Improving Carbon Efficiency: is Economic Growth so Favourable?

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***Abstract*--In this paper we present an empirical study to verify the assertion of a negative impact of economic growth on carbon efficiency using a cross country analysis. More precisely we are concerned with the relation between past growth and CO_2 emissions, assuming that rapid growth in the past may explain lower carbon efficiency today. The central idea tested is that hasty growth is likely to slow down the improvement of energy and carbon efficiency. In other words, using an ordinary least square multifactor model to explain carbon intensity, we verify that the coefficient for an exogenous variable measuring the average past growth rate (apgr) for each country in our sample, is significantly positive.**

***Index Terms*--Carbon efficiency, Carbon intensity, Carbon ratio, Economic growth, Energy, Energy consumption, Energy management, Energy conservation, Energy efficiency, GDP per capita.**

I. Introduction

SUSTAINING economic growth to improve standards of living worldwide, while avoiding disastrous environmental damages, is a major challenge, high on the agenda of policy makers. We are now facing a situation that most experts consider as critical. In particular, the increase in concentration of greenhouse gases (GHG) – due mainly to CO_2 emissions – and its long term effect on the climate is perceived as the most pressing issue. Indeed it seems that economic recovery now predominates, and that less attention is paid to environmental issues. But with growth rates around 6% in the emerging world - a low rate in comparison with growth in the pre-crisis years – sustainability remains a serious issue. For instance the UN Panel's final report on global sustainability (2010) contains 56 recommendations to put sustainable development into practice and to mainstream it into economic policy as quickly as possible.

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According to a traditional view point, made explicit by Kuznets (1955) and Solow (1992), we can count on economic growth to curb this dangerous trend. Growth requires investment and therefore provides the opportunity to adopt recent carbon efficient technologies. However, one may also assert that economic growth, if too rapid, is rather a deterrent to the improvement of carbon efficiency. If growth is expected to provide the opportunity to adopt cleaner technologies, hasty growth may slow down this adoption process. Advanced sustainable technologies, if available, also need to be accessible and deemed appropriate. For many reasons, it may not be the case in countries enjoying spectacular growth, where decision makers may rather opt for proven and cheap traditional technologies, not necessarily the most efficient.

Furthermore, it is widely accepted that environmental performance is closely related to the level of income per capita because both the activity mix, the level of consumption and environmental awareness change along the development path. However, empirical studies based on large sample of countries do not reveal any clear relation. The proposition put forward in this paper may provide an explanation: it is not just the level of income that counts, but also how the country got there.

The structure of this paper is as follows. Section 2 outlines the existing literature on the topic which provides useful indications as to the sources of carbon emissions, trends and factors explaining discrepancies across countries. Section 3 presents the arguments for our proposition relating the speed of economic growth and carbon efficiency. Section 4 offers the empirical results of the study and, finally section 6 concludes the paper with a few recommendations for policymakers.

II. Literature Review

A. *Carbon emissions: sources and trends*

As far as carbon emissions are concerned, a number of recent surveys provide a rather precise picture of the worldwide situation, examine scenarios and identify the necessary conditions to achieve reasonable emission targets in the future (Stern 2007; WEC 2008; IEA 2008; WEC 2011). What is more, the sources of carbon emissions are many and diverse, as indicated in Fig. 1, which means that more effort needs to be deployed in many different directions.

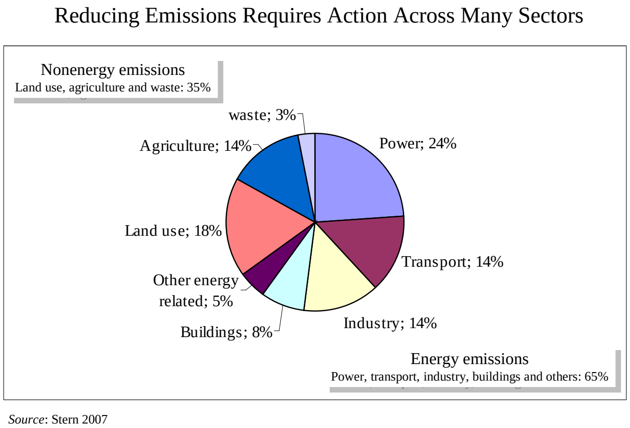


Fig. 1. Sources of carbon emissions.

Energy related emissions represent 65% of all sources, including power generation (24%), transport (14%), industry (14%), buildings (8%) and others (5%). Indeed a lot has already been achieved to find a way to curb emissions through technological innovation rather than slowing growth, and research is very active. Non-energy emissions (35%) include land use, agriculture and waste. In this domain also there is big potential to cut emissions, halting deforestation coming first on the list.

