IMT Institute for Advanced Studies
Lucca, Italy

Three Essays on the Economics of Climate Change

Ph.D Program in Economics, Markets, Institutions
XX Cycle

By Carlo Stagnaro
2009

The dissertation of Carlo Stagnaro is approved.

Programme Coordinator: Prof. Fabio Pammolli, Università di Firenze

Supervisor: Prof. Sergio Grea, Università di Genova

Tutor: Prof. Fabio Pammolli, Università di Firenze

IMT Institute for Advanced Studies, Lucca
2009

Contents

Acknowledgements

Scientists have calculated that the chance of anything so patently absurd actually existing are millions to one. But magicians have calculated that million-to-one chances crop up nine times out of ten.

- Terry Pratchett, *Mort* (1987)

I am deeply grateful to all the people who have helped me by commenting upon earlier drafts of this thesis, or by allowing me to "free ride" on the opinions they were as kind as to share with me. I am particularly indebted to Filippo Cavazzoni, Corrado Clini, Alberto Clò, Stefano Clò, Francesco Forte, David Henderson, Carlo Lottieri, Alberto Mingardi, Massimo Nicolazzi, Fabio Pammolli, David Perazzoni, Massimo Romano, Jacopo Perego, Federico Testa and Stefano Verde.

I wish to apologize with my colleagues at IBL and *Il Foglio*, for having disappeared for more than a while. I take the opportunity to say thanks to them, as well, for all the insightful conversations we have had on a daily basis.

A special thanks goes to Sergio Grea for believing this could actually be done more than I myself did.

This thesis is dedicated to my wife Silvana for her patience, as well as to the senior little one and the forthcoming little one.

The usual disclaimer applies.

Vita

September 9, 1977 Born, Sestri Levante, Italy

2004 Degree in Environmental Engineering
Final marks: 103/110
Università di Genova
Genoa, Italy

Publications

1. FORTE, F. and STAGNARO, C. (2009). "Il sistema energetico in Calabria. Criticità, investimenti e regole", forthcoming.
2. CLO', A. and STAGNARO, C. (2009). "Otto, nessuno o centocinquantamila. La trasparenza dei prezzi dei carburanti in rete", forthcoming.
3. STAGNARO, C. (2009). "Energy Security: The Need for Consistent Policies". In HERA Foundation, *International Security and the Threat of Climate Change*, forthcoming.
4. STAGNARO, C. (ed.) (2009). *Indice delle liberalizzazioni 2009*. Torino: IBL Libri. ISBN: 978-88-6440-008-2.
5. STAGNARO, C. and TESTA, F. (2009). "Nell'ambito grosso sta l'azienda buona? Alcune riflessioni sul caso della distribuzione locale del gas", *Management delle Utilities*, no.1, pp.20-25.
6. STAGNARO, C. (2009). "L'ultima risorsa. Simul stabunt, simul cadent", *Aspenia*, no.44, pp.55-63.
7. STAGNARO, C. (ed.) (2009). *Il mercato del gas naturale*. Soveria Mannelli, CZ: Rubbettino e Facco. ISBN: 978-88-498-2340-0.
8. STAGNARO, C. (ed.) (2008). *Cambiamento climatico e libertà economica. Sviluppo, innovazione e trasferimento tecnologico*. Rome: Giovani Imprenditori – Confindustria.
9. STAGNARO, C. (ed.) (2008). *Indice delle liberalizzazioni 2008*. Torino: Istituto Bruno Leoni.
10. STAGNARO, C. (2008). "Prezzi: cade il 'mito' della doppia velocità", *Notizie*

Statistiche Petrolifere, no.8-9, pp.3-6; 22-24.

11. STAGNARO, C. (2008). "US can learn from European experience with cap and trade", *Oil & Gas Journal*, vol.106, no.19, pp.22-26.
12. STAGNARO, C. (2008). "Riflessi della produzione energetica sull'ambiente". In CORDOVA, G. and SCURO, S. (eds.). *Sicurezza per l'energia.* Roma: Centro studi difesa e sicurezza, pp.91-96.
13. STAGNARO, C. (ed.) (2007). *Sicurezza energetica*. Soveria Mannelli, CZ: Rubbettino e Facco. ISBN: 978-88-498-1922-9.
14. STAGNARO, C. (ed.) (2007). *Indice delle liberalizzazioni 2007*. Torino: Istituto Bruno Leoni.
15. STAGNARO, C. (2007). "European gas supply hinges on solving LNG issues", *Oil & Gas Journal*, vol.105, no.26, pp.60-67.
16. STAGNARO, C. (2007). "Clima caldo, Pil freddo", *Aspenia*, no.38, pp.123-131.
17. STAGNARO, C. (2007). "EU Energy investments drop as development obstacles rise", *Oil & Gas Journal*, vol.105, no.4, pp.18-22.
18. STAGNARO, C. (2007). "Battisti e contrabbandieri del global warming", *Limes*, no.6, pp.111-122.
19. STAGNARO, C. (2007). "Biocarburanti. Efficienza energetica o inefficienza agricola?", *Energia*, no.1, pp.52-55.
20. STAGNARO, C. (2007). "The EU and Biofuels: Protectionism as Energy Policy", *Energy Tribune*, 14 March.
21. STAGNARO, C. and VERDE, S. (2007). "Collusione e carburanti. L'altra faccia della medaglia", *Energia*, no.2, pp.38-48.
22. STAGNARO, C. (2006). "Italy". In KUMARIA, S. and NOLAN, P. (eds.). *Power Failure*. London: Stockholm Network, pp.10-11.
23. STAGNARO, C. (2006). "Una via d'uscita dal vicolo cieco di Kyoto", *Energia*, no.2, pp.52-57.
24. STAGNARO, C. (2006). "EU may miss Kyoto targets despite EEA recommendations", *Oil & Gas Journal*, vol.104, no.10, pp.24-26.
25. STAGNARO, C. and THORNING, M.M. (eds.) (2005). *Più energia per tutti*. Soveria Mannelli, CZ: Rubbettino e Facco. ISBN: 978-88-498-1094-3.
26. STAGNARO, C. (2004). "I nuovi campi dell'onnipotenza dello Stato: salute e clima". In INFANTINO, L. and IANNELLO, N. (eds.). *Ludwig von Mises: le scienze sociali nella Grande Vienna*. Soveria Mannelli, CZ: Rubbettino, pp.283-296. ISBN: 978-88-498-0901-5.
27. STAGNARO, C. and OKONSKI, K. (eds.) (2003). *Dall'effetto serra alla*

pianificazione economica. Soveria Mannelli, CZ: Rubbettino e Facco. ISBN: 978-88-498-0739-4.

28. STAGNARO, C. (2003). "The political economy of climate change". In OKONSKI, K. (ed.). *Adapt or Die.* London: Profile Books, pp.202-217. ISBN: 1-86197-795-6.

Presentations

1. OAPEC – Kuwait City – 15 February 2009 – "Energy Security and European Environmental Policies".
2. Lithuanian Free Market Institute – Vilnius – 21 October 2008 – "The Energy Challenge for Europe – and Lithuania".
3. ICEI – Aix-en-Provence – VII International Conference – 23 June 2008 – "Possibility and Limits of Tradable Permits".
4. Università Europea di Roma – Rome – 21 April 2008 – Master in Environmental Science – "Environment, Energy, and the Free Market".
5. Heartland Institute – New York City – I International Conference on Climate – 3 March 2008 – "Uncertainty, Damned Uncertainty, and Climate Policies".
6. Laboratorio sui Servizi a Rete – LUISS Guido Carli – Workshop on "Climate change: myths and false myths between information and disinformation" – 16 October 2007 – "Short Term Policies and Long Term Risks".

Abstract

This dissertation collects three essays on the economics of global warming and climate policies. The papers, each of whom can be read as a stand-alone essay, are arranged in a way that goes from a more radical, more general approach to a more pragmatic, more specific one.

The first essay deals with the very essence of global warming: is it a global public bad? Does its nature justify, or even require, international collective action in order to let the external costs be internalized? In order to provide an answer, a Coasian approach is undertaken. The starting point is an original interpretation of the so-called Coase Theorem, which is derived from Forte (2007). Forte argues that the symmetry underlying the theorem can only be held true in the short run. In the long run, however, the symmetry ceases to exist because, among the other reasons, a different return on invested capital may emerge under a different initial allocation of rights. It follows that the initial allocation of rights does matter, even in a transactions costs-free world. An intuitive consequence of this, is that the long-term consequences of the initial allocation should be considered. In the case of pollution, this may mean that it is not always efficient to follow the Polluter Pays Principle. In fact, while pollution is a negative externality, the venture that causes it may also generate positive externalities. When this is the case, by imposing to the polluter the cost of getting rid of pollution, the positive externality may be lost together with the negative one. The present paper argues that this is precisely the case of global warming. Greenhouse gases emissions – which are suspected of causing man-made global warming, as opposed to natural climate change – are, at the present state of technology, an unavoidable byproduct of energy production and economic growth. Cutting emissions – as is requested by many stakeholders as well as by international treaties such as the Kyoto Protocol – might result in curbing economic growth, and by so doing it might impose a social cost that is greater than the avoided cost from global warming. The econometric evidence on the costs of global warming and the costs of climate policies, as well as on the respective benefits, is still unclear. Hence, the present scenario is characterized by a deep uncertainty on the side of the costs and benefits of collective action (or the lack thereof), and by a lack of cost-efficient technological alternatives to the current technologies, particularly in the energy and transportation sectors. By applying the Forte interpretation of the Coase Theorem, it may be argued that—when this is more efficient—it might well be the case to let the cost of pollution (or the cost of eliminating pollution) bear on the polluted party, instead of the polluter. Since the polluted party, as far as global warming is concerned, is future generations, this means that a case can be made against climate change mitigation. Temperatures might be left free to grow (that is, carbon dioxide might be left free to accumulate in the atmosphere) until cost-efficient technologies

become available. Policies should instead focus on accelerating the process of technological innovation, and on developing adaptation measures in order to better face the effects, rather than addressing the alleged causes, of global warming.

The second paper looks at the existing patterns from greenhouse gases (GHGs) emissions, widely suspected of contributing to global warming. Assuming that some sort of political action is to be taken, and that some result may follow, it is noted that emissions – both in aggregate, on a per capita basis, and in terms of carbon intensity, i.e. the ratio between total emissions and gross domestic product (GDP) – are stabilizing or slightly declining in most developed countries. On the contrary, total emissions, per capita emissions, and carbon intensity are dramatically increasing in the developing world. A higher carbon intensity is interpreted as a proxy of a more obsolete technology. An analogy is then made with the pattern governing other pollutants, that is the so-called Environmental Kuznets Curve. Empirical evidence shows that as a general rule in most countries pollutants have increased at first, then peaked and decreased as GDP has grown. This phenomenon has been theoretically understood as a consequence of the increased concentrations of pollutants that made them ever more intolerable on the one hand, and the increased availability of wealth to be invested in newer technologies and/or in innovative investments on the other hand. It is unclear, however, whether or not carbon emissions are following such a bell-shaped curve, too. Further investigations into this pattern have suggested that GDP growth is not the only independent variable. The existence of free market institutions also matter, in that this allows GDP growth and creates a more favourable environment for investments. An empirical measure of the existence of free market institutions has been gleaned by the *Index of Economic Freedom*, published yearly by the Heritage Foundation and the *Wall Street Journal*. A panel dataset has been built with data regarding the *Index of Economic Freedom*, its subcomponents, total GHGs emissions, and a number of other macroeconomic and environmental indicators. A model has been built that relates GHGs emissions with economic freedom, controlling for one or more of the above-mentioned variables. A significant, negative correlation has been found, which means that economic freedom – along with other factors – may explain part of the difference in carbon intensity between countries. The correlation is stronger for lower values of economic freedom, consistently with other evidence that correlates economic freedom with economic growth. There are theoretical reasons to believe that the correlation may be a sign of a causal link, even though the empirical evidence is still not enough to support such a claim. If the causal link should be proven true, a policy consequence would be that–all else being equal–increasing economic freedom might lead to a reduced carbon intensity in the developing world, which is expected to account for an increasing share of global emissions in the next few decades. If this is correct, promoting economic freedom could be an effective, no-regret way to contain future emissions.

The third paper focuses on the European Union's climate policies. A first assessment is made by looking at the stated objectives of the policy, i.e. limiting temperature growth within 2 degrees above the pre-industrial levels, and the broader context of GHGs emissions. It is shown that the EU is responsible for a relatively small share of world emissions, which is going to decline if the present trends continue. Under this reasonable assumption, the impact that European efforts may or will have on world emissions is negligible, as is their possible consequences on temperatures rise and global warming. This means that EU policies, absent an international cooperation on curbing emissions, can't hold vis-à-vis any cost-benefit analysis, however low is the "cost" side. The existing policies are not only unlikely to deliver a measurable environmental benefit: they are also working very poorly. The most important European policy is the Emissions Trading Scheme (ETS), a cap & trade scheme that covers some 12,000 facilities in all Europe. In the ETS First Phase (2005-2007), emissions in the areas covered by the ETS did actually rise. There is evidence that this is at least partly a consequence of an over-allocation that happened in the initial stage of the process. The Second Phase (2008-2012) is expected to deliver more substantial emissions cuts, even though it is not yet clear whether ETS or the economic crisis will be the major driver. As to the Third Phase (2013-2020) new rules are to be implemented, under which a growing number of allowances (starting from 30 % in 2013) will be auctioned instead of distributed free of charge; however, some areas or sub-areas will still be given extra-permits free of charge, in order to limit the risk of carbon leakage, i.e. delocalization of energy-intensive firms exposed to international competition from countries who don't have stringent emissions regulations. The new framework is critically evaluated, by emphasizing the risk that a very high degree of uncertainty and politicization undermines the system. An alternative policy is then proposed, by suggesting that a carbon tax can be more appropriate. Two different models of carbon taxes are finally examined, one dependent upon the projection of the future costs from warming, the other dependent upon a state-contingent function that measures the amount of global warming in place at any given time.

Chapter 1.

Let the Polluted Pay:
A Coasian Approach to Global Warming

Abstract

Anthropogenic climate change has been widely regarded as a market failure, or even "the greatest market failure". As such, government interventionism has been invoked in order to achieve "climate stability". This paper critically assesses the notion that man-made global warming is a global public bad. It goes on by applying to global warming an interpretation of the Coase Theorem provided by Forte (2007). Under this framework, the symmetry regarding the initial allocation of the rights in the Coase Theorem applies only to the short run. In the long run, the initial allocation of rights may make a difference. It follows that it may be reasonable to attribute the polluter a right to pollute, if this creates the conditions for positive externalities to be generated, that are greater than the negative externalities involved. With regard to global warming, it is shown that greenhouse gases (GHGs) emissions – which are the alleged cause of temperature rise – are a byproduct of economic growth. In the short run, there is a tradeoff between economic development and environmental sustainability. In the long run, such tradeoff may or may not be valid. If the latter is true, it is possible that GHGs emissions will spontaneously decouple from economic growth, which would make climate policies questionable both from an economic and an environmental point of view (even though policies might be needed to accelerate the process of decoupling). If instead there is and will be a tradeoff, a careful assessment should be made of what is at stake. Global warming, as an external diseconomy, might be the other side of economic growth, as an external economy. In this case, fighting global warming at the cost of curbing economic growth may not be justified, that is, it may be reasonable to give the polluter (present generation) the right to pollute, while shifting onto the polluted (future generations) the cost of pollution (that is, pollution itself, or global warming).

Climate change is the greatest market failure the world has ever seen.

- The Stern Review, p.xviii

How is that these great men have, in their economic writings, been led to make statements about lighthouses that are misleading as to the facts, whose meaning, if thought about in a concrete fashion, is quite unclear, and which, to the extent that they imply a policy conclusion, are very likely wrong?

- Ronald H. Coase (1990), "The Lighthouse in Economics", p.211

1.1. Introduction

Climate change is widely regarded as the greatest challenge humanity has ever faced collectively. According to the conventional story-telling about climate, man-made greenhouse gases (GHGs), mostly produced by the combustion of fossil fuels, are causing global average temperatures to rise. Temperature rise would determine a number of consequences, most of which are supposedly negative, including (but not limited to) sea level rise, desertification, a wide change in climate patterns, an increase in the frequency and severity of extreme weather events, water stress, resource wars, etc. While some of these attributions are unfounded, questionable, or grossly exaggerated, they have been either collectively or individually considered in the economic literature about climate change. As a result, it would be probably fair to assess that a majority of economists dealing with climate have supported some sort of coordinated government intervention as to mitigate climate change and, to some extent, improve the humanity's ability to adapt to changes.

