (GDP ratios) trends. Certainly, a familiar definition for economic development is the ability to produce more value added (capital and labor income). Hence carbon to GDP ratios might have nothing to do with efficiency but with productivity instead. We must remember at this point that GDP is a national accountability measure. As we know from any introductory economics text book, GDP could measure alternatively three different concepts: total value added, total gross income and total consumption

[37] Actually Golley and Meng (2012) tried to explain the relationship among energy and carbon along the income ranges according to the EKC hypothesis and concluded from their empirical exercise that "The fact that the quadratic model implies an eventual downturn in per capita emissions while the cubic model implies a non-monotonic but eventually continuous rise in emissions […]. While this means that the turning points themselves cannot be taken too seriously, it should not detract from the key point that, over the vast majority of the per capita income range, Chinese household per capita total emissions are increasing".

of final goods and services. Therefore, an increasing value added generation capacity will naturally result in lower carbon intensity[38].

As a result carbon intensity measures might be good proxies for carbon efficiency (from an engineering or physical point of view) as long as there is a close correlation between physical output and monetary output. Unfortunately, that may be not the case and many authors tend to overlook this important point. For instance Hsiao and Chung (2010) might provide a good example exemplifying the close link made by many authors among carbon intensity and efficiency in the literature. That lack of correlation among physical and monetary variables will help us to explain why developed economies usually present simultaneously the lowest carbon intensity coupled with the highest CO2 per capita (apart from oil exporting countries). Thus we may reach to our third conclusion: diminishing carbon intensity (GDP ratios) trends might be a sort of "monetary illusion" in some instance.

There is actually an "indirect" testimony for this explanation of the empirical evidence. Löfgren and Muller (2010) have reported the existence of a diminishing reduction in energy intensity for developed countries after early 1990s[39]. That takes place during a major economic expansion and increasing TIC development. Both should contribute to increasingly energy and carbon efficiency gains but it does not seem to be the case, at least for developed countries. Besides there are also

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[38] That might be the case, for instance, as a result of additional investment in human and physical capital. China recent structural transformation represents indeed a good example: a reoriented exporting economy centered in the manufacturing sector which encourages a push on Chinese productivity and GDP, and by the way huge improvements in carbon intensity. But simultaneously it is one of the main "machineries" for increasing global carbon emissions for some years to come.

[39] Simultaneously a growing number of developing countries are reducing their energy intensities.

researches reporting a continuous decrease in energy intensity for the manufacturing sector. However "this seems to be less the case in other sectors"[40] in developed economies (Löfgren and Muller, 2010; Hamilton and Turton, 2002; Ang and Zang, 2000). Thus, the greatest reduction on energy intensity might took place simultaneously with the greatest increase in productivity (traditionally they are stronger in the industrial sector) while lacking for a good understanding of what is going on with carbon efficiency.

7. Conclusions and policy implications

The EKC hypothesis predicts that more developed countries present simultaneously lower CO2 per capita and carbon intensity values than developing countries "no too far away" in economic sense (i.e., close to the turning point; let say middle income countries according to the World Bank classification[41]). But what we usually observe in more developed economies is just the opposite: the lowest carbon intensity coupled with the highest CO2 per capita (apart from oil exporting countries). Thus they are "resembling to be" on the turning point over the EKC. That has no sense for economies like for instance the US, Finland, Denmark, Germany, UK, Norway, Luxembourg or Netherlands[42]. We may found some exceptions of course. Some industrialized countries have accomplished significant reductions on CO2 per capita during the course of

[40] Hamilton and Turton (2002) found for the OECD as a whole that the energy intensity increases for agriculture as much as an 80%.

[41] http://data.worldbank.org/about/country-classifications

[42] We do not pretend to provide a comprehensive list of countries but just some notorious examples.

economic development. But in many cases the foundation is not economic development on itself but technological or political shocks that produce structural breakpoints[43].