Mainly due to a lack of reliable and comprehensive data pertaining to non-energy CO_2 sources, most studies tackle energy related emissions only which are about two thirds of total emissions. As a consequence, the focus is often placed on improvements resulting from greater energy efficiency leading to a lower quantity of $C0_2$ emissions per unit of GDP – which we will consider in this study as a country measure of carbon efficiency.

As a key finding of a survey on "Worldwide Trends in Energy Use and Efficiency" (IEA, 2008) the authors note "*Detailed analysis for IEA countries shows that improved energy efficiency continues to play a key role in shaping energy use and CO_2 emissions patterns, but that the rate of improvement has slowed substantially*". More precisely, the improvement rate averaged 2% per year between 1973 and 1990 compared to only 0.9% between 1990 and 2005. This trend looks alarming at a time when so many voices demand immediate and drastic action, to shift from business as usual to a more sustainable model (Lomborg, 2010).

Indeed, efficiency mainly depends on the technologies used in each domain – power generation, transport, industry and housing. Hence the following questions are raised: What determines the adoption of carbon efficient technologies? How can we explain the differences observed between countries?

B. Economic development and carbon efficiency

Undeniably, the economic status of a particular country, whether it is emerging or mature as revealed by its GDP per capita, has an influence. We can normally expect a correlation between the income per capita and carbon emission intensity – defined as the ratio of CO_2 emissions over GDP – since each stage of economic development corresponds to a certain activity mix, with capital intensity and household equipment growing with GDP and pushing energy consumption up. This is consistent with the "energy ladder" concept of Barnes and Floor (1996) which states that the linkages between energy and economic activity change as the economy grows. Toman and Jemelkova (2003) have provided a valuable synthesis on this issue noting: "*At the lowest levels of income and social development, energy tends to come from harvested or scavenged biological sources (wood, dung, sunshine for drying) and human effort (also biologically powered). More processed biofuels (charcoal), animal power, and some commercial fossil energy become more prominent in the intermediate stages. Commercial fossil fuels and ultimately electricity become predominant in the most advance stages of industrialisation and development*".

Earlier, Kuznets (1955) introduced the concept of "inverted U-shaped Environmental Curve" arguing that pollution is expected to increase with income per capita up to a limit, and then start decrease as environmental awareness and care increase. The idea backing the model seems reasonable, however the peak differs across countries and the model does not provide any explanations for that. Grossman & Krueger (1995) provide more detailed results by analysing the relation between economic development and a variety of pollutants and conclude that the Kuznets' Curve does not apply to all. In particular they indicate that the release of CO_2 may well continuously increase with GDP per capita. Today there is no clear cut conclusion concerning the relation between economic development and carbon emissions; discussions are still underway (Vivien, 2008) and number-crunchers, for their part, are focussing on appropriate econometric methodologies to be used to reveal the true relation (Wagner, 2008).

Fig. 2 shows the distribution of carbon emissions, proxied by the carbon ratio of CO_2 emissions per unit of GDP, for a sample of 56 countries (see Appendix 1), thus representing a large array of economic profiles. The average carbon ratio is 0.38 kg per unit of GDP, however the distribution is spread over a wide range of values; the lowest being for Peru at 0.14 whereas the highest being for Ukraine at 1.07. Though we observe higher values for countries in their emerging phase, there is no clear correlation between the level of income and carbon emissions as expected[1]. This suggests that apart from the level of income per capita, other discriminating factors need to be thought about.

[1] The R^2 of 4.4% is too low to reject the null hypothesis.

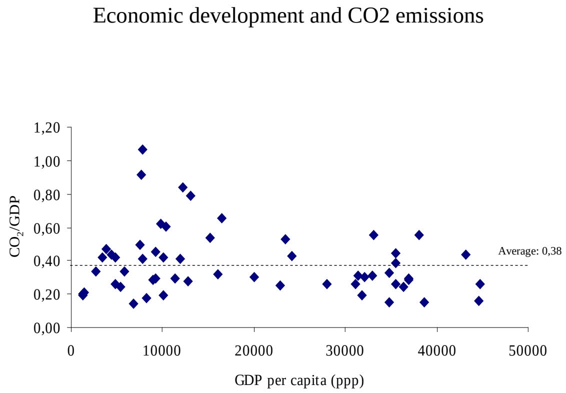


Fig. 2. GDP per capita and carbon ratios (2006)

It may also well be that the GDP per capita is not the best indicator to take into account the structural changes resulting from economic growth; some countries though they may have a similar GDP per capita, can be very different in terms of their economic activity mix. For the aforementioned reason we propose to use in our model[2] the proportion of labour force in agriculture (L) as an alternative to GDP per capita. Indeed there is a high degree of correlation between the two measures, as the lower the GDP per capita, the higher the labour force employed in agriculture (see Fig. 3). Nonetheless, L may be a better indicator to capture the degree of industrialisation and urbanisation in each country, as both affect directly and unambiguously energy consumption, and as a result CO_2 emissions.