Economists have both dealt with the theoretical aspects, and tried to assess costs and benefits of global warming and/or the proposed measures to react to global warming. Often, however, they have failed to properly consider the huge uncertainties underlying climate science (Lawson 2008; Henderson 2009). In fact, most economists have almost taken for granted that (a) climate change is happening; (b) the leading or sole cause of global warming is anthropogenic GHGs; (c) the effect of climate change will be, on balance, negative for most countries in the world (although not *always* negative for *any* country in the world); (d) there can be no spontaneous response to global warming from the market; and (e) as a consequence, government should intervene in order to achieve emissions reductions and mitigate the effects of global warming.

This paper is not aimed at dealing with scientific issues, so it will not address (a) and (b), except for assuming that a significant degree of uncertainty is attached to (b), which means that any policy which is designed to address global warming should be flexible enough to be adapted to new scientific evidence regarding the role of natural causes, changing temperature patterns, or new economic evidence on the costs of global warming and the benefits of climate policies. In turn, this paper will deal with (c), (d), and (e). We will try to show that the economic evidence that the costs of global warming are such that require immediate action is less clear than commonly believed, partly because climate change may not be a market failure. By the same token, the benefits of political action may be lower than expected, particularly in the light of a theoretical framework that can be derived from the so called "Coase Theorem" (Coase 1960; Coase 1990; Stigler 1966; Medema and Zerbe 2000). In fact, the Coase Theorem will hereby be revisited, following Forte (2007a), in order to show that it was not in Ronald Coase intention's, nor is a logical consequence of his 1960 Nobel Prize-awarded essay, to claim that the mere presence of a "public good" or of an externality, provides a case for government intervention as to provide the supposedly public good or to solve the externality problem.

1.2. Climate stability as a public good

Sandler (1998, p.225) claims that "global warming is the quintessential global pure public good, because each country's release of GHGs augments the world's atmospheric stock in an additive fashion and each country's cutback results in a greater cost than benefit for that country unless assurances can be given that a sufficient number of nations will act". According to Grasso (2004, p.4), climate stability is a "(global) public good with no market nor price, and that do not offer proper incentives against overexploitation of the atmosphere". These statements do not exactly *prove* that climate change is a global public good: they merely assert so. Little or no demonstration is provided, despite the fact that – assuming global warming really is "the mother of all externalities" (Freebairn 2007) – an equal effort is to be put in motion. Wils (1994) goes so far as to argue that people might suffer from "psychic spillovers" from knowing about the potential effects of global warming.

Michel (2007, p.5) argues that "*every* country has an interest in ensuring a stable climate system. But *every* country also as an interest in ensuring economic development, agricultural production, energy supply, industry, transportation, the whole panoply of human enterprise from which greenhouse emissions arise. The *common* interest of *all* states in controlling global warming thus contends with the individual interest of *each* state in continuing the emitting activities that cause climate change" (emphasis added). While this statement may appear obvious, it contains two strong logical mistakes, which deserve to be dismantled in order to proceed with an ordered discussion of the issue.

The first mistake is an inappropriate generalization: as it will be shown, it is *not* true that *every* country has an interest in countering global warming. In fact, global warming – defined as the increase in the global *average* temperature – is a complex phenomenon, which can also be seen as the aggregate of individual changes. For example, not always temperature increase is bad per se. There is evidence that cold regions will benefit from warming; by the same token, there is evidence that an increased concentration of GHGs in the atmosphere – particularly CO_2 – might result in faster plant growth, under appropriate conditions. So, some countries or economic sectors will benefit from global warming, while other will be harmed. It can be argued that the *sum* of these costs and benefits is, on balance, negative, but not that *all* the consequences of global warming are negative for *all* the recipients. Secondly, Michel (2007) argues that the world as a whole has a common interest, at the same time, in economic growth (which determines GHGs emissions) and in cutting emissions. There is clearly a trade off between the two goals, at least in the short run. Again, it can be argued that the benefits of economic growth are not enough to compensate the costs of global warming, but one can hardly have the pie and eat it too.

Helm (2008, p.225) states that global warming is "a public bad" (no justification is provided), while the famous *Stern Review* (Stern 2006) suggests it is the biggest externality ever (interestingly, and erroneously, enough, Stern does not distinguish between the natural and the anthropogenic components of climate change). A more sophisticated argument comes from Nordhaus (2005, p.4), who argues that global public goods (as opposed to the "usual" public goods) do generally show up as "stock externalities", i.e. "their impact depends upon a stock of capital-like variable that accumulates over time". In the case of climate, the flow of man-made GHGs will increase the stock of GHGs in the atmosphere, which in turn will cause temperature increase. This is an important feature, as the *flow* of GHGs is the variable that can be controlled, while GHGs *concentration* (that is, a *stock*) is what actually determines the impacts of global warming. Time scale, hence, is also a fundamental variable: future generation alone will know the consequences of global warming, even though it is caused by past and present emissions. So, to the extent that global warming is a global public bad, externalities will occur both cross-country (i.e., every country will be affected, although not all countries in the same way and with no proportionality to the amount of emissions that each country has generated) and over time. A consequence of this, as Nordhaus (2005, p.7) shows, is that "there exists today no workable market or governmental mechanism that is appropriate for the problems. There is no mechanism by which global citizens can make binding collective decisions to slow global warming". Finally, Gardiner (2007) defined global warming as "the perfect moral storm".

To make the picture more confused, it should be emphasized that – while most authors speak about climate – they are in fact referring to climate stability, or, to be more precise, what might be defined "de-anthropogenized climate". Climate variability is a fact of nature, that no human interference or policy can alter. Climate has always changed and it always will. What is contended is that, since the Industrial Revolution took place, climate has been changing in a somehow "unnatural" way. We don't know how climate would have changed absent anthropogenic GHGs, as the counter-factual is obviously not available. We just know it might have changed in a different way, as well as we suppose it would change in a different way if we stop emitting GHGs right now. We also assume that, *all else being equal*, humanity would be better off if the anthropogenic component of climate change could be removed. The trick is that the anthropogenic component can, at least theoretically, be removed, but that can in no way happen while all else remains equal. Indeed, all else would dramatically change, too. This is the core of the argument we will develop in the next paragraphs.

1.3. The Coase Theorem revisited

As Robinson (2008) argues, the idea that climate is a public good, hence collective action is needed, may well be defined as "conventional wisdom", in the sense defined by Galbraith (1958). Robinson himself exposes a number of reasons why such wisdom is rather a prejudice. One reason is its very theoretical foundation, according to which the mere existence of a public good or an externality provides a case for government intervention aimed at the provision of the public good or the internalization of the externality. Such idea has been challenged by many economists, most notably Coase himself in his 1974 essay on the lighthouse (now reprinted in Coase 1990).

An innovative application of the Coase Theorem to the case of externalities, including environmental externalities, has been developed by Forte (2007a). Forte shows that "even in the absence of transaction costs, the optimal allocation of resources may be reached when the polluted, if wants to be free from the pollution, is obliged to do so at his own costs or has to pay the polluter to eliminate them". To develop such arguments, Forte argues that Coase's "symmetry theorem" under the assumption of zero transaction costs, was a simplified version of what he actually had in mind. In fact, the focus was not on symmetry per se, but on the fact that an optimal allocation could be reached through spontaneous negotiations between the parties. As to the symmetry, it may be a reasonable assumption under a short-term, static framework, but can in no way be held true as a longer-run, dynamic perspective is undertaken.

To make the argument clearer, Forte starts with Coase's classical example of a farmer (F) rivaling with a rancher (R) for the use of F's piece of land (L). The possible combinations are listed below, depending upon (a) the value of F's and R's product and (b) the initial allocation of rights. Assume that F's loss from grazing is equal to x, and R's rent from the use of L is equal to y. Table 1 shows the possible combinations.

	F has the right	R has the right
x < y	1A. R uses L, pays F	1B. R uses L
x > y	2A. F uses L	2B. F uses L, pays R

Table 1. Possible cases under the Coase Theorem.

As is clear from the table, absent transaction costs, in the short run the initial allocation of rights has no effect on the outcome, as in both cases 1s R uses L, and in both cases 2s F uses L. The longer run, however, is quite another story, as is evident from the table. "At the margin", writes Forte with regard to 1B, "the price of meat shall be lower than in case 1A and its consumption greater while the price of corn shall be higher and its consumption smaller" (the opposite applies to 2A and 2B, of course). Since the rents from agriculture are presumably the result of an investment, all else being equal one may expect less investments in agriculture and, in the long run, a reduced supply of agricultural goods (this point has also been explored by Calabresi 1965 and many others). If R is a polluter, and F is a polluted party, it may well be the case that, in the long run, it is socially desirable to have more goods of which pollution is a byproduct.

By the same token, it should be considered that the liability rule changes the actor's behavior, therefore potentially raising a moral hazard problem. For example, in the case of a train generating sparks that burn the neighboring forest, the assignment of the rights to the forest-owner may prevent him from adopting low cost measures aimed at reducing the risk of fires (say, keeping lower trees). So, by shifting the liability onto the polluter may result in a sub-optimal employment of resources – an higher amount of which would be spent by issuing compensations to the forest-owner or by paying for a spark-free technology, or both. Not irrelevant to this, is that the information about the most efficient way of caring about the tress, and the cost of it as opposed to the cost of the alternatives, might be un-known to either the rail company, or a judiciary: it may be the case that they may be accessible only to the forest owner.

Now, consider the case of a polluting industry vis-à-vis a polluted community. Even in a transaction-free world, if the original rights are assigned to the polluted community, one may expect to have less industrial goods in the long run. If the output of the industry is energy, one would expect less, more costly energy. If the business of energy production becomes less profitable, investments may fall, too, and as a consequence the probability of technological advancements declines, including those that would leave the humanity better off by removing or reducing the pollution. “The broad principle that the industries must bear the costs of pollution”, writes Forte, “implies that there is less industrial growth and that consumption prices are higher”. Ex post, if the reduction is “excessive”, in the long run one would expect an impoverished, although less polluted, humanity. Another way to express the same concept is that pollution, and more generally externalities, may be an inherent feature of human progress, which is reflected in higher GDP per capita as well as in better living standards. The cost of removing pollution, may be that of curbing progress, which can hardly be defined as a desirable goal. To quote Forte, “the essence of the Coase theorem consists in telling us that there is no absolute reason to believe that the external negative effects are always distorting. The same is true with positive externalities. My additional conclusion is that both may be important to promote economic growth”. If this is true, a state intervention aimed at removing the externality, may generate itself a greater external diseconomy.

1.4. The costs and benefits of (in)action

How, and to what extent, does this apply to climate? Before a proper argument is developed, it may be worth recalling what the available literature tells about the costs and cost structure of global warming and of policies aimed at mitigating global warming. Figure 1 shows the available results, as presented by Tol and Yohe (2006).

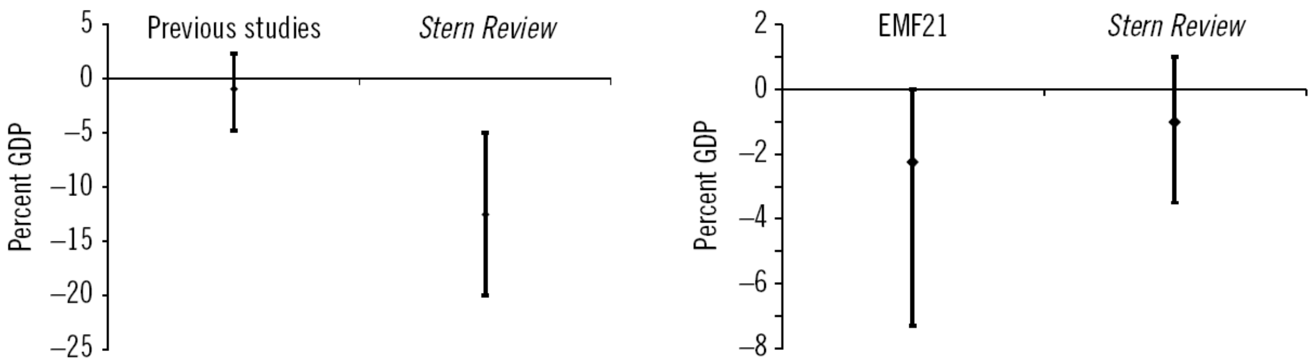

Figure 1. Estimates of the costs of climate change (left panel) and the costs of emission reduction (right panel) according to the *Stern Review* and according to previous studies. Source: Tol and Yohe (2006).

Two clear facts emerge from the literature review: on the one hand, there seems to be a consensus that the costs of climate change are of the same order of magnitude than the costs of emissions reductions; on the other hand, the famous *Stern Review* (Stern 2006) clearly finds an outlier estimate, with higher estimated costs of global warming and lower estimated costs of climate action than the previous studies. The two main reasons for this difference, which is indeed remarkable if one considers that the *Stern Review* doesn't produce new evidence but rather relies on the existing one, derive for the most from two reasons: (a) The Review selectively emphasizes the results from the most alarmistic studies on the scientific and economic aspects of global warming, and (b) The Review questionably assumes a discount rate as low as 0.1 percent, which obviously magnifies the effects of highly uncertain, far distant in the future climate effects. Tol and Yohe (2006), Helm (2008), Henderson et al. (2006) and Nordhaus (2008, pp.165-190) provide persuasive criticisms of the Review's methodology, results, and internal consistency. Helm (2008, p.228) claims that the zero-discount approach relies upon a "moral argument" that, however philosophically relevant, tells little in terms of welfare and provides little basis for the creation of the international consensus that is needed for climate action to be taken.

Others, most notably Weitzman (2009, p.1), argue that "the probability of a disastrous collapse of planetary welfare is nonnegiglible, even if this tiny probability is not objectively knowable". As a consequence, "the climate change economist can help… by stressing somewhat more openly the fact that such a [cost-benefit] estimate might conceivably be arbitrarily inaccurate depending upon what is subjectively assumed about the high-temperature damage function along with assumptions about the fatness of the tails and/or where they have been cut off" (p.18). The position thereby endorsed is somehow paradoxical: from the assumption that not just we don't know, but in fact we *can't* know the actual damage function from climate change, whether or not man-induced, the author seems to draw the conclusion that we should act *as if* the worst-case scenario was also the more probable one, if not certain. In other fields, "fat-tailers" tend to emphasize that, in presence of wide and deep uncertainties, policies should be as flexible and little-distorting as possible (see for example Taleb 2007); and the legal consequence is that "simple rules" should be adopted "for a complex world" (Epstein 1995). But when it comes to climate, a more aggressive attitude seems to emerge, based on the assumption that "it *might* happen so we should act as if it *will* happen", which can be justified – again – sonly on moral grounds. In his seminal work on catastrophe, alas, Posner (2004), while recognizing that catastrophic risk of climate change can't be ignored, seems to support a more relaxed, no regret policy, by suggesting that measures aimed at addressing climate change (for example emissions taxes) should be designed in a way as to also achieve other targets (for example substituting income taxes in order to reduce the deadweight loss). (On the benefits of revenue-neutral carbon taxes see also Nordhaus 2008, pp.148-164 and Chapter 3 of this thesis).

It should also be added that the costs of global warming can't be immediately compared with the costs of emission reductions, insofar as the former do not coincide with the benefits of the latter. In other words, some amount of global warming is still to be expected even if the most radical policies are implemented to reduce anthropogenic GHGs. So, at least part of the costs will persist in the future. This means that the costs of global warming provide by definition an overestimate of the benefits of climate policies. The cost of climate policies, moreover, is also underestimated because it relies on an implicit assumption of efficient implementation, that is not credible. As Helm (2008, pp.225-226) argues, "climate change… is likely to be one of the largest sources of economic rents from policy interventions. There is a large and growing climate change 'pork-barrel'. It is highly unlikely that the policy costs will be zero. Indeed, there are good reasons to suppose otherwise – at every level of climate change policy".