As a general conclusion high carbon intensity values should not be linked to mismanagement of energy and therefore to a source of high carbon saving potentials. The same reasoning applies in the opposite direction. Otherwise we might end up with conclusions like the one in Wang, Chen and Zou (2005). They found that China "has made a significant contribution to reducing global CO2 emissions, especially since 1980" by comparing the total "theoretical decrease" of CO2 emissions (according to the evolution on GDP and population) with the "total decrease". They realize that the 95% of Chinese contribution to curb global CO2 emissions may be attributed to the energy intensity effect. In other words, without efforts for improving energy intensity "CO2 emissions for China in 2000 would have been […] more than 50% higher than its actual emissions"[44]. But we may conclude instead that this amazing Chinese contribution to reducing global CO2 emissions is just a "monetary illusion" resulting from increasing carbon productivity.

The approach to the EKC followed in this section will help us to rationalize some contradictory observations found in the literature. The EKC for CO2 might be flawed with the sort of

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[43] Like for instance the important development of nuclear utilities in France and Sweden before the nineties. For the Swedish case Löfgren and Muller (2010) assert "The discrepancy to the literature on the earlier years is mitigated by the literature finding that the energy intensity contributes less to reduced emissions after the early 1990's than before". That may also be the case for developments of unconventional gas fracking in several countries in the near future.

[44] Similar conclusions for China may be found in Fan et al. (2007), Zhang et al. (2009). Similar arguments for other developing countries based on the lower substitution elasticicty among GDP and CO2 could be found in Narayan et al. (2010) and Arouri et al. (2012) for instance.

misconceptions highlighted in this piece of research thus providing misleading guidelines for policy makers. Actually many policy makers and institutions are very concerned by the path followed by Chinese energy and CO2 emissions because of obvious reasons (not only the scale of this country but also for the geopolitics of climate change). There are obvious distributional consequences from any climate change policy that eventually jeopardize any international climate change agreement. It has been extensively reported that abatement cost will have a heterogeneous impact regarding countries carbon intensities where less-developed and emerging countries will usually bear the highest cost whereas it will be moderate for developed countries (see Brechet and Tulkens (2013), Luderer et al. (2012), Edenhofer et al. (2010) and Giordano and Watanuki (2012), among others). Some researches consider that equity issues will represent the next frontier in climate talks[45]

Two additional interesting reflections are in order. Firstly York, Rosa and Dietz (2003) found that “the energy footprint […] increases with affluence [GDP] at an escalating pace. This finding suggests that observed instances of economic ‘decarbonization’ may be very misleading; de-carbonization appears to come at the cost of increases in other types of impacts” and that finding may falsify conventional “tests of the environmental Kuznets curve and modernization theory”[46]. Secondly the EKC hypothesis may be valid for concentration of pollutants in local areas (such us suspended particulate matter or sulfur dioxide) but that might be not the case for emissions as it is the case for GHG (i.e., Holtz and Selden, 1995; Stern, 2004) because “their effects [GHG] are substantially more costly to abate and less restricted to local areas. Thus, the free-rider problem

[45] Gosseries (2007) offers a philosophical perspective on this issue.

[46] That would be the case for instance of any eventual substitution of nuclear power and unconventional gas fracking for coal

argues against a tendency for greenhouse gas emissions to decline at higher per capita incomes”[47].

Finally, we would like to highlight the role of renewable energy and relative energy prices on the reduction of carbon emission. Actually, policymakers could use energy prices to encourage the consumption and to promote the research on less pollutant energies.

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[47] Holtz and Selden (1995).

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Appendix A: Variables definitions and calculations

- **CO_2 discharge on the environment:** CO_2 sectoral approach (mt of CO_2).

- **Gross domestic Product per capita** (expressed in thousands 2000 $ US using PPPs per person).

- **Total primary energy consumption** (it includes oil, coal, gas and renewable) (ktoe per person).

- **Weighted average price of oil products** (2000 $ US - using power purchase parity/kl): It is calculated as a weighted average of industry and household prices (we use the final consumption as weights). Industry prices include representative heavy fuel oil, light fuel oil and automotive diesel but not fuels used for electricity generation. The household index includes representative gasoline and light fuel oil.

- **Weighted average price of coal** (2000 $ US using power purchase parity/ton): It is calculated as a weighted average of industry and household prices (we use the final consumption as weights). For coal, the industry index includes representative steam coal and coking coal. The household index includes steam coal.

- **Weighted average price of gas** (2000 $ US using power purchase parity/m^3): It is calculated as a weighted average of industry and household prices (we use the final consumption as weights).