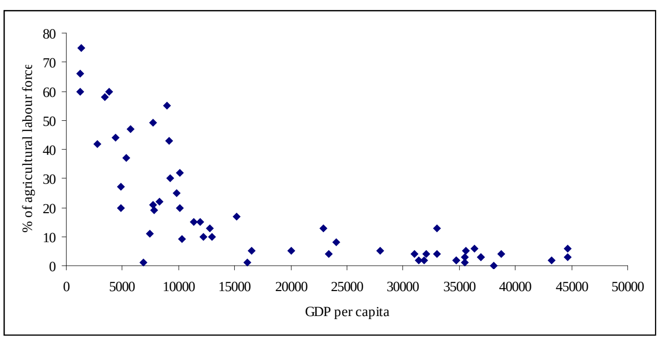


Fig. 3. The proportion of labour force in agriculture decreasing with GDP per capita.

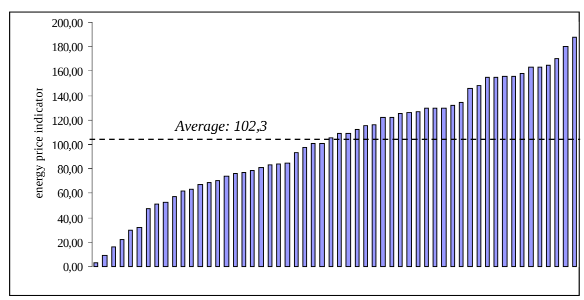
C. Energy price: an unambiguous influence

Apart from structural factors, the price of energy in each country should also be considered. Indeed, a high price of energy is an incentive for economic agents to substitute inefficient energy technologies for better ones (Gayle and Karlson, 1993; Pizer et al., 2002). As a consequence, a positive relation is normally assumed between the price of energy and energy efficiency. Nevertheless, the price elasticity ratio may vary across countries since the speed of substitution depends on the economic and business environment in which economic agents operate (see next section).

However, there is another argument to justify a positive link between energy prices and carbon efficiency. In a particular country, the price of energy also captures the level of environmental awareness. Making a decision affecting energy prices is often politically sensitive. In particular, a price increase may not be well accepted by users; in that case policy makers may just abandon the idea fearing negative reactions from their electorate. In other words, low prices may signal a weak concern for the environment, either from state authorities, convinced that high prices would slow down growth, and/or from the population refusing any effort to be more eco-efficient.

Finally, it should be noted that where the price of energy is high, energy taxes are also high. Therefore, expensive energy often goes with active state intervention, in particular in the domain of environmental efficiency. This is another reason to predict a positive correlation between the price of energy and carbon efficiency.

Taking international fuel prices (GTZ, 2007) as an indicator of the level of energy prices in each country, we can observe from Fig. 4 large discrepancies across our sample. The empirical tests seem to confirm a clear positive relation between the price of energy and carbon efficiency, in other words a negative relation between energy prices and carbon intensity measured by carbon ratios. As expected, the lower the price, the higher the carbon ratio.



Source: International Fuel Prices 2007, prices November 2006 US$ cents, GTZ

Fig. 4. Distribution of international fuel prices.

III. SPEED OF GROWTH AND CARBON EFFICIENCY

Assuming that growth might be a deterrent to the adoption of energy and carbon efficient technologies is somewhat counterintuitive. As stressed by Beckerman (1992) only rich countries can afford the cost of a clean environment. Growth requires investment and therefore provides the opportunity to adopt recent technologies integrating innovation. According to Solow (1992) we can count on a substitution effect, sustainable technologies replacing progressively former

[2] For all models tested and presented in part 3, taking L to capture the structural changes going along with economic development appeared to provide better results than choosing GDP per capita.

"natural capital" intensive technologies[3]. Yet, as we have noticed, countries with similar income per capita may perform quite differently with significant variations in their carbon ratios. In other words, the expected substitution does not occur at the same pace. Why is it so?