It would be fair, hence, to describe the evidence as "unclear", even though a majority of economists – including the majority of the above-mentioned ones – do favor some climate policies as opposed to the business-as-usual. There seems to be a consensus, indeed, that carbon emissions do have a social cost (Tol 2005), that may be small in the short run (hence the preference for moderate, not radical, immediate emission reductions – see Kelly and Kolstad 1999 and Nordhaus 2008, for example) but growing over time.

Since immediate, dramatic impacts are unlikely, some authors have suggested that different strategies are employed, aiming not at emission reductions in the short to medium run (the so called mitigation), but at long-run-oriented goals such as preventing (rather than solving) climate-change related problems or achieving an economically sustainable de-carbonization of the economy through technology improvements.

Goklany (2007), for example, argues that climate change doesn't *create* problems, it rather exacerbates existing problems, especially in the developing and the least developed world. Hunger, thirst, and malaria, as well as other negative consequences of global warming, will not arise after the global average temperature will have increased by a given amount, however defined. They all are already here. Global warming may just make them worse. The relevant fact, then, is that even the developed world used to suffer from them, and could defeat them despite the moderate increase in world temperatures observed in the last couple of centuries. As Goklany states, "most of the improvements in climate-sensitive indicators of human well-being are because of technological progress, driven by market- and science-based economic growth, secular technological change, and trade" (p.290). Therefore, according to this framework, it would be more rational to employ resources to fight these threats *now*, instead of trying to mitigate global warming *in the future*. With regard to climate change, Goklany suggests that a limited amount of resources is invested on adaptation.

From a different perspective, Lomborg (2007) argues that the only way to achieve a more sustainable energy and economic pattern, is to invest more on innovation and the diffusion of efficient *and* cleaner technologies (not just cleaner technologies, that are for the most part very uncompetitive with conventional technologies even under the existing climate policies, that have the effect of increasing the costs of fossil fuels in order to reflect their social cost). According to Lomborg, an aggressive, short run-oriented climate policy – such as the Kyoto Protocol – is both costly in the short run and ineffective in the long run. In other words, this author suggests that we invest in innovative technologies for tomorrow, rather than investing in the existent, cleaner technologies for today (under the reasonable assumption that, at the margin, money invested for today's technological change are subtracted from innovative investments).

1.5. The Polluter, the Polluted, and the Pollution

How does the Forte interpretation of the Coase Theorem apply to the above discussion? To summarize once again, Forte showed that, even in absence of transaction costs, (a) there is no absolute asymmetry in the initial rights allocation and (b) under some circumstances, it may be more efficient to give the polluter – instead of the polluted – party(ies) the right to pollute. If, and up to the extent that, the marginal damage of pollution is higher than the marginal cost of abatement, the polluted parties may or will pay the polluter to stop, reduce, or move pollution and its sources. That is particularly true when the polluting processes produce positive externalities, such as economic growth, along with negative externalities, such as pollution. Under this perspective, the negative externality may go hand in hand with the positive one: simul stabunt, simul cadent. The policy question, hence, is whether global warming has such feature, in which case it might be inappropriate to adopt mitigation policies or, to be more precise, to shift the burden of abatement on pollution-producers rather than on the polluted.

First of all, it is necessary to characterize the actors and the nature of the pollution.

1.5.1. The polluter

The polluter is the present and past generations. Since global warming is a consequence of the accumulation of GHGs in the atmosphere, whoever did, does, or will emit even one single molecule of GHGs is pro-quota responsible for the pollution. To the extent that present generations inherit liabilities from the past ones, Western people are comparatively more responsible than the rest of the world. To the extent that projections on future consumption are reliable (see for example IEA 2008), the developing world holds a growing responsibility for future warming.

From a geographical standpoint, more populous countries (such as China) hold a greater responsibility than scarcely populated ones (such as Luxemboug). From an individual standpoint, individuals who emit more on a per capita basis (such as those living in Luxembourg) hold a greater responsibility than those emitting less (such as the Chinese). The atmosphere is not able to tell where a given GHG molecule comes from, so any single country or individual is directly responsible for the amount of emissions it has generated. Yet, the impact of the amount of emissions that any given individual, even those who live a very carbon-intensive life such as Nobel Prize winner Al Gore (Schweizer 2006), is negligible (Reisman 2002). According to the legal rule that liability can just be individual, and consistently with the "de minimis non curat praetor", nobody can be held responsible for anything. Even if one looks at countries, rather than individual, the aggregate amount of emissions generated by most countries in the past two hundred centuries is very low, if compared with the amount of GHGs that can have a discernible impact on climate – perhaps just the wealthiest and/or most populated countries in the world, such as the US, former USSR, and China can be held individually responsible for any amount of global warming, however tiny. Only when one looks at the aggregate world emissions can a responsibility principle emerges, but it would be very weak to tell before a court that all are responsible for something.

The question of who is the polluter becomes even more complex as one considers the time dimension. In fact, in order to find a liability, one has to find a harmed party, in the first place. Then one has to show that a causal relationship exists, between the supposedly guilty party and the harm. Global warming – as it will be argued in next paragraph – is a continuous process. It is very hard to tell when, and to which extent, anthropogenic global warming, as opposed to natural global warming, begins. It is also very naïve to confuse *anthropogenic* global warming with global warming per se, as the *Stern Review* (among the others) does (see the initial quotation of this paper, and Henderson 2009).

1.5.2. The pollution

Global warming is inherently different from the cases of conventional pollution for at least two reasons: (a) the external diseconomy will be borne by future generations, that is, virtually no living person does or will pay the cost; (b) global warming does or will not, per se, cause harm to anybody, at least in a strict sense. With the conventional sources of pollution, for examples particulates, asbestos, lead, or carbon monoxide, a causal, direct link could be established between exposure to the pollutant and negative effects on human health or the environment. For example, and perhaps much to the layman's surprise, a recent inquiry from the US Environmental Protection Agency (EPA 2009) concluded that the projected increases in atmospheric concentrations of carbon dioxide are "well below published thresholds for adverse health effects" (p.157). As to the other GHGs, the expected concentrations for methane are "well below any recommended exposure limits" (p.157); the concentrations of nitrous oxide will be "well below any recommended exposure limits" (p.158); and the concentrations of fluorinated gases will be "many orders of magnitude below the exposure limits" (p.158). This tells nothing about the consequence of global warming, but it suggests that (a) GHGs can't be defined as pollutants in a strict sense and (b) there will be no *direct* effects from the supposed source of so-called pollution (the very term "pollution", in fact, is widely adopted in this paper, too, for the sake of simplicity).

GHGs emissions' impact is much more complicated, and not just because, in order to assess the costs, one should be able to distinguish the consequences of anthropogenic global warming from those of natural global warming. For example, desertification or biodiversity loss are supposedly linked with global warming: yet, it is unclear what amount of desertification or biodiversity loss would remain, if the man-made causes of global warming could be removed. To put it otherwise, it is unclear how much increase in world average temperatures in the next, say, one hundred years can be attributed to anthropogenic global warming, as opposed to natural global warming. For the sake of simplicity, most economic analyses tend to assume that anthropogenic global warming is the same as total global warming, but this inevitably leads to overestimate the damages. Fair enough, but at least it should be always acknowledged that the estimated costs – which in an over-simplified world coincide with the expected benefits from climate policies – are, in fact, overestimated.

Not just the amount of future warming is unknown, but also its spatial distribution is unknown. Obviously, at least some people (for example those in the business of tourism in places that would experience longer and warmer Summers) and some countries (for example cold countries in the higher latitudes) would benefit from global warming. For them, global warming is a *positive* externality, not a negative one. Even assuming that the aggregate costs from warming are higher than the aggregate benefits, how would this be addressed? Would they have a right to compensation? According to Brubaker (1975, p.157), collective action "results in 'forced riding' by individuals who are coerced into expressing non-existent 'demands' for collective goods. Or worse a 'good' in fact may be a bad, in some views, from which is economically not feasible for the individual to exclude himself, and for which compensation may be appropriate". Therefore, collective action to control climate would be a massive redistributionist action, not the provision of a public good (on the theory of public goods being, in fact, a theory of public transfers, see Forte 1967). Some people would be better off – moving from a worse climate to a better one, under their own preferences and concept of what a good climate is – and others would be worse off.

A right to experience Summer or Winter as they used to be, or a right to a given temperature, can't be defined not just because the legal or economic bases to do so are lacking. It can't be defined for the mere reason that such a right couldn't be enforced. First, climate, or average temperature, is just an arbitrary synthesis of a virtually infinite number of variables, most of which are well beyond human control and as a matter of fact are unknown or unmeasurable (Labohm et al. 2004). Mean temperature tells little or nothing regarding what really matters, that is the individual ability to predict weather in a way that make it possible to make plans – to make decisions concerning whether or not farming a piece of land and how, whether or not to build an house in a given place, whether or not going to the sea or to the mountains on vacation, etc.

On the top of that, another question arises, that makes it even more difficult to define global warming as "pollution". When does global warming becomes harmful, that is, what is the threshold beyond which global warming becomes a "bad"? One naïve answer might be, that global warming becomes a bad when, and to the extent that, global temperatures exceed the pre-industrial level. That would imply the all the emissions-generating activities that have taken place in the past 150 years are to be considered "costly". To our knowledge, however, nobody has ever argued that humanity today is worse off, because it lives in a warmer planet, where some biodiversity loss may have occurred because of the man-induced temperature increases (Goldberg 2007; Stagnaro 2007). Alternatively, it may be identified a "temperature threshold" beyond which the expected effects of global warming become intolerable. This is the choice made by the European Union, that adopted the goal of keeping temperature increases below 2°C more than the pre-industrial levels. However, this is questionable not just because such a threshold – given the wide uncertainties – in inherently arbitrary, but also it may well be well beyond the policy's scope, even under optimal conditions of global participation. For example, the process of natural warming might be strong enough to determine a temperature increase higher than two degrees (a possibility which is recognized by IPCC 2007), or the inertial nature of global warming – which is due to the long time of persistence of GHGs molecules in the atmosphere – may be such that temperatures will keep growing beyond the threshold even if anthropogenic emissions fall to zero immediately.

Finally, the need to identify a threshold begs a significant problem regarding the very concept of optimal temperature. It should be recalled that climate has always changed, and it always will: which means that temperatures either increase, or decrease. Claiming that we should stop temperature rise and keep temperatures in the nearby of the present levels, seems to rely on the assumption that the present temperatures are the optimal ones (a very fortunate coincidence). After all, if climate stability is a public good - That means that lower temperatures would be harmful, too. What should we do, if temperatures started to decrease, either for natural or man-made reasons? Should we subsidize carbon emissions in order to prevent too much cooling?

Such problem may be pure speculation at the time being, but it poses a fundamental question on the true goals of climate policies, that so far – according to our knowledge – has not been answered.

1.5.3. The polluted

The polluted party is, obviously, future generations. Less obvious is, what should be meant by "future generations". Does next generation qualify as a future one? And the one after? And all the generations since the next until the end of times? The question is all but trivial. First, it relies upon how global warming will turn out to be, as opposed to what scenarios suggest. If the increase in world average temperature will be slow and mild, it is likely that the next generation will not experience significant bads from global warming. If, instead, abrupt climate change should happen, possibly even the present generation would suffer from it. Moreover, whatever global warming looks like, there will be a time when its effects will be absorbed, or offset by economic growth, adaptation, or both. That suggests that not every future generation belongs to the operational concept of "future generations" that is needed to define the expected costs from global warming.

This problems is most evident, for example, in the *Stern Review*, which adopts a very long-term scenario in order to estimate the discounted cost of global warming. As Nordhaus (2008, p.181) puts it, "the projected impacts from climate change occur far in the future. Take as example the high-climate scenario with catastrophic and non-market impacts. For this case, the mean losses are 0.4 percent of world output in 2060, 2.9 percent in 2100, and 13.8 percent in 2200". Large and largely uncertain impacts in the far distant future are magnified by the zero-discounting, but they can hardly provide useful information, as they rely on scenarios on climate, economic growth, technology, etc. that can be fairly described as "assumptions".

As far as the distant future is concerned, it is very complex to assess what are the opportunity costs from global warming, as opposed to those of anti-global warming policies. We don't know how the world will look like; we don't know whether, under a business-as-usual, warmer world, humanity will be able to develop technologies to protect biodiversity, contrast desertification, fight malaria, colonize other planets, etc. even in the presence of higher temperatures. Since we can't have information about that, it is quite hard to derive information, or even to make reasonable assumption, about the kind of world that those "future generations" will want to inherit from us. Perhaps they will want a cooler world; or perhaps they won't care about temperatures, and will want us to pass them on a richer world, with more capital accumulation and more technology. As Cordato (1999, p.9) puts it, “This would require information about the course of future technological change, entrepreneurial insights, and innovation. More importantly, it would require information about these variables both in the absence and in the presence of the policy. Clearly, this is information that we can only pretend to have. Even if this information could be ‘known,’ the analyst would somehow have to be able to assess the ‘aggregate amount of satisfaction,’ a concept that would first have to be defined in an ‘operational’ way, that would be experienced in the presence and absence of the policy. The kind of information that would be necessary to make these precise interpersonal and intergenerational cost comparisons required to justify the policy is practically and conceptually impossible to gather”.

Vis-à-vis the unknowable, it seems naïve to try and model the distant future. Too many information are lacking, including those affecting climate patterns. It seems more reasonable to focus on information regarding the effects from global warming in the near future. They may still justify collective action to be taken, especially if abrupt climate change – as opposed to gradual climate change – has a tiny, but non-negligible, probability (Weitzman 2009).

1.6. The state of the world

But again, before we turn to the future, it is important to understand the past. So far, carbon has been the basis for progress and economic growth (Smil 1994; Smil 2008). In the past 150 years, the net balance between the costs from increased temperatures and the benefits from cheap, easily accessible, reliable, and “dense” energy (Huber and Mills 2005) can only be regarded as positive. Arguably, had a policy aimed at controlling carbon emissions in the early XIX Century been enforced, the world could hardly be better off. Most notably, that is true even as far as the environment is concerned.

Part of the misconceptions related to the future impacts from global warming, derive from a number of prejudices concerning the environmental performance of “unrestrained capitalism”, as we had in the XX Century. True enough, “unrestrained capitalism” is actually a wrong definition, because – among the other reasons – for the large part, the XX Century was “the century of the State”, as the Italian dictator Benito Mussolini famously said. It would be unfair to claim that, in the past century, the environment was unregulated. It is true enough, however, that – until at least the 70s – it was comparatively less regulated than in the following decades. Now, the idea that, absent specific regulation, environmental degradation is inevitable should be confronted with an inconvenient truth: environmental quality, in fact, tended to *increase*, rather than decrease, at least in the free market economies. The failure to understand this fact, and its theoretical foundations, undermines a proper understanding of what lies in front of us. Examples of such misunderstanding are wide and common.

For example, Helm (2008, p.223) claims: "The oceans are already highly polluted, agricultural land is being affected by salinization and desertification, and global warming will have serious effects on the areas where population is most heavily concentrated". The temptation arises, to comment upon this by quoting Coase (1990, p.211) on the lighthouse economic literature: "How is that these great men have, in their economic writings, been led to make statements about lighthouses that are misleading as to the facts, whose meaning, if thought about in a concrete fashion, is quite unclear, and which, to the extent that they imply a policy conclusion, are very likely wrong?".

As to the past, Helm mentions ocean pollution, land salinization, and desertification as a proof of the (supposedly man-induced) increasing pollution. Data on the pollution of coastal waters in the developed world do not univocally support this belief: in the EU, for example, pollution has been declining for decades (EC 2000), while the evidence for the US is controversial because a common framework for data is missing. Oil spills in the oceans have also been declining, both in frequency and size.

As far as forests are concerned, "Some regions… have made significant progress; institutions are strong, and forest area is stable or increasing. Other regions… continue to lose forest area… However, even in regions that are losing forest area, there a number of positive trends" (FAO 2007, p.viii). On desertification and salinization, the evidence is mixed and different authors provide different interpretation both on the extent of the phenomena, and their causes (Cotton and Pielke 2007).