- **Production of renewable energy per capita** (Ktoe/person). It includes nuclear, hydro, geo, solar and waste.

- **Interior production of energy** (ktoe): Energy production before including imports and exports

Tables

Table 1: Main descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
CO2pc	390	9.26	3.98	1.55	21.66
GDPpc (using ppp)	390	19.02	7.51	4.38	36.24
Oil prices ($/kl using ppp)	390	935.56	411.45	292.76	2465.90
Coal prices ($/t using ppp)	390	150.71	126.50	25.31	624.41
Gas prices ($/m^3 using ppp)	387	431.63	196.59	89.44	1147.46
Coal prices/oil prices	390	0.19	0.19	0.02	0.89
Gas prices/oil prices	387	0.54	0.33	0.11	1.65
Oil interior production/primary energy consumption	390	9.72	18.37	0.12	98.98
Coal interior production/primary energy consumption	390	17.94	26.65	0.00	103.12
Gas interior production/primary energy consumption	390	6.97	9.83	0.00	42.49
Renewable interior production/primary energy consumption	390	0.00	0.00	0.00	0.00

Table 2: Results from the static fixed effects models

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ln(GDPpc)	0.076	0.018	0.072	-0.025	-0.014	0.614*	0.561*
$ln(GDPpc)^2$	0.059	0.076	0.068	0.075	0.072	-0.036	-0.036
ln(Oil prices)		0.106***	0.127***			0.145***	
ln(Coal prices)		-0.025	-0.018			-0.016	
ln(Gas prices)		-0.009	-0.002			-0.003	
ln(renewable pc)			-0.032**		-0.011		
ln(coal/oil prices)				-0.046***	-0.047***		-0.052***
ln(gas/oil prices)				-0.015	-0.014		-0.016
ln(oil interior production/primary energy consumption)						-0.053***	-0.060***
ln(coal interior production/ primary energy consumption)						-0.017*	-0.019**
ln(gas interior production/ primary energy consumption)						0.001	0.004
ln(renewable interior production/ primary energy consumption)						-0.080***	-0.056***
Constant	1.589***	1.386***	0.873*	1.827***	1.720***	-0.765	0.302
Observations	390	387	387	387	387	387	387
R2_within	0.829	0.827	0.83	0.825	0.825	0.852	0.846
Adjusted_R2	0.801	0.797	0.799	0.794	0.794	0.823	0.817

* p<.1, ** p<.05, *** p<.01

Year dummies and country trend included

Appendix B: Tables from the dynamic model

Table B1: Results from the dynamic model. System GMM

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ln(GDPpc)	0.787	0.29	-0.034	0.155	0.027	0.327	0.165
$\ln(GDPpc)^2$	-0.159	-0.06	0.014	-0.029	0.005	-0.061	-0.025
ln(Oil prices)		-0.024	-0.013			-0.015	
ln(Coal prices)		-0.015*	-0.014**			-0.009	
ln(Gas prices)		0.001	-0.007			-0.005	
ln(renewable pc)			-0.014*		-0.018**		
ln(coal/oil prices)				-0.009*	-0.009*		-0.009
ln(gas/oil prices)				0.001	-0.006		-0.007
ln(oil interior production/primary energy consumption)						0.002	0.001
ln(coal interior production/ primary energy consumption)						0.004	0.005
ln(gas interior production/ primary energy consumption)						-0.002	-0.002
ln(renewable interior production/ primary energy consumption)						-0.010**	-0.010***
L.ln(CO2pc)	0.938***	0.964***	0.955***	0.966***	0.949***	0.943***	0.943***
Constant	-0.576	0.024	0.145	-0.101	-0.152	-0.254	-0.316
Observations	390	387	387	387	387	387	387
Instruments	53	50	65	63	73	54	61
P-values Arellano-Bond AR(1)	0	0	0	0	0	0	0
P-values Arellano-Bond AR(2)	0.306	0.361	0.326	0.32	0.295	0.339	0.306
P-values Sargan test	0.246	0.198	0.341	0.247	0.388	0.163	0.217

* p<.1, ** p<.05, *** p<.01

Year dummies and country trend included