In a report presented at the World Economic Forum, Daniel Esty (2008) suggests that tough regulations, and above all, their enforcement, are the key factors in keeping things green. In other words, poor governance in fast growing countries might be a dominant factor to explain why rapid growth does not automatically contribute to greater environmental performance. Adding to the aforementioned, a number of reasons, as we will see in the following section, lead to the observation that it is the growth pattern – its speed – that can have a major influence on the technology substitution pace, explaining the discrepancies across countries.

A. The role of multinational companies

Whether it is a cause or a consequence of rapid growth, foreign direct investment is clearly part of the process, and needs to be discussed first. It is commonly agreed that multinational firms have a positive role as far as environmental performance is concerned. Foreign investors, beyond doubt, take part in the industrialisation process of emerging countries where spectacular growth rates are observed. These countries have benefited from the outsourcing strategy followed by most multinationals looking for low manufacturing costs. As a matter of fact, a relocation of energy intensive activities from developed to emerging regions has taken place. The latter, indeed, explains part of the reduction of GHG emissions in developed countries. This trend was often supported by cheap energy policies that most emerging countries practice to boost industrial growth though it also reduces the incentive to save energy.

At this point, one should also bear in mind the risk of "CO_2 leakage", i.e. when developed countries impose taxes on emissions, multinational companies can avoid them by outsourcing wherever they can pollute for free (Gruub and Neuhoff, 2006; Demailly and Quirion, 2008; IEA, 2008). Nonetheless, to a certain extent, globalisation has also favoured a convergence of industry performance, particularly for energy intensive industries: "*The energy efficiency of energy intensive industries, e.g. steel, cement, pulp and paper is converging and improving rapidly as a result of ongoing globalisation"* (World Energy Council, 2008). Unsurprisingly, considering the importance of energy in their cost structure, energy savings for large multinationals in these industries remains a priority, no matter where they produce.

[3] More precisely, Solow (1992) argues that new generations should benefit from innovation – resulting in saving of natural resources – so that the current destruction of "natural capital" would be compensated, and well being maintained.

One should also reflect on the tendency of western rich customers, and regulators, to integrate environmental considerations in their demand since the purpose of foreign direct investments in emerging countries is often to export to rich countries. Recent boycotts and bad publicity to imported goods from low cost countries, raising protectionism and competition from local more eco-efficient companies are all signals that multinationals have well perceived and integrated energy efficiency in their strategy. The recent move by large companies setting rules for their Chinese suppliers perfectly illustrates this point[4]. Finally, multinationals also tend to select managers educated in their home-base country to run their operations in emerging countries. These managers, in general, have an environmental awareness above average which is recognised as a significant driver to foster environmentally friendly actions (Eidat et al., 2008).

On the other hand, small and medium size independent corporations still represent the bulk of the corporate population in emerging countries. They remain largely outside the reach of global corporate strategies and therefore do not benefit from their positive influence. As far as household choices are concerned, very little positive impact is expected – if any. In addition, a high level of foreign direct investment also contributes to the emergence of large concentrated industrial areas, favouring land and real estate speculation, and anarchic urban development. As a conclusion, the role of multinationals may be partly positive for the environment due to the technology transfers they organise and due to their impact on awareness; nevertheless this may not be enough to compensate for all the negative side-effects of rapid growth.

B. Rapid growth and economic rationality

Rapid growth generates an urgency situation, a need for quick action to meet urgent demand, with no time for investigation so that rationality is bounded. This view seems all the more plausible if one considers the observations of recent surveys on energy efficiency. They reveal that a lot could be done to improve energy efficiency, and future income, at little or no cost (McKinsey, 2008), thus demonstrating the predominance of non rational behaviour. This view is also consistent with the so called "Porter Hypothesis" that the adoption of energy efficient technologies should be considered as an opportunity rather than a costly constraint. This assertion – which is now dominantly accepted – cannot be valid if one assumes economic rationality and perfect competition (Palmer et al., 1995). As noted by Paton (2001) "*the validity of the Porter Hypothesis rests on pre-existing opportunities for cost savings or profitable product enhancements that have, for some reason, gone unrealized. Such unrealized efficiencies should not be significant under the traditional micro-economic assumptions of profit maximisation and perfect competition*…." First, perfect competition is a normative concept which may make sense to guide regulators but does not provide so much help to understand how markets actually work, particularly during

[4] See: Wal-Mart issues rules for Chinese suppliers, The Wall Street Journal, 23rd October 2008.

phases of rapid economic growth when supply is lagging behind demand. In this context, inefficient firms are not sanctioned by the market. Second, poor information and bounded rationality may explain why inefficiencies persist albeit competition prevails (Paton, 2001), particularly if one considers the case of industries where a large number of small and medium size enterprises compete.