A positive trend is also evident for a number of other environmental indicators, including those relating to air quality, water quality, lands and forests, toxic pollution, etc. For example, Lomborg (2001, p.177) summarizes his findings on air pollution as follows: "The achievement of dramatically decreasing concentrations of the major air pollutants in the Western world… is amazing by itself. But it is all the more impressive that it has been attained while the economy and the potential polluters have increased dramatically". Moore and Simon (2000) show a decrease in smog, particles, as well as cleaner lakes, river and streams in the major US cities and regions. Still on air quality, Goklany (1999) show the decrease in air pollution-related diseases in the US as a consequence of improved air quality, that is partly due to stricter regulation, but in large part can be traced back to business-as-usual process of technological innovation and turnover.

Possibly, the most relevant proxy for environmental quality – life expectation at birth for human beings – has been improving for decades. Several positive trends are shown, for example, by Lomborg (2001) and Hayward (2008). A theoretical framework on why environmental quality tends to improve in the long run is provided by Simon (1996) and Goklany (2007), among the others.

The fact that many environmental indicators are improving does not in any way mean that there is no environmental problem, or that no action is needed to address specific problems. It just means that some caution is needed, when speaking about environmental degradation as a general, unavoidable consequence or byproduct of economic growth. Some data may be controversial, so some believe a major problem does exist, while others argue the problem is either misinterpreted or it is in the process of being solved. Controversy over data should not lead to immediate, radical action, but to an attempt of more objectively assess the reality. It also means that specific problems should be addressed, possibly in specific ways, while it may not be the best strategy to put altogether as if an "environmental problem" did exist which stems from one single cause and can be solved by one single, global measure or policy.

To summarize, at least so long as the past is concerned, human and economic development is inherently bond with carbon-based sources of energy. It is also clear that fossil fuels will dominate the 21st Century, both in a business-as-usual and in alternative scenarios (IEA 2008; Odell 2004). It logically follows that global warming mitigation, however well-designed, would imply severe costs – although these costs may be lower than the costs of global warming, in which case they might be justified. To estimate the costs of mitigation, however, a portfolio of low- or zero-carbon technologies should be available, that can substitute fossil fuels at an acceptable cost. Unfortunately, so far there seems to be little evidence that the various political and technological proposals that have been set forth will not fall short of their goals (Pacala and Socolow 2004). Apparently, the most promising strategy to reduce carbon emissions increase in the next few decades come from technological transfer and the modernization of the industrial base in the emerging economies (Bernstein et al. 2006). Unfortunately, technology transfer – however useful – in the short run can at most save potential emissions, rather than reducing emissions in absolute terms. In fact, virtually no credible scenario forecasts a reduction in global emissions, particularly in the emerging economies, in the next few years or in the foreseeable future. Moreover, since global warming is a strongly inertial process, whatever will be done in the short run, by developing countries, developed countries, or both, will have little effect in the short run. The results will be delivered in the longer run (which is one reason why international agreements are so hard to close – see Enevoldsen 2005).

While the future looks gloomy if put in this perspective, there are also reasons for hope, even under a business-as-usual scenario. First, the warming effect from GHGs follow a logarithmic pattern, that is, the marginal warming effect of any given GHG molecule declines. This means that, assuming that doubling the amount of GHGs in the atmosphere caused an increase in global average temperatures by *x*, a further temperature increase by the same amount requires GHGs concentration to double again. To put it otherwise, the amount of temperature increase that can be attributed to any given molecule of GHG is lower than that of the previous molecules, and lower than the average molecule. In very rough terms, future emissions are less harmful than past ones (IPCC 2007, Visconti 2005).

Secondly, it is likely that global warming will occur gradually, and that temperature increase in the foreseeable future will not be catastrophic. According to IPCC (2007), in the most likely scenario the expected temperature increase will be in the range 1.8-4°C by 2100. This means that there is a chance the goal of the EU policy – to keep temperature increase below 2°C – will be met even in the absence of specific policies (if the lower estimate is true), as well as there is a chance that it will never be met even under the most ambitious policies (if the higher estimate is true). The low probability of European policies having a significant impact on temperatures depends not just on the fact that Europe alone accounts for a small and declining share of global emissions, but more fundamentally on the inertial nature of the climate system. As Nordhaus (2008, pp.152-153) explains, "the benefits of emissions reductions are related to the stock of greenhouse gases, while the costs of emissions reductions are related to the flow of emissions. This implies that the marginal costs of emissions reductions are highly sensitive to the level of reductions, while the marginal benefits of emissions reductions are insensitive to the current level of emissions reductions" (see also Pizer 1999 and Hoel and Karp 2001). A consequence of this may be that, even in presence of a very small probability of catastrophic climate change, the need for urgent or immediate action may not be as high as the need to design efficient policies. That is, we are not running out of time.

The above leads to a policy conclusion that may be quite different from the policies that are generally advocated by policy-makers and, to some extent, by economists.

1.7. The economics of decoupling

The simplest way to reduce emissions, in fact, is to curb economic growth. Significantly enough, 2008 has been the first year EU's emissions have fallen dramatically, the most significant difference with respect to the past being that the European economy fell because of the global economic crisis. Obviously, the idea that economic growth should be entirely given up in order to cut emissions is trivial. The real challenge is to design a proper set of incentives, as to decouple economic growth from emissions growth. As Figure 2 shows, thus far emissions have grown hand in hand with population, GDP, and energy consumption. As is clear from the Figure, in the last 50 years GDP and emissions have grown slightly faster than population and energy consumption, indicating that per capita consumption has grown, and that the share of fossil energy has increased reflecting its many economic and technological advantages.

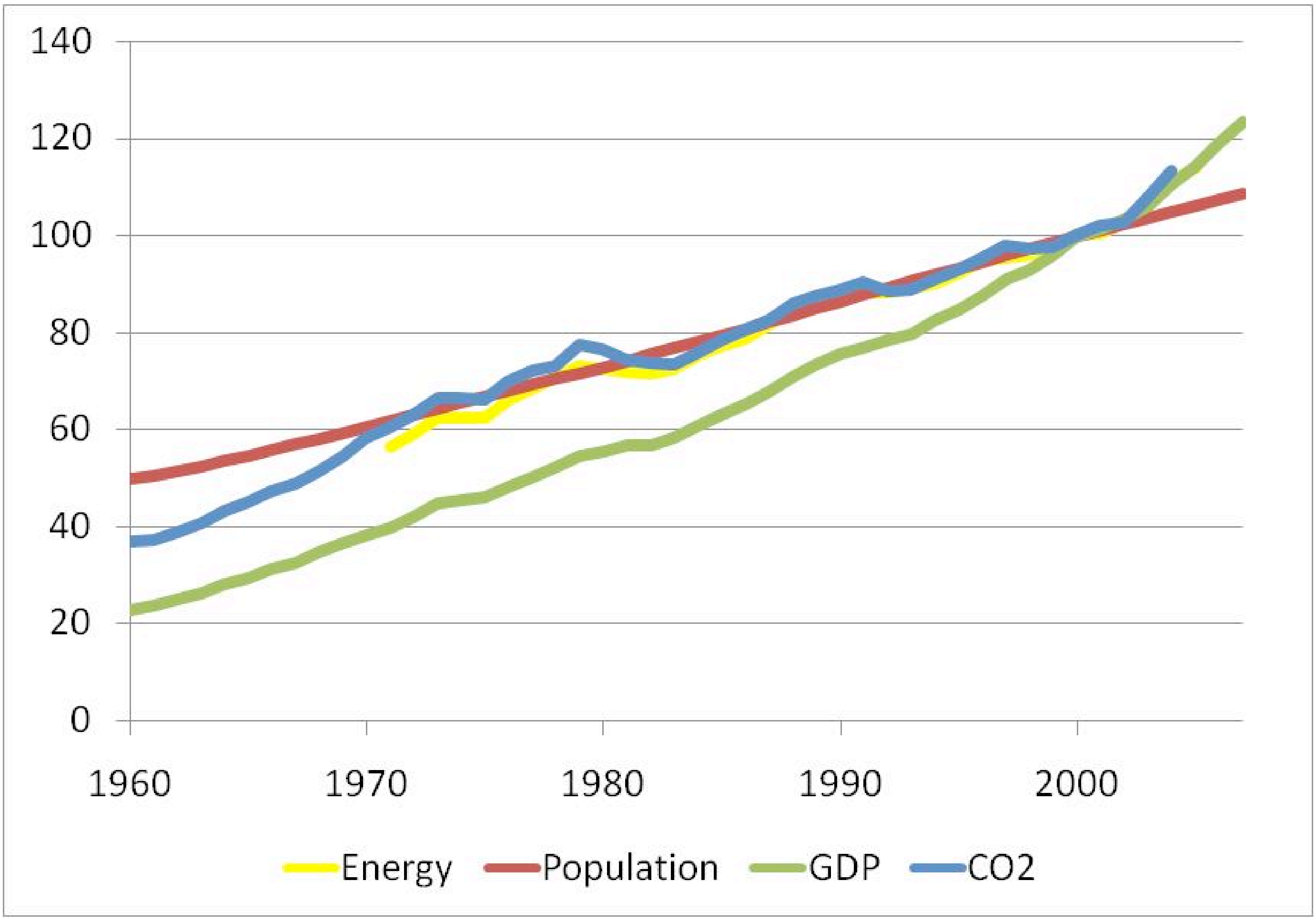

Figure 2. Energy (1971-2001), Population, GDP, and CO_2 emissions (1960-2001) growth. Each variable has been adjusted so that the 1990 level is set equal to 100. Source: Elaboration on the World Bank's World Development Indicators.

The apparent aim of climate policies, is to decouple emissions growth from GDP growth, which may or may not entail decoupling energy consumption from GDP growth. Absolute decoupling refers to the fact that GDP grows, while emissions stabilize or decline. There is no evidence that absolute decoupling does or will happen in the foreseeable future at a global level; a few examples of absolute decoupling exist but they can hardly be reproduced (Pacala and Socolow 2004). Relative decoupling refers to the fact that emissions grow slower than GDP. Relative decoupling is a reality in most of the developed world, as a consequence of increase affluence and higher possibility and willingness to spend for cleaner technologies, as well as of specific regulations (OECD 2002; OECD 2006; Lu et al. 2007).

Zhang (2000) shows that the major driver for emissions increase in China has been economic growth; Mazzarino (2000) and Gonzales and Suarez (2003) obtained the same result, respectively, for Italy and Spain. At the same time, there is some encouraging evidence from other sources of pollution, as it has been emphasized above. In fact, as to most pollutants of the past, a "bell-shaped curve" has been observed, whereby the amount of pollution grows up to a point together with GDP or GDP per capita, and after that stabilizes and eventually declines. A huge amount of literature has addressed this so called "Environmental Kuznets Curve", since it was introduced by such authors as Grossman and Krueger (1995); Selden and Song (1994); Shafik and Bandhopadyaya (1992) (for a longer discussion on the Environmental Kuznets Curve for carbon, see Chapter 2). As to carbon dioxide and other GHGs the evidence is mixed, to say the least. Some authors, such as Goklany (2007), argue that what he calls the "ecological transition" – that is, the shift from more polluting to less polluting technologies as GDP and the technological level grows – will happen; others claim that GHGs are not showing any trend towards stabilization or reduction in absence of specific policies (Roca and Alcàntara 2001); still others believe the Environmental Kuznets Curve may or may not apply to GHGs (Vollebergh et al. 2005; Galeotti and Lanza 1999). One possible explanation for the lack of a univocal evidence is that in almost no country in the world per capita GDP is high enough to start the trend reversal for GHGs emissions.

Whatever is the reality of Environmental Kuznets Curve for GHGs, we are left with three hypotheses, each of them supported by some piece of evidence:

(a) Environmental Kuznets Curve will eventually show up for GHGs, in which case the market will take care of global warming – even though collective action may be needed either to increase resilience against the adverse consequences of global warming, or to accelerate the process;

(b) Environmental Kuznets Curve will not show up, in which case carbon emissions will never be decoupled from economic growth – that is, any policy aimed at cutting emissions, will subsequently curb economic growth;

(c) The existence of Environmental Kuznets Curve for GHGs depends on local variables, which means that some countries will eventually be able to decouple carbon and growth, while others will face the choice between growing or contributing to the fight against global warming.

For the sake of simplicity, only the first two alternatives will be considered, assuming a global consensus can be found on whether or not action is needed. This is a very strong – and apparently unlikely – assumption, that leads to consciously overestimate the scope of climate policies, if and when they are adopted.

1.7.1. EKC does exists

If an Environmental Kuznets Curve (EKC) exists for GHGs, one would expect emissions to stabilize and/or decline spontaneously in the long run, starting from the developed world. That is, a natural process will take us to the final solution of the global warming process, even though that may happen "too late", that is, when the atmospheric concentrations of GHGs have reached a dangerous level. Ideally, however, this poses us quite a different problem than the one which is commonly addressed by the global warming literature: the challenge, in fact, would not be to change human behavior or to force the adoption of inefficient technologies. It would rather be about how to improve or accelerate the transition.

According to the framework introduced by Forte (2007a), this would be as to say that the external diseconomy (global warming) can't be decoupled from the external economy (GDP growth) in the short run. A consequence of this is that any policy aimed at curbing emissions would reduce GDP growth as well, and would delay – instead of making faster – the ecological transition (Goklany 2007). In the short run, any such policy would either be ineffective (if GDP growth is to be preserved), or economically very negative (if emissions are to be cut), especially for the low-income countries. In both cases, the outcome would be questionable in terms of welfare effects, and politically hard to justify.

A further consequence of this would be that a meaningful policy should be long run-oriented, and should focus on the "low hanging fruits" that have not been picked yet. As a matter of fact, most of them lie in the developing countries, that have far less efficient industrial and energy sectors than the developed countries. Bernstein et al. (2006), for example, have estimated that the potential for reducing future emissions in the major emerging economies through cost-effective technological transfers is more promising than what could be delivered by international treaties such as the Kyoto Protocol, at a lower cost (in fact, it would be an investment).

Under the EKC hypothesis, moreover, the major driver for the ecological transition in the long run would be GDP growth. That is, pro-environment, anti-growth policies might be effective in the short run, but in the long run would be anti-environment, not just anti-growth. On the contrary, the best policy in the long run would be one, that encourages economic growth as a solution to environmental problems, particularly global warming.

Obviously, this means that at least some global warming will happen, beyond the amount of warming that we will get anyway as a consequence of the inertial nature of climate. It would be reasonable, then, to focus our policy efforts on adaptation to changes, rather than on mitigation. Mitigation, in fact, will come when GDP levels will be high enough.

1.7.2. EKC doesn't exist

If EKC doesn't apply to GHGs, it means that either decoupling will not happen, or that it will be very costly to achieve, because any permanent reduction of emissions requires either to permanently slow down economic growth, or to go through a major technological shift that, at the time being, doesn't seem likely or even possible (Pacala and Socolow 2004). For example, with regard to solar power – which is widely regarded as the most promising technology – even under the most favorable assumptions, will not be competitive or technically feasible on a large scale for decades (Borenstein 2008; Bradford 2008). As in the case of EKC, hence, a transition problem arises, that should be addressed by proper policies, and should not be overlooked.

In other words, absent EKC in the foreseeable future humanity will face a tradeoff between economic growth in a warmer world, or economic stagnation in a cooler world. The choice between these two alternatives is not just an economical one, as it implies a number of ethical arguments regarding, for example, to what extent the human genre has a right to interfere with the environment and, even more fundamentally, what are the rights of the future generations, as well as what is in their best interest. The moral side of the issue derives from the fact that we know that the current economic framework is incompatible with "sustainability" strictly defined, as many environmentalists have argues (see for example WWF 2008). A previous version of the same report (WWF 2006, p.19) went as far as to claim that "No region, nor the world as a whole, met both criteria for sustainable development. Cuba alone did". While a similarly explicit statement can't be found in the most recent edition of the *Leaving Planet Report*, the result is pretty much the same. It is worth being emphasized that this is not the result of a selective interpretation of the reality or of a poor methodology, but the logical consequence of a definition of "sustainable development" as basically a lack of interference with the natural environment, which is consistent with much of the environmental movements as well as with a significant part of the literature on global warming, that has often considered the environment as an "independent variable" (Clò 2008).

If this is the case, not just the immediate or foreseeable costs and benefits of action and lack thereof, as well as the underlying uncertainties, should be considered, but also the long-term consequences of climate action on the future of economic growth, willingness to invest, and possibility of creating a better world for the future generations. That is, addressing the external diseconomy is at least as much important as preserving the external economies deriving from growth.

1.8. A case against government intervention

Under this respect, the non-EKC case leads to similar conclusions as the EKC-case: under the former, the environment can't be saved without giving up economic growth, or it can be saved only to the extent that economic growth is given up. Significantly enough, most estimate on the costs and benefits of global warming and climate policies find comparable result for the two sides. The main reasons why most economists seem to believe that action is needed have to do with a precautionary approach (Morris 2000) and/or an over-simplified vision of the underlying scientific issues (Henderson 2009).

In the EKC-case, instead, the environment can and will be saved, but for this to happen, the world's economy will have to grow enough. Wealthier countries do or will experience first their ecological transition, while less developed countries will have first to build up their own institutions, capital accumulation, and solve the most basic problems before they can consider, and can be asked to consider, GHGs as a legitimate environmental threat. As Adler (2000, p.22) puts it, in an EKC-like world, "wealthier is healthier and richer is cleaner". Public policies may play a role, insofar as they make faster the innovation process and/or the technological improvement, especially in the developing world.

If things are like this, the two cases hereby considered are clearly symmetrical: in both cases, there is short- and long-run tradeoff between reducing emissions and keeping growth. Hence, there is an intimate relationship between the world's economic performance and its environmental future.

Now, let's consider global warming as conventional pollution (which it is not, because temperature increase per se is not linked with human or environmental deterioration) that determines an external diseconomy. The public good which is apparently under-produced, absent collective action, is "climate stability", that can be defined as the rate of climate change that is driven by non-human causes, plus the rate of climate change whose marginal cost is equal to the marginal benefit from its primary cause, i.e. economic growth. Let's forget for a while that none of the above variables – natural as opposed to man-made global warming, and "acceptable" as opposed to "non acceptable" anthropogenic global warming – is known, neither is it possibly knowable.

The standard approach that would be undertaken in such case is described by Forte (2007b, p.188-190): the prima facie approach would be to tax the polluter in order to compensate the polluted, and by so doing an incentive would be set for the polluter to adopt cleaner technologies. Often, however, the costs of the underlying transactions are too high, so it may be decided that the state subsidizes cleaner technologies, that is, the burden is shifted onto tax payers (who may roughly coincide with the polluted party). Alas, "not all diseconomies can be eliminated. Too many vehicles in the streets generate diseconomies to the other vehicles. Urban growth increases the value of land and generates monetary, external diseconomies to the other users. Noise and part of the atmospheric pollution from productive and commercial activities can't be eliminated, but only reduced. The costs of external diseconomies in congested areas will increase not just for individuals, but also for businesses. Not always this will reduce their demand for those areas, because there are also 'external economies' generated by the existing businesses. The market, if left alone, will stop 'new entries' only when they will stop producing differential benefits".

There is a clear analogy. Emissions can't be eliminated without giving up the world economy as it is, causing the death of many who can live just because of the capitalism-induced progresses (Hayek 1991; Simon 1996). In the foreseeable future, they can't even be reduced. The rate of growth of emissions can just be slowed, at high cost. This high cost consists, precisely, in the loss of what is clearly an "external economy" that goes hand in hand, and at the present state of technology can just go hand in hand except for a small number of highly developed countries, with the external diseconomy.

The current global markets may underprice carbon. As a consequence of this, emissions may be higher than the optimum, and present and future temperatures may be higher than the optimum accordingly. Yet, the other side of the same coin is that the world as a whole has grown to a level of welfare – as measured by GDP and virtually any other indicator – that, even in the close past, was probably unthinkable. It would be important to let carbon be properly priced, but it is even more important to keep the benefits of economic growth, especially when it is emphasized that energy poverty is probably a more urgent, immediate, and catastrophic threat than global warming itself (Lomborg 2004).

Moreover, it should be emphasized that, although indirectly, carbon is already priced in most developed economies, and in many developing ones. Energy taxation has the same effect of carbon pricing, as it disincentives the use of fossil energy. In fact, carbon is indirectly priced at least in four different ways, some of which are truly global by nature. First, energy taxation. In the European Union, for example, the country that taxes gasoline and diesel the least was Cyprus, that in the first 10 months of 2008 had an average taxation of 0.445 and 0.399 euro per liter of gasoline and diesel, respectively (UP 2009), which translates into 189 and 130 euro per ton of carbon dioxide, respectively. According to Nordhaus (2008, p.91) the optimal price for carbon in 2010 is 34 US$, that equals to slightly more than 9 US$ per ton of carbon dioxide. The amount of taxes that any European driver pays for petroleum taxation is much higher than what any estimate for the social cost of carbon would suggest (Tol 2005).

Secondly, while many countries in the world subsidize energy consumption, many others tax it more than proportionally. A large part of world energy consumption happens in countries where the amount of energy taxes exceeds the amount of energy subsidies (see data from WB 2008). Petroleum, for example, is taxed in many ways and in many jurisdictions, and it is likely that, for example, the consumption reductions due to the taxation of the oil companies' revenues in the oil-rich countries exceeds the increases in consumption in the same countries because of domestic subsidies or price controls (for an overview on petroleum taxation, see Nakhle 2008). The inefficiencies of many national companies in oil-producing countries is likely to have the same result (Marcel and Mitchell 2006). Subsidies and mandates for non-fossil energies also work the same way.

Thirdly, the amount of oil and gas that is produced every year, is probably lower than the amount that would be produced in a perfect market, as a consequence of the numerous political restrictions, cartels (such as OPEC), etc.

Fourthly, most developed countries and an increasing number of developing countries have adopted environmental regulation that also increase the cost of energy. To the extent that regulation is, to practical purpose, equivalent to taxation (Posner 1971), even this works as a carbon tax, even though it is obviously intended for other goals (including abating different pollutants from carbon dioxide).

One may still argue that all the above is not enough, but at least all the above should be considered. On the contrary, most of the global warming literature tends to completely ignore this point, as if the price of carbon-based energy was a true market price, except for the externality which is not priced, instead of the result of market forces *and* many other components, including (but not limited to) market distortions, taxation, regulations, and subsidies to carbon-free energy sources or energy-saving technologies.

To sum up, the following can be stated: (a) in the past as well as in the foreseeable future, carbon emissions are a byproduct of economic growth; (b) a relative decoupling between emissions and growth is very likely to happen at a global level, as well as it occurred for the developed world, while an absolute decoupling may or may not happen; (c) in either case, it is possible that an Environmental Kuznets Curve describes fairly enough the long-term pattern for carbon emissions, that have not yet started to fall because the GDP per capita has not yet reached the level corresponding to a trend reversal; (d) if the EKC hypothesis is true, and if the political goal is to achieve a long-term reduction of emissions, the policy instrument should possibly accelerate the rate of growth in order to get sooner to the turning point, or at least should carefully avoid to have an anti-growth effect; (e) if instead the EKC doesn't describe the long-term pattern for carbon emissions, or if it applies only to regional cases and depends on local variables, whatever policy is adopted, a tradeoff will emerge between a cooler world, and a wealthier future. Ultimately, the question is a moral one, and it refers to the amount of future wealth that should be given up in order to reduce the expected amount of future warming. In comparing the costs and benefits of the policy, it should be considered the fact, that the benefits of mitigation policies are likely to be less certain than the costs (because the complexities of the climate system are very high), and that there will be a significant time lag between the latter (that will start immediately) and the former (that will show up sometime in the future).

The most important statement in the above summary, is that, whether or not the EKC exists at a global level, the economic consequences of climate policies should be adequately considered. It should also be considered that even the most aggressive policies, aimed at achieving the most dramatic reduction in global emissions in the shortest time, will be paid for not just by the present generation, but also by future generations. In fact, all else being equal, reducing carbon emissions for the present generations requires to consume less energy (that is, to pay more for the same amount of energy) and hence grow more slowly. This slower growth will result in lower capital accumulation, less wealth, and arguably less technological improvement for the future generations, who will be impoverished by climate policies, and not just by the amount of unmitigated global warming.[1]

In other words, future generations will face climate costs whatever choice is made today and whatever is the real state of the world and scientific truth. Table 2 shows the distribution of costs in simplified scenarios, depending on the science and the policy of global warming.

[1] Some amount of warming will happen anyhow, unless (a) all global warming is assumed to be anthropogenic and (b) emissions are reduced to zero instantaneously. (b) would lead to starvation and the death of many, maybe most, human beings. (a) implies a scientific assumption, that – absent man-made forcing – global temperatures would be either stable or decreasing. If this is true, we are in the very fortunate event of living under a climate optimum that, differently from what happened in the past, will persist. If temperatures decrease, a case might be made (following exactly the same kind of reasoning which is underlying most of the global warming economic literature) for subsidizing emissions, in order to stabilize temperatures at the present level. In fact, when in the past scientists feared the planet could get into global cooling, economists suggested that measures are taken in order to address the threat of cooling. See, for example, Adler (2006).

	Warming is mostly anthropogenic	Warming is mostly natural
Strong climate policies are implemented	1A. Less warming, less wealth	1B. Less warming, less wealth
Weak or no climate policies are implemented	1B. More warming, more wealth	2B. Less warming, more wealth

Table 2. Possible scenarios for the future generations.

From Table 2, it is clear that the most favorable condition for future generations is 2B, while the less favorable may be either one of the remaining three, depending on the expected costs and benefits from warming and from the policies. Prima facie, keeping in mind the estimates for the costs and benefits of climate policies that were reviewed in a previous paragraph, the three scenarios may be thought of as being equivalent. What is relevant from our perspective, however, is that future generations will face some costs anyway, either in form of reduced growth, or increased warming, or both. The real political choice we are facing is how much cost should be passed onto them, as opposed to how much cost should be borne by the present generation.

Under the Forte framework, this case resembles the one where it may be reasonable to shift the cost of pollution on the polluted party, instead of the polluting one. Three different arguments can be raised.

In the first place, adopting strong climate policies today would raise a fairness dilemma: since, under the business as usual, future generations may be expected to be wealthier than the present one, bearing a cost today in order to produce a future benefit would be equivalent to taking from the poor to give to the rich.

Secondly, not only the poor will be poorer as a consequence of the policy, but also the rich will be poorer despite the subsidy, because they might be living in a cooler world, but they will also have had a lower rate of economic growth and presumably a lower capital accumulation.

Third, while it may be true that global warming is a global public bad whose abatement is costly, it is equally true that economic growth is a public good whose production is costly, at least in terms of higher carbon concentrations in the atmosphere. At the present state of scientific knowledge, little can be said regarding the actual effects of global warming or the effects of mitigation policies, but we know that the marginal greenhouse effect of GHGs molecules will be decreasing. This suggests that the decision to make strong climate policies might be shifted sometime in the future, without losing much in terms of slower temperature increase.

Consistently, most climate economists (for example Nordhaus 2008), albeit favorable to implementing climate policies, suggest that a moderate action is taken, not a radical one, with increasing intensity over time.

Hence, a prima facie case can be made for shifting the cost of pollution onto the polluted party, i.e. on future generations, because on the one hand there seems to be still time enough to make policy changes as the evidence on the scientific facts becomes more (or less) compelling,[2] on the other hand the external diseconomy (global warming) apparently goes hand in hand with the external economy (economic growth). In this perspective, anthropogenic global warming is neither distorsive nor a market failure; it is rather part of the big picture.

Forte (2007) argues that the symmetry between external economies and diseconomies, when it exists such as in the present case, may not be enough to justify the choice of shifting the burden onto the polluted. Some sort of reasoning on the risk of moral hazard should be considered. For example, in the most-cited case of a train generating sparks that burn the tree, if a choice is made that the polluter pays, the forest-owner might end up with not taking care of the forest itself. This lack of attention might lead to higher social costs.

In the case of global warming, of course, the polluted party has no choice regarding how to behave, as they will just inherit the world as we leave it. However, moral hazard still exists.

Policies are often assumed to work properly. However, a great amount of literature has focused on the extent to which "government failures", that can be cause by a variety of reasons such as inefficient implementation of pressure groups, can be as much harmful as market failures (see, for example, Buchanan and Tullock 2004, Tullock et al. 2002, and more specifically on climate change, Yandle 1998). Beyond that, which turns almost every estimate of the benefits of a policy into an overestimate, several authors have emphasized that, under appropriate circumstances, safety regulations may result into higher a net loss of safety, because people tend to react by increasing other risky behaviors. This is what has been called the "Peltzman effect", named after the Chicago economist Sam Peltzman (1975) who famously argued that mandatory seat belts didn't reduce highway deaths. An application of the Peltzman effect, which has directly to do with environmental issues, is the perverse consequences of the Endangered Species Act (ESA), a US law that aims at protecting wildlife that faces extinction. Peltzman (2007, pp.194-196) showed that ESA creates an incentive for immediate tree-cutting in order to prevent endangered species to move onto new pieces of land, otherwise ESA regulations would enter in force (see also Lueck and Michael 2003 and Margolis et al. 2007). A wide amount of literature discusses whether or not regulation may have an adverse

[2] Remarkably enough, the estimates for such variables as temperature increase and sea level rise over time have fallen. See IPCC (2007) for the most recent ones.

effect (see, for different perspectives, Adams 2001; Sunstein 2002; Sunstein 2005; and, contra Peltzman, Sklansky 2006).

To find moral hazard within the global warming debate, one should better understand the issue of adaptation versus mitigation policies. Mitigation, namely carbon emission cuts, is intended to reduce the amount of future warming. A cost is incurred today, in order to prevent a cost tomorrow. If the discounted value of the avoided future cost is higher than the cost of the mitigation policy, than the latter is justified on economic grounds. Since global warming is a very long-term phenomenon, one needs to understand what future costs will look like, and to solve the very complex question about discount rates, for example in the way the *Stern Review* does (that is, by picking a close-to-zero discount rate) or in the way Nordhaus (2008) does (that is, by picking a higher discount rate). Even more challenging than picking the "right" discount rate, is how to address the distant future. As Adams (2001, p.175) recalls, "300 years ago the US dollar did not exist and most of the North American continent was still owned by the Indians. One way of appreciating the magnitude of the task that the greenhouse economists have set themselves is to imagine them transported by time machine back to 1693, and set the task of doing a cost-benefit analysis of the European conquest of North-America – with the net present value of the conquest calculated in 1693 wampum".

Adaptation consists of changing human behavior, or adjusting industrial processes, our way of life, buildings, cities, and protection measures to a changing environment. If sea levels rise, a gradual migration is expected from what are now coastal areas to the internal ones, as well as more investments in coastal protection. If warm regions will become too hot while colder regions will gain a moderate weather, the value of land in the former will decrease, while the land value in today-inhospitable lands will gradually increase, creating an incentive to urbanize the latter. Most proponents of climate policies, most notably the IPCC (2007), propose that both adaptation and mitigation efforts are taken. Unfortunately, there is a tradeoff between adaptation and mitigation, which is due not just to the fact that once a given amount is spent for mitigation (say, in installing more renewable capacity) it can't any longer be spent in adaptation (say, in building coastal protection devices), and viceversa.

The real nature of the tradeoff is a deeper and conceptual one. In the first place, the tradeoff is related to the outcome of the policies. There is, in fact, an inverse relationship between adaptation and mitigation: the more you adapt to climate change, the less you need to mitigate it, and viceversa. On one extreme, if we can and do fully mitigate global warming, you have no need to adapt to changes; on the other extreme, if you can and do completely adapt to changes, we don't need to mitigate them. To put it otherwise, unmitigated climate change requires huge investments in adaptation, while no adaptation is required as temperatures growth is close to zero.

More substantially, as Wildavsky (1989, pp.78-79) explains in his fundamental book on the concept and policies for safety, "the very purpose of anticipatory measures is to maintain a high level of stability. Anticipation seeks to preserve stability: the less fluctuation, the better. Resilience accommodates variability; one may not do so well in good times but learns to persist in the bad". Wildavsky goes on by clarifying that there is no a priori reason to prefer the one strategy over the other, except that "An environment with periodic extremes would correspond to a situation where uncertainties are large… while the condition of steady, unvarying stability would correspond to a situation of low uncertainty about the future… Thus, under considerable uncertainty, resilience is the preferable strategy". This approach seems to fit very well with the characteristics of global warming, a threat which is defined by the large amount and scope of uncertainties, rather than by a reasonably good knowledge of causal relationships and the future weather patterns.