C. Importance of financial deterrents

Among factors explaining slow adoption of new clean technologies, financial deterrents also deserve a particular attention, especially when considering a situation of rapid growth. Explicitly, when using traditional investment decision criteria based on discounting techniques, or implicitly when demanding a short payback, economic agents always try to compare the expected return on their investment with the cost of the funds. In a fast growing environment, with many opportunities, choosing an option means rejecting another since capacity to raise funds is limited. In these circumstances the cost of funds is an opportunity cost, obviously higher than the cost of funds derived from market rates (Hausman, 1979; Train, 1985; Anderson and Newell, 2002). In other words, energy efficient projects have to compete with many other alternative investment opportunities, and unless they over perform, they are not adopted. And they are unlikely to over perform since negative externalities resulting from carbon inefficiency are usually not priced, or not at their full value.

D. The equity principle

The next argument relates to the equity issue. Due to the strong incentive to improve energy efficiency in most developed countries, as a consequence of rising cost of energy and the force of the environmental constraint, the motivation to innovate is great. As a result, most new technologies that we expect emerging countries will adopt, and pay for, were invented in developed countries. First, these new technologies designed for western educated users, may not be quite appropriate for developing countries where the workforce is cheaper and poorly trained. But most importantly, the environmental demand coming from the developed world is seen as a new source of technological dominance which decision makers in the emerging world are not keen to accept with good grace. Unsurprisingly they do not welcome the idea that they should take the lead to make the necessary efforts to promote sustainable development, they would rather claim they have now a “right to pollute”. More sensibly, they put forward the “principle of equity”. Concerning climate change *“they would like to initiate sustainable development practices in their countries and contribute to the world wide emissions schemes under the principle of common but differentiated responsibilities…They keenly remind developed countries of their historical responsibilities for releasing GHG emissions since the industrial revolution.”* (Pamukeu, 2008). Therefore, solutions will have to be found to redistribute the benefits of innovation in this field, finding compensations to favour the adoption of costly investments. The latter is identified as a major issue today, but so far not much has been done.

E. Coal: an easy solution to meet urgent energy needs

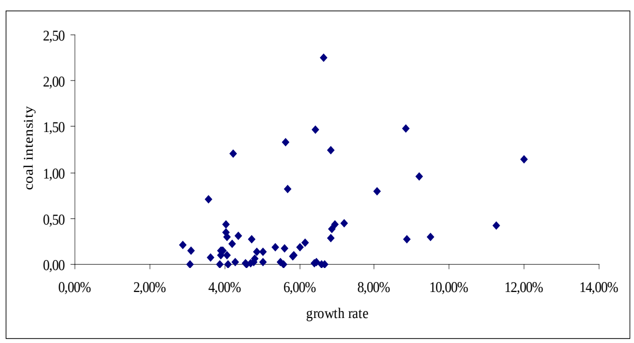
The last point to be considered is the issue of power supply in fast growing economies. Without a doubt, power supply is a prime concern for governments in emerging countries, capacity shortage being a persistent threat as energy demand is growing faster than the economy. It is a basic need requiring heavy investments to sustain economic growth, and it remains a dominant source of CO_2 emissions (24% of total emissions). For most countries the objective can be summarized in the following statement: security of energy supply under budget constraints. In other words, policy makers tend to take advantage of whatever available sources of energy, starting with the cheapest; that is often coal. Unfortunately, coal is by far the most polluting technology (see Table 1).

TABLE I
GRAMS OF CO_2 EMITTED PER KWH
(LIFE CYCLE ANALYSIS)

Energy	**g CO_2** *emitted per kwh*
Coal	800 - 1050
Gas	430
Photovoltaic	60 - 150
Wind	3 - 22
Nuclear	6
Hydrolic	4

Source: World Energy Council

To a certain extent, choosing coal as a dominant fuel, though the most polluting one, it is a consequence of a state of urgency due to rapid growth. As suggested in Fig. 5 there exists a rather high degree of correlation between the quantity of coal used in a country as a proportion of total primary energy supply (TPES) and the average growth rate of that country in previous years (correlation coefficient = 0.57).