In economic terms, the main difference between adaptation and mitigation is that adaptation costs are more likely to occur over the long run, as the physical evidence of global warming will become clearer, as well as the magnitude, sign, and intensity of its consequences. On the opposite, mitigation requires an immediate commitment to invest in order to reduce carbon emissions, without having a clear idea of what the outcome will be and perhaps even what probability is attached to any possible outcome. Mitigation efforts are made even more complicated by the large uncertainties underlying the probability of a global participation to GHGs cuts, the quality of implementation, and the role of pressure groups in turning anti-global warming efforts into rent-seeking activities (Helm 2009; Kasper 2007; Bailey 2008).

Under the Forte framework, hence, adaptation – as opposed to mitigation – equals to letting the polluted pay. A policy mix that includes both adaptation and mitigation measures, as real policies do, shares the risk between the present and future generations, proportionally to the amount of mitigation and adaptation, respectively. Obviously, real policies are inherently a mix of adaptation and mitigation. Moreover, it is very likely that mitigation efforts, however ambitious, will fall short of avoiding all future warming, at least because of the inertial component of climate dynamics (i.e., some future warming will happen as a consequence of today's atmospheric concentrations of GHGs) and, even more important, the natural component of global warming. Nevertheless, it is most useful to operate a theoretical distinction between the two policies, in order to better understand both the respective "doses" and "timings".

As it has been already recalled, some authors – such as Goklany (2000) and Okonski (2003) – have emphasized that adaptation is more economically efficient than mitigation because it focuses on real problems, not on uncertain ones. Moreover, it allows to tackle problems that may be exacerbated, rather than caused, by global warming, such as the diffusion of tropical diseases and the lack of access to clear, drinking water in the developing world. Finally, adaptation has been usually underestimated (Mendelsohn 1999), as, for example, it has often been assumed that no health response would be taken against rising malaria. On the contrary, adaptation efforts are likely to produce significant results in terms of mitigating the effects, rather than the presumed cause, of global warming (Mendelsohn and Neumann 1999).

As compared with mitigation, adaptation is relatively less exposed to the risk of moral hazard. Every adaptive measure is inherently more transparent, in the first place, so the risk and cost structure can be more clearly known. Paradoxically, mitigation can lead to higher risks: for example, investing considerable resources in "green" energy might prevent investments in more efficient, conventional fuels, that are more substantially contributing to the global amount of emissions. This problem has emerged clearly with the so called Clean Development Mechanisms (CDMs) under the Kyoto Protocol, that generate carbon credits in regulated markets from investments in the developing, less carbon-efficient world. By insisting on energy sources that are well beyond even Western standards, CDMs generated a fair amount of investments, but could do little to address what is the main source of pollution, today as well as in the future. It would be far more profitable to create a common framework for investment in *cleaner*, rather than *clean*, energies, but it is clear that emissions would still rise (instead of being reduced). A mitigation-oriented policy can hardly capture such ongoing process (Bernstein et al. 2006).

By the same token, under a lower degree of uncertainty, rent seeking activities – while still existent – would be less ambitious, because the time would come when a line is drawn in the sand to tell which investments and policies are producing the expected results, and whether or not these results are actually desirable.

Finally, it would be morally questionable to fund – through subsidies or regulation – the creation of costly "green" capacity, when so many people in the world lack access to electricity. The problem of energy poverty can't be separated from that of growing carbon emissions: as people get connected to electricity lines, emissions are likely to grow. Under a mitigation policy, the reduction of energy poverty would be indirectly disincentived, because it would require emitting installations to offset their own emissions by buying credits, paying taxes. The alternative would be to install only clean energies, but this would mean – assuming the amount of the investments is the same – that less people would get out of energy poverty. This may or may not be seen as a good economic argument, but for sure it is a moral one that can hardly be ignored.

1.9. Conclusion

Global warming has been described as the biggest threat the world is facing, or as a global public bad. Climate economists, however, have sometimes failed to properly assess (a) the real magnitude and scope of scientific uncertainties, and (b) the reciprocal nature of global warming, that can be seen as a byproduct of economic growth. If these two questions are properly set, one will realize that the effectiveness – leave aside efficiency – of the proposed policies may be lower than expected. Moreover, to the extent that global warming is a public bad, it goes hand in hand with the many positive externalities of economic growth. Economic analysis of the costs and benefits of global warming and climate policies suggest that they may be of the same order of magnitude. Differently from most climate economists, we conclude that this provides a prima facie case against government interventionism. Given the distribution of the costs and benefits and the large inefficiencies that can be assumed to be underlying the policies implementation, this may well be a case when it is reasonable to shift the cost of pollution onto the polluted party, instead of the polluter.

Following a framework proposed by Forte (2007) who speculated upon the long-term consequences of the Coase Theorem, this paper argues that the future generations, all else being equal, would be better off by being wealthier in a warmer world, rather than poorer in a cooler world. The present generation might also be better off by keeping a high rate of economic growth. In this respect, aggressive climate policies such as those proposed by the *Stern Review* might result into relatively high costs, and little or non-discernible benefits. A further reason to better check the usefulness of aggressive climate policies today, is the risk of moral hazard underlying new regulations. In the case of climate, a particular sort of "political moral hazard" should be considered, in the sense that wrong policies might lead to perverse results and that the policies themselves might become a Troy Horse for rent seekers.

Under the Forte framework, it might be sensible to shift the cost of pollution onto the polluted. In practice, this would mean that the present generation should focus on accelerating the rate of economic growth in order to leave future generations well-equipped with capital accumulation, human capital, and technologies that may be gradually employed to adapt to changes, rather than preventing changes. Adaptation may also be a no-regret short-run policy: global warming is likely to exacerbate existing problems, rather than creating new ones, and this provides a point for the solution of those problems as soon as possible, instead of preventing their growth in the future.

The largest issue surrounding global warming policies is, anyway, the amount and scope of scientific, economic, and political uncertainties. Further and better focuses research is needed to address each field of uncertainty, in order to design better policies. While the degree of uncertainty is still so high, though, investing in making human systems and the environment more resilient might be a more comprehensive strategy, than investing in the conservation of things as they stand.

References

ADAMS, J. (2001). *Risk*. London: Routledge.

ADLER, J. (2000). "Greenhouse Policy Without Regres. A Free Market Approach to the Uncertain Risks of Climate Change", *CEI Issue Analysis*, http://cei.org/pdf/1783.pdf.

ADLER, J. (2006). "Remember Global Cooling?", *Newsweek*, 23 October.

BAILEY, R. (2008). "Four Ways of Looking at Global Warming Policy", *Reason Online*, 1 July, http://www.reason.com/news/show/127279.html.

BERNSTEIN, P.M., MONTGOMERY, W.D. and TULADHAR, S.D. (2006). "Potential for reducing carbon emissions from non-Annex B countries through changes in technology", *Energy Economics*, vol.28, no.5-6, pp.742-762.

BORENSTEIN, S. (2008). "The Market Value and Cost of Solar Photovoltaic Electricity Production", *CSEM Working Paper*, no.176.

BRADFORD, T. (2008). *Solar Revolution. The Economic Transformation of the Global Energy Industry*. Boston: MIT Press.

BRUBAKER, E.R. (1975). "Free Ride, Free Revelation, or Golden Rule?", *Journal of Law and Economics*, vol.18, no.1, pp.147-161.

BUCHANAN, J.M. and TULLOCK, G. (2004). *The Calculus of Consent. Logical Foundations of Constitutional Democracy*. Indianapolis: Liberty Fund.

CALABRESI, G. (1965). "The Decision for Accidents: An Approach to Nonfault Allocation of Costs", *Harvard Law Review*, vol.78, pp.713-745.

CLO', A. (2008). *Il rebus energetico*. Bologna: Il Mulino.

COASE, R.H. (1960). "The Problem of Social Cost", *The Journal of Law and Economics*, vol.3, no.1, pp.1-44. Now in Coase (1990), pp.95-156.

COASE, R.H. (1990). *The Firm, the Market and the Law*. Chicago: The University of Chicago Press.

CORDATO, R.E. (1999). "Global Warming, Kyoto, and Tradeable Emissions Permits", *Studies in Social Cost, Regulation, and the Environment*, no.1, Institute for Research on the Economics of Taxation, http://iret.org/pub/SCRE-1.PDF.

COTTON, W.R. and PIELKE, R.A. Sr. (2007). *Human Impacts on Weather and Climate. 2nd Edition*. Cambridge: Cambridge University Press.

EC (2008). "Quality of Bathing Water. 2007 Bathing Season", European Commission, http://ec.europa.eu/environment/water/water-bathing/report2008/en_summary.pdf.

ENEVOLDSEN, M. (2005). *The Theory of Environmental Agreements and Taxes. CO_2 Policy Performance in Comparative Perspects*. Cheltenham: Edward Elgar.

EPA (2009). "Technical Support Document for Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act", http://www.epa.gov/climatechange/endangerment/downloads/TSD_Endangerment.pdf.

EPSTEIN, R.A (1995). *Simple Rules for a Complex World*. Cambridge, MA: Harvard University Press.

FAO (2007). *State of the World's Forests 2007*. Rome: Food and Agriculture Organization.

FORTE, F. (1967). "Should Public Goods Be Public?", *Public Choice*, vol.3, no.1, pp.39-47.

FORTE, F. (2007a). "Coase Theorem Revisited", *Rivista di diritto finanziario e scienza delle finanze*, vol.66, no.3, pp.348-363.

FREEBAIRN, J. (2007). "Economic policy issues for climate change", *Insights. Melbourne Economics and Commerce*, vol.2, http://insights.unimelb.edu.au/vol2/2_Freebairn.html

GARDINER, S.M. (2007). "A Perfect Moral Storm: Climate Change, Intergenerational Ethics and the Global Environmental Tragedy", http://faculty.washington.edu/smgard/GardinerStorm06.pdf.

GALEOTTI, M. and LANZA, A. (1999). "Desperately Seeking (Environmental) Kuznets", *FEEM Working Paper*, no.2.99.

GOKLANY, I.M. (1999). *Clearing the Air. The Real Story of the War on Air Pollution*. Washington, DC: The Cato Institute.

GOKLANY, I.M. (2000). "Applying the Precautionary Principle to Global Warming", *Weidenbaum Center Working Paper*, no.PS158.

GOKLANY, I.M. (2007). *The Improving State of the World. Why We're Living Longer, Healthier, More Comfortable Lives on a Cleaner Planet.* Washington, DC: The Cato Institute.

GOLDBERG, J. (2007). "Global cooling costs too much", *National Review Online*, 13 February.

GONZALES, F.P. and SUAREZ, P.R. (2003). "Decomposing the variation of aggregate electricity intensity in Spanish industry", *Energy*, vol.28, no.2, pp.171-184.

GRASSO, M. (2004). "Climate change: The global public good", *Working Paper*, No.75, May 2004, Department of Political Economy, Bicocca University, Milan, http://dipeco.economia.unimib.it/pdf/pubblicazioni/wp75_04.pdf.

GROSSMAN, G.M. and KRUEGER, A.B. (1995). "Economic Growth and the Environment", *Quarterly Journal of Economics*, vol.110, no.2, pp.353-377.

HAYEK. F.A. (1991). *The Fatal Conceit: The Errors of Socialism*. Chicago: The University of Chicago Press.

HAYWARD, S.F. (2008). *Index of Leading Environmental Indicators 2008*. San Francisco: Pacific Research Institute.

HELM, D. (2008). "Climate change policy: why as so little been achieved", *Oxford Review of Economic Policy*, vol.24, no.2, pp.211.238.

HENDERSON, D. et al. (2006). "The Stern Review: A Dual Critique", *World Economics*, vol.7, no.4, pp.165-232.

HENDERSON, D. (2009). "Economists and Climate Science: A Critique", *World Economics*, vol.10, no.1, forthcoming.

HOEL, M. and KARP, L. (2001). "Taxes and Quotas for a Stock Pollutant with Multiplicative Uncertainty", *Journal of Public Economics*, vol.82, no.1, pp.91-114.

HUBER, P.W. and MILLS, M.P. (2005). *The Bottomless Well. The Twilight of Fuel, the Virtue of Waste, and Why We Will Never Run Out of Energy*. New York: Basic Books.

IEA (2008). *World Energy Outlook 2008*. Paris: International Energy Agency.

KASPER, W. (2007). "The Political Economy of Global Warming, Rent Seeking and Freedom", *CSCCC Report*, no.25, http://www.csccc.info/reports/report_25.pdf.

KELLY, D.L. and KOLSTAD, C. (1999). "Integrated Assessment Models for Climate Change Control". In Henk Folmer and Tom Tietenberg (eds.). *International Yearkbook of Environmental and Resource Economics 1999/2000: A Survey of Current Issues*. Cheltenham: Edward Elgar.

LABOHM, H.H.J., ROZENDAAL, S. and THOENES, D. (2004). *Man-Made Global Warming: Unravelling a Dogma*. Brentowood, Essex: Multi-Science Publishing.

LAWSON, N. (2008). *An Appeal to Reason. A Cool Look at Global Warming*. London: Gerald Duckworth & Co.

LOMBORG, B. (2001). *The Skeptical Environmentalist. Measuring the Real State of the World*. Cambridge: Cambridge University Press.

LOMBORG, B. (ed.) (2004). *Global Crises, Global Solutions.* Cambridge: Cambridge University Press.

LOMBORG, B. (2007). *Cool It. The Skeptical Environmentalist's Guide to Global Warming*. New York: Knopf.

LU, I.J., LIN, S.J. and LEWIS, C. (2007). "Decomposition and decoupling effects of carbon dioxide emissions from highway transportation in Taiwan, Germany, Japan and South Korea", *Energy Policy,* vol.35, no. 6, pp.3226-3235.

LUECK, D. and MICHAEL, J.A. (2003). "Preemptive Habitat Destruction under the Endangered Species Act", *Journal of Law and Economics*, vol.46, no.1, pp.27-60.

MARCEL, V. and MITCHELL, J.V. (2006). *Oil Titans. National Oil Companies in the Middle East*. Washington, DC: Brookings Institution Press.

MARGOLIS, M., LIST, J.A. and OSGOOD, D.E. (2006). "Is the Endangered Species Act Endangering Species?", *NBER Working Paper*, no.W12777.

MAZZARINO, M. (2000). "The economics of the greenhouse effect: evaluating the climate change impact due to the transport sector in Italy", *Energy Policy*, vol.28, no.13, pp.957-966.

MEDEMA, S.G. and ZERBE, R.O. Jr. (2000). "The Coase Theorem". In Boudewijn Bouckaert and Gerrit De Geest (eds.). *Encyclopedia of Law and Economics*. Ghent: Elgar, pp.836-892.

MENDELSOHN, R. (1999). *The Greening of Global Warming*. Washington, DC: AEI Press.

MENDELSOHN, R. and NEUMANN, J. (eds.) (1999). *The Economic Impact of Climate Change on the United States Economy*. Cambridge: Cambridge University Press.

MICHEL, D. (2007). "What good is protecting the world's climate system? Global public goods and international public policy-making", 32nd Annual Conference of the British International Studies Association, 17-19 December, http://www.bisa.ac.uk/2007/pps/michel.pdf

MORRIS, J. (ed.) (2000). *Rethinking Risk and the Precautionary Principle.* London: Butterworth-Heinemann.

NAKHLE, C. (2008). *Petroleum Taxation*. London: Routledge.

NORDHAUS, W.D. (2005). "Paul Samuelson and Global Public Goods", Yale University, http://nordhaus.econ.yale.edu/PASandGPG.pdf.

NORDHAUS, W.D. (2008). *A Question of Balance. Weighing the Options on Global Warming Policies*. New Haven and London: Yale University Press.

ODELL, P.R. (2004). *Why Carbon Fuels Will Dominate The 21st Century's Global Energy Economy*. Brentwood: Multi-Science Publishing.

OECD (2002). "Indicators to measure decoupling of environmental pressures from economic growth", SG/SD(2002)1FINAL, http://www.oecd.org/dataoecd/0/52/1933638.pdf.