Coal intensity: coal consumption (millions tonnes) / TPES *(mtoe) – 2006.*
Growth rate: average annual growth rate of GDP per capita, ppp, 2000 - 2006
Sources:
Coal consumption: Survey of Energy Resources, World Energy Council 2007
Total Primary Energy Supply, IEA
GDP per capita, IMF

Fig. 5: Coal intensity and growth.

Indeed, countries with important coal reserves have a natural incentive to use coal. Therefore one can expect a particularly low carbon performance in fast growing countries with coal reserves. To take into account this specific aggravating coal factor we suggest to consider, as one of the explanatory variables in our model, the relative importance of coal reserves[5] (Cr: Coal reserves over GDP) in each country.

F. Model Structure

As a summary of all the above, Fig. 6 presents the model structure, including the various explanatory variables and their respective expected impact on the carbon ratio.

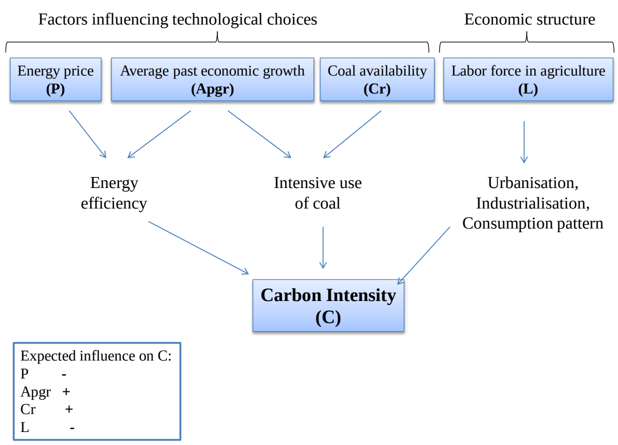


Fig. 6: Model Structure: combination of explanatory variables.

IV. Empirical Results

To analyse the influence of the growth pattern of countries on their carbon efficiency it is necessary to avoid periods of strong instability, therefore we have deliberately chosen to ignore the years following the recent debt crisis. The statistical analysis presented below concerns a period of relative worldwide economic stability from 2000 to 2006. The models presented aim at explaining the carbon intensity ratio observed at the end of this period, i.e. 2006. The precise definition and the sources used are presented in Annex 2.

Considering the full sample of countries, the analysis of the matrix of correlation coefficients (Table 2) reinforces our intuition. Average past growth (apgr), energy price (P) and coal availability (Cr) are rather strongly correlated with carbon intensity with the expected influence. However the influence of L, the proportion of the labour force employed in agriculture, is not significant.

Table 3 summarizes the results obtained for three regressions starting with a basic model where only L and P are considered. Unsurprisingly, the influence of energy price is confirmed, whereas the student-t coefficient for L is too low to conclude positively. All together this model explains only 18.7% of total variance.

[5] Using coal consumption would not be acceptable since it technically relates to CO_2 emissions. Coal reserves instead capture the availability of coal in the country, which may or may not be used for power supply.

Interestingly however, the inclusion of the average past growth (apgr) in the second regression improves significantly the quality of the model. Not only nearly 60% of the variance is now explained, but in addition, L becomes significant with a student t of -4.12. As expected, the level of development, measured by the proportion of the labour force in agriculture, contributes to increase carbon intensity (since economic development normally goes together with a decrease in the weight of agriculture). This observation is important since the ambiguity concerning the impact of the level of economic development on carbon intensity is now resolved: it is definitely a positive influence, or in other words a negative influence for the environment.

It should be noted that the same result would be obtained using the GDP per capita as a measure of economic development, but the student t would be significantly lower. This suggests that L, in this case, is a better indicator. Finally, adding coal availability as an influential factor improves further the model with 74.2% of the variance explained, with all student-t high enough to conclude positively.

Table 2
Matrix of correlation coefficients

	C	*apgr*	*P*	*L*	*Cr*
Cr	1				
apgr	0,61	1			
P	-0,42	-0,18	1		
L	0,01	0,43	-0,29	1	
Cr	0,68	0,39	-0,10	-0,08	1

Table 3
Regressions (full sample)

C =	a1 L +	a2 P +	b
	-0.0019	-0.0012	0.598
Student t (95%)	-0.93	**-3.49**	**8.44**
R square: **18.7%**			

C =	a_1 L +	a_2 P +	a_3 apgr +	b
	-0.004	-0.002	7.109	0.234
Student t (95%)	**-4.12**	**-4.43**	**7.26**	**3.29**
R square: **59.6%**				

C =	a_1 L +	a_2 P +	a_3 apgr+	a_4 Cr +	b
	-0.0027	-0.0015	4.885	3.058	0.278
Student t (95%)	**-3.20**	**-4.88**	**5.47**	**5.37**	**4.80**
R square: **74.2%**					

One could argue that past growth may not be a discriminating factor across mature countries with little difference in growth rates. For that reason we have carried out a similar analysis making a distinction between mature countries (GDP per capita (ppp) above 25,000 US$) and developing countries (GDP per capita (ppp) under 25,000 US$).