OECD (2006). *Decoupling the Environmental Impacts of Transport from Economic Growth*. Paris: Organisation for Economic Cooperation and Development.

OKONSKI, K. (ed.) (2003). *Adapt or Die*. London: Profile Books.

PACALA, S. and SOCOLOW, R. (2004). "Stabilization wedges: Solving the climate problem for the next 50 years with current technologies", *Science*, vol.305, no.5686, pp.968-972.

PELTZMAN, S. (1975). "The Effects of Automobile Safety Regulation", *Journal of Political Economy*, vol.83, no.4, pp.677-725.

PELTZMAN, S. (2007). "Regulation and the Wealth of Nations: The Connection between Government Regulation and Economic Progress", *New Perspectives on Political Economy*, vol.3, no.2, pp.185-204.

PIZER, W.A. (1999). "Optimal Choice of Climate Change Policy in the Presence of Uncertainty", *Resource and Energy Economics*, vol.21, no.3-4, pp.255-287.

POSNER, R.A. (1971). "Taxation by Regulation", *The RAND Journal of Economics*, vol.2, no.1, pp.22-50.

POSNER, R.A. (2004). *Catastrophe. Risk and Response*. New York: Oxford University Press.

REISMAN, G. (2002). "Environmentalism in the Light of Menger and Mises", *The Quarterly Journal of Austrian Economics*, vol.5, no.2, pp.3-15, http://mises.org/journals/qjae/pdf/qjae5_2_1.pdf.

ROBINSON, C. (2008). "Economia, politica e cambiamenti climatici: hanno ragione gli scettici?", *Energia*, no.4, pp.24-34.

ROCA, J. and ALCANTARA, V. (2001). "Energy intensity, CO_2 emissions and environmental Kuznets curve. The Spanish case", *Energy Policy*, vol.29, no.7, pp.553-556.

SANDLER, T. (1998). "Global and regional public goods: a prognosis for collective action", *Fiscal Studies*, 19(3), 221-247.

SCHWEIZER, P. (2006). "Gore isn't quite as green as he's led the world to believe", *USA Today*, 12 July.

SELDEN, T.M. and SONG, D. (1994). "Environmental Quality and Development: Is There a Kuznets Curve for Air Pollution Emissions?", *Journal of Economics and Management*, vol.27, no.2, pp.147-162.

SHAFIK, N. e BANDHOPADYAYA, S. (1992). "Economic Growth and Environmental Quality: Time Series and Cross-Country Evidence", *World Bank Policy Research Working Paper*, no.94.

SIMON, J.L. (1996). *The Ultimate Resource 2*. Princeton: Princeton University Press.

SIMON, J.L. and MOORE, S. (2000). *It's Getting Better All the Time*. Washington, DC: The Cato Institute.

SKLANSY, D.A. (2006). "Killer Seatbelts and Criminal Procedures", *Harvard Law Review*, vol.119, pp.56-64.

SMIL, V. (1994). *Energy in World History*. Boulder, CO: Westview Press.

SMIL, V. (2008). *Energy in Nature and Society. General Energetics of Complex Systems*. Boston, MA: MIT Press.

STAGNARO, C. (2007). "Temperatures up, GDP down", *Aspenia*, no.37-38 (English edition), pp.204-212.

STERN, N. (ed.) (2006). http://www.hm-treasury.gov.uk/sternreview_index.htm

STIGLER, G. (1966). *The Theory of Price*. New York: MacMillan.

SUNSTEIN, C. (2002). *Risk and Reason. Safety, Law, and the Environment*. Cambridge: Cambridge University Press.

SUNSTEIN, C. (2005). *Laws of Fear. Beyond the Precautionary Principle*. Cambridge: Cambridge University Press.

TALEB, N.N. (2007). *The Black Swan: The Impact of the Highly Improbable*. New York: Random House.

TOL, R.S.J. (2005). "The marginal damage costs of carbon dioxide emissions: an assessment of uncertainties", *Energy Policy*, vol.33, no.16, pp.2064-2074.

TOL, R.S.J. and YOHE, G.W. (2006). "A Review of the Stern Review", *World Economics*, vol.7, no.4, pp.233-250.

TULLOCK, G., SELDON, A. and BRADY, G.L. (2002). *Government Failure. A Primer in Public Choice*. Washington, DC: The Cato Institute.

UP (2009). *Data Book 2009. Energia e petrolio*. Rome: Unione Petrolifera.

VISCONTI, G. (2005). *Clima estremo. Un'introduzione al tempo che ci aspetta*. Milano: Boroli Editore.

VOLLEBERGH, H.R.J., DIJKGRAAG, E. and BERTRAND, M. (2005). "Environmental Kuznets curves for CO2 : heterogeneity versus homogeneity", CentER Discussion Paper Series, no.2005-25.

WB (2008). *World Development Indicators*. Available on the World Bank's website.

WEITZMAN, M.L. (2009). “On Modeling and Interpreting the Economics of Catastrophic Climate Change”, *The Review of Economics and Statistics*, vol.91, no.1, pp.1-19.

WILDAVSKY, A. (1989). *Searching for Safety.* Piscataway, NJ: Transaction Publishers.

WILS, W.P.J. (1994). “Subsidiarity and the E.C. Environmental Policy: Taking People’s Concerns Seriously”, *Journal of Environmental Law*, 85-90.

WWF (2006). *Living Planet Report 2006*. Gland: WWF, http://assets.panda.org/downloads/living_planet_report.pdf.

WWF (2008). *Living Planet Report 2008*. Gland: WWF, http://assets.panda.org/downloads/living_planet_report_2008.pdf.

YANDLE, B. (1998). “Bootleggers, Baptists, and Global Warming”, *PERC Policy Series*, no.14, http://www.perc.org/pdf/ps14.pdf.

ZHANG, Z. (2000). “Decoupling China’s Carbon Emissions Increase from Economic Growth: An Economic Analysis and Policy Implications”, *World Development*, vol.28, no.4, pp.739-752.

Chapter 2.

Economic Freedom and Carbon Intensity: How Free Market Can Address Global Warming

Abstract

Greenhouse gases (GHGs) emissions are a function of population, GDP, and carbon intensity of the economy, i.e. the ratio between carbon emissions and GDP. In order to reduce emissions, at least one of the above variables should be reduced. This paper focuses on the determinants of carbon intensity. Two factors are considered, in particular: one is GDP, the other is "economic freedom". The relationship between GDP and carbon intensity is unclear: according to some authors, in the long run GDP growth will lead to reductions of carbon intensity (so-called "Environmental Kuznets Curve"). Economic freedom is a measure of how much open is an economy, and of the freedom of businesses and individuals to invest, operate, trade, and of the stability of the legal framework. Economic freedom is measured by the Heritage Foundation and the *Wall Street Journal* ("Index of Economic Freedom"), which estimate the degree of economic freedom for any country in the world, based on a number of objective indicators. A panel dataset has been built, that includes – but is not limited to – several macroeconomic and environmental variables, such as carbon intensity, population, GDP, the industrial sector as a share of the whole economy, the number of private vehicles, etc. The dataset refers to 162 countries for the period 1995-2008. The correlation is searched between economic freedom and carbon intensity, controlling for all or some of the above-mentioned variables. Consistently with the theoretical insights and some results available in literature, the correlation is found consistently significant and negative, indicating that an increase in economic freedom is associated with a reduction in carbon intensity. While this does not mean, per se, that a causal link between the two does exist, it suggests that there may be a relation between the institutional factors subsumed in the Index of Economic Freedom, and carbon intensity (that can be interpreted as a proxy for the average technological level of an economy). If the theoretical approach hereby developed is grounded, it follows that promoting economic freedom (especially in the developing countries) may be an effective way to reduce carbon emissions below the baseline.

2.1. Description of the problem

Under the assumption that anthropogenic greenhouse gases (GHGs) emissions are a discernible driver of global warming, the international community has set ambitious goals of reducing GHGs. In 1997, the Kyoto Protocol was agreed upon, which requires to ratifying countries an emissions cut of 5.2% below 1990 levels, by 2008-2012. The European Union has made the Kyoto target of reducing its own emissions by 8% below the reference year by 2008-2012 a mandatory target, and subsequently has passed a plan to achieve a major cut by 20% by 2020. The newly elected US President, Barack Obama, has also committed himself with the goal of reducing emissions. At a global level, talks are still in process to reach a post-Kyoto agreement, which might emerge as early as late 2009 in Copenhagen. There seems to be, however, a sort of divide as far as GHGs policies are concerned: while the developed world – which is relatively less populated, less carbon-intensive, and with higher levels of emissions per capita – is designing policies in order to move towards a carbon-free world, the developing world seems less involved in the process. Two major reasons are often raised for this: (1) developed world is historically responsible for the observed, anthropogenic global warming, so it should take action in the first place; (2) economic growth is more important than the environment, in countries with low per capita income which still suffer for poverty. Underlying this criticism, is the assumption that climate policies are not cost-free. That criticism should be taken very seriously, as it will be seen in the next chapter, that will address two policy models that can be employed to reduce GHGs – namely, a cap & trade scheme and a carbon tax.

This chapter will address the question whether or not a policy can be found, that is at the same time able to achieve a long-term reduction in emissions, and generate more economic benefits than costs.

2.2. What drives emissions

Carbon emissions are not an independent variable. They depend on many inputs, some of which are well beyond human control. For example, weather significantly affects carbon's short run variability: colder Winters and warmer Summers are usually associated with higher emissions, because people tend to consume more for heating or air conditioning. The long run trend in emissions, however, can be thought as being described by an equation that is known as the "Kaya Identity" (Kaya and Yokobori 1997):

$$C = P\frac{GDP}{P}\frac{E}{GDP}\frac{C}{E} \qquad (2.1)$$

Where: C = carbon emissions; P = population; E = energy consumption. Consequently, GDP/P = GDP per capita; E/GDP = energy intensity of the GDP, i.e. the content of energy per unit of GDP; and C/E = carbon intensity of energy, i.e. the carbon content of energy. The Kaya Identity tells how carbon emissions change as each of the drivers change, or what driver should be changed, and in what direction, if a given level of carbon emissions is to be achieved.

An increase in population, GDP per capita, energy intensity, or carbon intensity results in an emissions increase. Hence, the political goal of reducing emissions would require at least one of the above variables to be reduced at a faster rate than that at which the other variables increase (if they do).

All else being equal, one obvious way of reducing emissions is to reduce population. Several authors have, in fact, suggested that the world is overpopulated (see, for example, Ehrlich 1968; Ehrlich and Ehrlich 2008; Meadows et al. 1972; Meadows et al. 2004). Beyond the intellectual criticism to the overpopulation argument (for example Hayek 1988; Simon 1996; Eberstadt 2007), the issue of population control raises a number of moral as well as economic problems that won't be addressed in this paper. However, because of its controversial nature, population control will not be considered as a politically viable – leave aside morally acceptable or economically efficient – policy.

Also GDP growth (either as an aggregate or on a per capita basis), in the short run, is positively correlated with carbon emissions. In the long run, though, the relationship may be more complex, as it will be argued in the next paragraph. Anyway, assuming that the relationship is straightforward, reducing GDP in order to reduce emissions may not be the most efficient strategy, and definitely not a desirable one – unless it is assumed that the damages from global warming will be higher than the loss of welfare underlying a lower, or negative, GDP growth. Controlling GDP in order to control emissions, hence, should be considered as a residual option, and more like a lesser evil than a second best, so to speak.

Energy intensity of GDP and carbon intensity of energy are also positively correlated with carbon emissions. Energy intensity of the GDP expresses the content of energy of an economy, while carbon intensity of energy expresses the amount of carbon emissions[3] that is generated by burning fossil fuels. The two concepts may be unified

[3] To be more precise, the amount of GHGs that are generated, of which the most famous – but not the most dangerous – is carbon dioxide. GHGs emissions, though, can be – and usually are – expressed in tons of carbon equivalent, or carbon dioxide equivalent, so the simplification is reasonable.

in that of carbon intensity of an economy, that express the carbon intensity of the GDP. So a simplified form of the Kaya Identity may be written as follows:

$$C = P\frac{GDP}{P}\frac{C}{GDP} \qquad (2.2)$$

While it may be analytically useful to distinguish between energy intensity of the economy and carbon intensity of energy, to the purpose of this paper it is also sufficient to focus on carbon intensity of the GDP (from now on, just carbon intensity). Moreover, carbon intensity of the economy also includes some piece of information that may be lost by disaggregating it in just the product of energy intensity of the economy and carbon intensity of energy: in fact, even though most man-made emissions are energy related, a huge amount of emissions is generated by non-energy related activities, such as agriculture. The concept of carbon intensity of the economy is a straightforward way to embody all the emissions, whatever their source is.

Interestingly enough, while population and GDP can be expected to grow under a business-as-usual scenario as they did in the past, carbon intensity (as well as E/GDP and C/E) may be expected to decrease. That is, in the long run and under a business-as-usual scenario carbon emissions are subject to opposite forces: on the one hand, population and GDP will drive up emissions, while carbon intensity will drive it down. World carbon emissions have grown so far both in the world as a whole, and in most subsets of countries (most notably, both in OECD and non-OECD countries). That suggests that GDP and population growth have offset the gains in carbon intensity, as well as in energy content of GDP and carbon content of energy taken individually. Notwithstanding, the observed dynamics suggests that a policy priority should be placed in accelerating the trend in carbon intensity reductions – that is, doing the same (or more) with less and cleaner energy – rather than in decelerating population or GDP growth. Carbon intensity can also be viewed as a proxy for technical progress: in fact, the reduction in carbon intensity has not been driven so far by a lower consumption of energy or a lower use of fossil fuels, but by better and cleaner technologies (Gupta et al. 1997; Smil 2003; Lomborg 2008).

2.3. GDP and carbon

While the short run correlation between economic growth and carbon emissions is clearly and strongly positive, in the long run things may be quite different.

Figure 1 illustrates the per capita emissions trend in some countries.

As we can see, there is a difference between developed and developing countries in order of magnitude as well as trend when it comes to per capita emissions. In developed countries -- with the exception of Spain, which is clearly showing increases – per capita emissions are stable or in moderate decline in the period under consideration. In the developing countries, they start from a significantly lower level, but also show a trend of sharp increase. All other factors being equal, this will end up creating a very serious problem, as increases of per capita emissions by a very large mass of individuals will be destined to increase overall emissions, with possible consequences on the atmospheric concentration of GHGs and thus on the climate. Table 1 supplies further information.

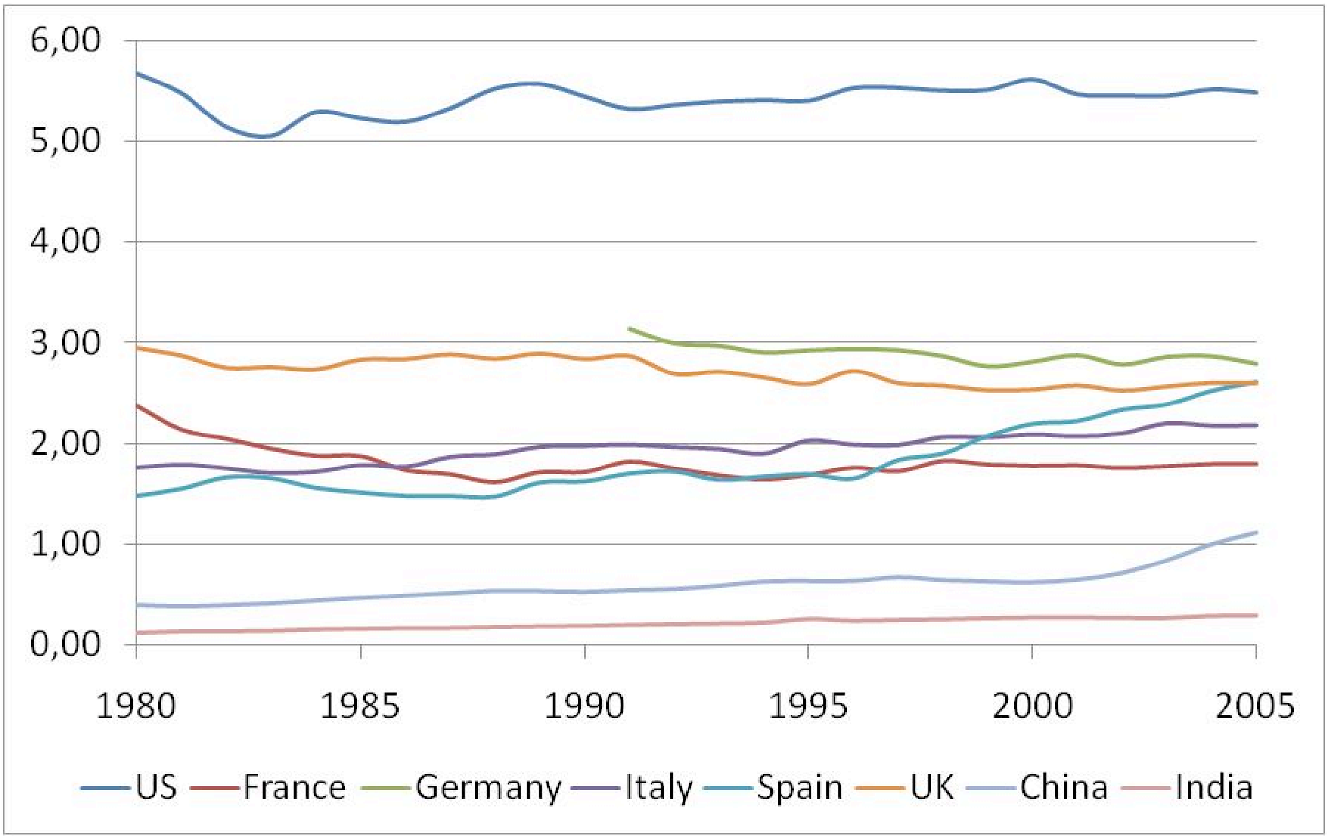

Figure 1. Per capita emissions in some countries (1980 – 2005). Note: for Germany, 1991 – 2005. Source: own elaboration on EIA (2008).