The results obtained for the group of the 20 mature countries (see Annex 1) are shown in Table 4. The model tested includes all the factors. As we can observe the results obtained are quite different. As expected, due to similarities in their economic structure and little difference in growth rates, only the price remains a significant factor. As we can see from the correlation coefficient matrix, this variable alone would explain about 50% of the variance.

Interestingly enough, isolating the emerging countries, and thus reducing our sample from 56 to 26 (see Table 5), contributes to a strengthening of our conclusions with 77.6% of the total variance being explained.

Table 4
Countries with GDP per capita above 25,000 US$

Table 4a
Correlation matrix (*GDP per capita > 25,000 US$)*

	C	*apgr*	*P*	*L*	*Cr*
C	1				
apgr	-0,14	1			
P	-0,71	0,12	1		
L	-0,12	0,72	0,05	1	
Cr	0,44	-0,06	-0,46	-0,12	1

Tables 4b
Regressions
Countries with GDP per capita > 25,000 US$

C =	a_1 L +	a_2 P +	a_3 apgr +	a_4 Cr +	b
	-0.0033	-0.0019	0.073	11.74	0.56
Student t (95%)	-0.29	**-3.19**	0.02	0.67	**4.00**
R square: **53%**					

Table 5
Countries with GDP per capita lower than 25,000 US$

Table 5a
Correlation matrix (*GDP per capita < 25,000 US$)*

	C	*apgr*	*P*	*L*	*Cr*
C	1				
apgr	0,65	1			
P	-0,25	0,05	1		
L	-0,21	0,18	-0,06	1	
Cr	0,72	0,46	0,05	-0,21	1

Table 5b
Countries with GDP per capita < 25000 us$

C =	a_1 L +	a_2 P +	a_3 apgr+	a_4 Cr +	b
	-0.0023	-0.0016	5.265	3.497	0.238
Student t (95%)	**-2.31**	**-3.67**	**4.73**	**4.63**	**3.17**
R square: **77.6%**					

V. Conclusion

In this paper we have reviewed a wide range of studies aiming at assessing the influence of various factors on environmental performance – taking carbon efficiency as an indicator – with the objective to isolate the influence of economic growth and verify the assumption that rapid growth may have a negative impact on the environment. The results of our statistical analysis confirm this assertion. Furthermore it also appears that economic development, as measured by the proportion of the labor force employed outside the agricultural sector, affects positively the carbon ratio. The latter conclusion is drawn from a model integrating several factors so that the impact of economic development can be isolated.

The findings of our research are valuable for policy makers suggesting that:

- Economic growth needs to be managed more effectively, even if the necessary actions result in slower expansion, as hasty growth is likely to slow down the improvement of energy and carbon efficiency.
- Considering that a higher GDP per capita also means to

have an increasingly negative effect on the quality of the environment, there is a need then to reflect on the relevancy of taking GDP growth as the ultimate economic objective.

VI. Appendix

Appendix 1 – List of Countries

56 countries with GDP (PPP) per capita (US$, 2006)		
> 25000	*5000 - 25000*	*< 5000*
United States	Brazil	Ecuador
Canada	Mexico	India
Australia	Argentina	Bangladesh
Japan	Chile	Indonesia
United Kingdom	Venezuela	Vietnam
Germany	Colombia	Pakistan
France	Peru	Egypt
Italy	Russia	Nigeria
Netherlands	Portugal	Kenya
Spain	Poland	
Switzerland	Turkey	
Belgium	Czech Republic	
Ireland	Ukraine	
Greece	Hungary	
Sweden	Romania	
Norway	Bulgaria	
Denmark	South Korea	
Austria	China	
Finland	Malaysia	
Kuwait	Thailand	
	Philippines	
	Saudi Arabia	
	Iran	
	South Africa	
	Morocco	
	Tunisia	
	Algeria	

Appendix 2 – Definition of variables and sources

- Gross Domestic Product (**GDP**), GDP per capita, and Purchasing Power Parity (**PPP**): Source: IMF, in US$, Data 2006.
- Average Past Growth Rate (**apgr**): simple average growth rate of GDP per capita over the period 2000-2006.
- **CO_2 emissions**: from fuel combustion only. Emissions are calculated using IEA energy balances and the revised 1996 IPCC guidelines. Source: Key World Energy Statistics, IEA 2008, Data 2006.
- Carbon intensity (**C**): CO_2 emissions per GDP.
- Total Primary Energy Supply (TPES), mtoe, Key World Energy Statistics, IEA 2008, Data 2006.
- Coal reserves, BP Statistical Review 2007, millions tons.
- Coal availability (**Cr**): Coal reserves per GDP.
- Agricultural Labour force (**L**): % of labour force in agriculture, the Economist Intelligence Unit 2007, and CIA world fact-book.
- Energy price indicator (**P**): International Fuel Prices 2007, prices November 2006, US$ cents, GTZ report.

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VIII. Biographies

Patrick Gougeon is a Professor in the Finance department of ESCP Europe and also the Director of the London Campus. In the course of his career with the school he has occupied several positions in France and abroad. In Asia he was the Director of the School of Management at the Asian Institute of Technology (AIT, Bangkok, Thailand); in Paris he was the Director of MBA programmes. Professor Gougeon has also contributed to the development of various international programmes, such as recently the MEBF (Master in Economics of Banking and Finance, Hanoi & Ho Chi Minh (Vietnam), an ESCP Europe/Paris Dauphine joint programme. Presently he is also co-director of a Specialized Master programme in «Energy Management» organized by ESCP Europe.

His research activities were first in the field of insurance and risk management. More recently he has also developed an expertise in the field of energy management with a particular focus on international project risk management and financing.

Kostas Andriosopoulos holds the position of Assistant Professor in Finance at ESCP Europe since September 2011, based in London. In this function he teaches courses at postgraduate level in “Corporate Finance”, “Futures, Options and Derivatives”, “Financial Analysis and Strategy”, and “Energy Markets”. He also taught “Company Valuation” and “Financial Engineering” at the undergraduate level at Cass Business School (2011) as a visiting Lecturer.

Dr. Kostas Andriosopoulos holds a PhD in Finance from Cass Business School, City University, London (2011). In support of his PhD studies he has been the recipient of the prestigious Alexander S. Onassis Public Benefit Foundation’s scholarship. He also holds an MBA and MSc in Finance, both with distinction, from Northeastern University, Boston, USA (2006), and a bachelor’s degree in Production Engineering & Management from Technical University of Crete, Greece (2004). During his postgraduate education he has worked as a research assistant for both the Accounting and the Finance departments at Northeastern University (2005-2006). Since 2006, he is a member of the Beta Gamma Sigma honour society, which recognizes outstanding academic achievements of students enrolled in collegiate business and management programs.

His current research interests include price modelling and the application of risk management techniques and innovative investment strategies in energy, shipping and agricultural commodities’ markets; other areas of expertise are in asset valuation, private equity, financial engineering, and international trade. His research papers have been published in international finance and commodities related Journals, and have been presented in established and recognized conferences world-wide. Since 2008 he is the Editorial Assistant (Special Issues) for the International Journal of Banking, Accounting and Finance (IJBAAF). In addition, since 2010 he is a reviewer for the Journal of Financial Decision Making, and Operational Research: An International Journal. He is also an active member in various professional and academic associations such as the International Association for Energy Economics, Financial Engineering and Banking Society, Hellenic Finance and Accounting Association, and Technical Chamber of Greece.

Othman Cole is an Assistant Professor at ESCP Europe teaching Mergers & Acquisitions, Corporate Finance, and Energy Management. Othman also teaches Corporate Finance on the Executive MBA programme at Judge Business School, University of Cambridge. Prior to this, Othman was a Research Associate at Judge Business School, investigating the resource-based view of oil & gas companies as well as the key challenges and opportunities facing National Oil Companies (NOCs). Othman was also a Postdoctoral Research Fellow at the Cambridge China Development Trust.

Othman’s areas of research include behavioural finance and capital structure decisions, the comparative advantages of oil & gas companies, the link between carbon emissions and economic growth, and the effect of hosting international sporting events on the construction and tourism sectors in the BRICs.

Othman holds a PhD and an MPhil in Finance, both from Judge Business School, University of Cambridge. Prior to that, Othman also completed an MSc in International Securities, Investment and Banking as well as an MEng in Computer Systems Engineering.