Table 1 shows the variation in per capita emissions between 1980 and 2005, and between 1997 (the year when the Kyoto Protocol was agreed upon) and 2005. In other words, it shows both the variation during the period under consideration, and the breakdown of that variation. Four countries out of the nine considered have reduced their per capita emissions during the last quarter century: the US, France, Germany and the United Kingdom. Emissions fell in France by 25%, and in Germany and the UK by more than 11%. The countries that increased their emissions in the period considered are China (+175%), India (+153%), and Spain (+75%). Italy too had a sharp growth trend, increasing its emissions by over 20%.

	1980-2005	1997-2005
US	-3,38	-0,85
France	-24,63	4,33
Germany*	-11,31	-4,67
Italy	23,64	9,85
Spain	75,76	41,94
UK	-11,60	-0,03
China	175,83	64,56
India	152,89	17,68

Table 1. Percentile variations of per capita emissions in some countries (1980-2005 and 1990-2005). Note: For Germany, the first interval refers to the 1991-2005 period. Source: own elaboration on EIA (2008).

If we compare these data with those concerning the 1997-2005 period (Figure 2), other very interesting elements emerge. Firstly, only Germany was able to maintain a consistent quota of per capita emissions reduction (-5%), followed by the USA (-1%), while the United Kingdom stayed basically at the same level. All other countries increased their emissions, with Italy and China by 10% and 65% respectively, thus confirming the preceding trend. India slowed the growth of per capita emissions, Spain accelerated it, and France reversed the trend.

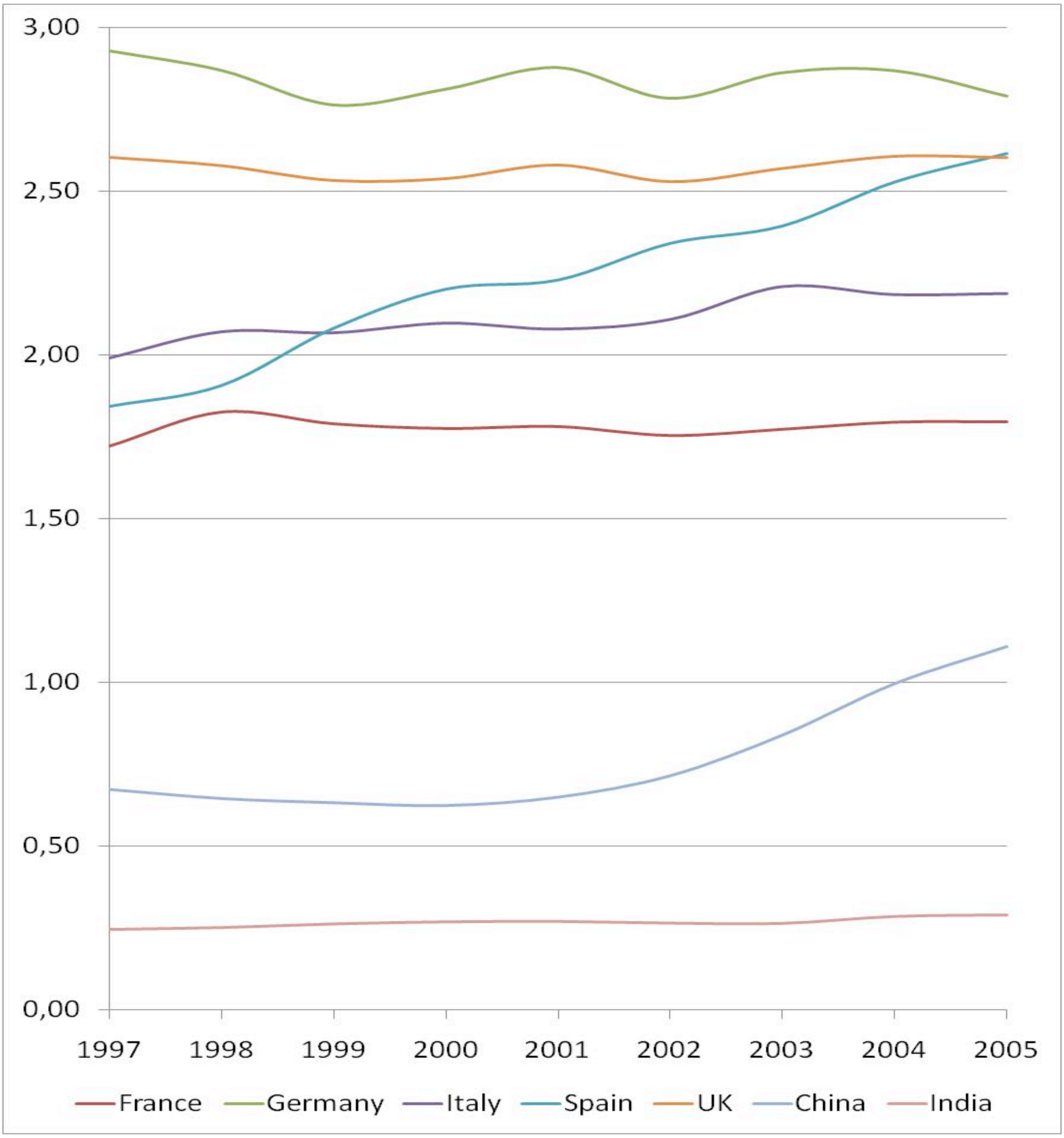

Figure 2. Per capita emissions in some countries (1997-2005). Note: in contrast with the preceding figure, the US curve has been omitted to facilitate reading. Source: own elaboration on EIA (2008).

The difference between the two graphs is explained by the fact that in countries such as the United Kingdom, France and Germany (which are the leaders of the per capita emission reductions in the 25-year period), the phenomenon of emissions reduction is mainly the product of policies adopted before 1997 and generally not associated with environmental goals: the introduction of nuclear energy in France for the sake of energy independence, the switch to natural gas and the relative increase of the financial and service sector as opposed to the industrial sector in Great Britain, and the industrial restructuring of East Germany after the unification. In Italy, most of the efficiency gains were achieved even earlier. That is mainly thanks to the traditionally high price of energy (due to both monopolistic inefficiencies and heavy taxation) and to what might be described as an over-reaction to the oil shocks in the 70s (Bernardini and Foti 1982). Again in the case of Italy, it must be emphasized that the increases in emissions have been relatively contained because increasing demand for electric energy has been satisfied by turning mainly to natural gas instead of relying on fuels such as coal and oil which are characterized by greater quantities of emissions per kWh. For Spain, China and India, the main cause of increasing emissions has been economic growth.

2.4. Does Kuznets apply to carbon?

For several traditional pollutants, economists have developed a wide literature on "Environmental Kuznets Curves" (EKCs), named after the Nobel-laureate Simon Kuznet's seminal work on average income and income inequality (Kuznets 1955). Kuznets found that, as average income grows, social inequalities grow up to a point, after which they start to decline. A similar bell-shaped curve (Figure 3) has been found for a number of pollutants.

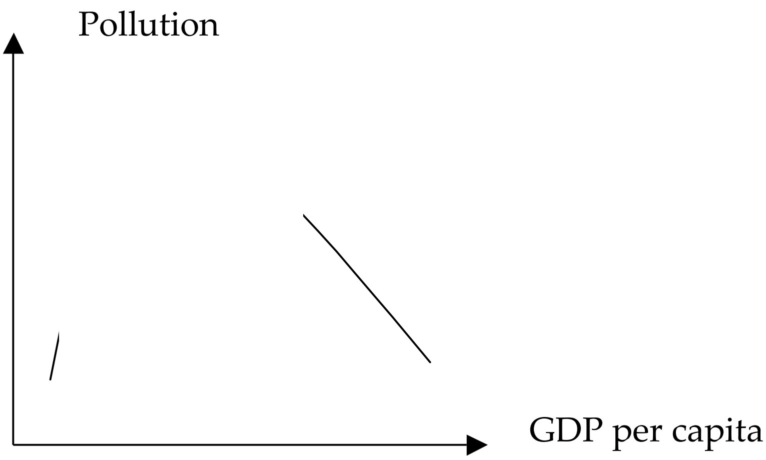

Figure 5. Environmental Kuzne

The EKC basically shows tha ment produces an increase in pollution (in our case, greenh s) during an initial phase that coincides with the left part of th e, society is extremely poor and, simply, does not consider the problem of pollution, as it first must solve more urgent questions such as hunger, mortality, unemployment and so on. As time passes, two things happen: society gets richer and pollution increases. This has two simultaneous consequences: one is a growth in the income that economic actors and society as a whole can dispose of in the improvement of their standard of living (since the most urgent problems have been solved); the second is that pollution becomes more intolerable. Eventually, the combination of these factors will induce the adoption of production technologies that are characterized by a smaller environmental impact. This explanation is also favored by the evidence that, in general, cleaner technologies are also more efficient, and therefore it is logical that they are obtained as soon as they are affordable. It is a consequence of the fact that a richer society has more available resources to either spend or invest in the environment. In conclusion, an increase in wealth may cause an environmental problem, but under the EKC hypothesis it may also solve it.

Shafik and Bandyopadhyay (1992) looked at eight different environmental indicators, and found that "many indicators tend to improve as countries approach middle-income levels". Selden and Song (1994) found an inverted-U curve for suspended particulate matter, sulfur dioxide, oxides of nitrogen, and carbon monoxide, although they concluded that the trend-inversion would show up in the very long run. Grossman and Krueger (1995) examined four types of environmental indicator – concentrations of urban air pollution; measures of the state of the oxygen regime in river basins; concentrations of fecal contaminants in river basins; and concentrations of heavy metals in river basins – finding that "economic growth brings an initial phase of deterioration followed by a subsequent phase of improvement". Carson et al. (1997) focused on the 50 US States and found evidence of the EKC for seven different types of pollutants.

Table 2 shows the results of some studies regarding the existence of EKCs and the per capita GDP level corresponding to the turning point, according to the studies reviewed by Cole et al. (1997).

Pollutant	Turning point (US$ 1985)	Turning point (US$ 2007)
CO_2	22500-34700	43000-66000
CO	9900-10100	19000-19500
NO_x	15600-25000	30000-48000
N_2O (industrial)	14700-15100	28000-29000
N_2O (transport)	15100-17600	29000-34000
SO_2	5700-6900	11000-13000
SO_2 (transport)	9400-9800	18000-19000
Particulates (non transport)	7300-8100	14000-15500
Particulates (transport)	15000-18000	29000-34500

Table 2. Average value of the per capita GDP corresponding to the peak of Environmental Kuznets Curves for some pollutants. Source: elaboration on Cole et al. (1997).

The evidence for a carbon EKC is mixed. Shmalensee et al. (1998, p.19) argue, "The developing countries, with lower values of GDP per capita, experience continued rapid carbon emissions growth, even through the period of oil shocks of the 1970s. The more highly developed countries showed a clear change in carbon emissions in the 1970s from growth to either stability or decline". Aldy (2005) finds no evidence for EKC in the 50 US States. Galeotti and Lanza (1999) found some evidence for EKC, but just for very high income levels, that will occur only in the long run for most developing countries. Aslanidis and Iranzo (2009) found no evidence for a carbon EKC, but highlighted that "we found two regimes, namely a low-income regime where emissions accelerate with economic growth and a middle to high-income regime associated with a deceleration in environmental degradation", which may not be inconsistent with EKCs.

A major criticism to the EKC hypothesis came from Arrow et al. (1995), who argued that the EKC assumes GDP and GDP growth as fully exogenous variables, with no feedbacks from the state of environment. On the contrary, they claim that environmental deterioration may have a negative impact on economic growth as well. Stern et al. (1996) also suggested that the EKC may just be capturing an effect of international trade, that induces developed countries to specialize in goods and services that are less intensive in factors that can damage the environment.

While the evidence for EKC in most cases – other than carbon – appears compelling, this paper will not take side in the EKC debate. One reason is that evidence for carbon dioxide is mixed, in part because the turning point may have been reached in a very limited number of countries, or no country at all, which makes it difficult to foresee the future trends with an acceptable degree of uncertainty. Moreover, most wealthier countries have also adopted carbon-specific policies, that may have hidden the EKC effects; or they may still be subsidizing carbon-based energy sources, which would offset the EKC.

2.5. From EKC to institutional factors

To the extent that EKC has been observed for carbon emissions, it would be too simplistic to think that just GDP drives emissions. Panayotou (2003) suggests three main reasons why this may happen: (a) a wealthier community place more value on environmental quality; (b) a wealthier economy becomes also more diversified, so that less carbon-intensive industries gain momentum; (c) a wealthier society is also more able and willing to invest in innovation. Beyond that, one may add that (d) a wealthier community can afford cleaner, more costly technologies and (e) as the turning point approaches, pollution becomes more and more intolerable, that is, it becomes more of a problem than it was originally perceived.

More deeply, Yandle et al. (2004, p.86) argue, "institutional change lies behind the observed correlation. Humankind is an institution builder. If new institutions are to emerge, older ones must be displaced. A process of creative destruction takes place when resources are conserved". (The reference is obviously to Schumpeter 1975). Along the same lines, Goklany (2007) developed a theory of "ecological transition" which, although it is formally similar to that of the Kuznets' Environmental Curve, differs from it because of a fundamental factor. On the abscissa axis, time is reported rather than per capita GDP. Time is utilized as a proxy for both per capita GDP *and* technological development.

Goklany's hypothesis is that, although there are cases in which the average income is reduced *on average* with the passage of time, societies follow their natural inclination to improve their standards of living and thus to increase per capita GDP and the level of technology utilized. The transition from a phase where environmental impact grows to one in which it is reduced – a reality captured by Environmental Kuznets Curves as well – coincides with the ecological transition. Goklany (2007, pp.106-7) writes: "An explanation offered for an environmental transition is that society is on a continual quest to improve its quality of life, which is determined by numerous social, economic, and environmental factors. The weight given to each determinant is constantly changing with society's precise circumstances and perceptions. In the early stages of economic and technological development, which go hand-in-hand, society places a higher priority on increasing affluence than on other determinants, even if that means tolerating some environmental deterioration, because increasing wealth provides the means for obtaining basic needs and amenities (e.g. food, shelter, water, and electricity) and reducing the most significant risks to public health and safety (e.g. malnutrition, infectious and parasitic diseases, and child mortality). Also, in those early stages, society may, in fact, be unaware of the risk posed by a deterioration in the specific environmental impact, measured by the particular indicator in question. However, as society becomes wealthier; tackles these problems; and, possibly, gains more knowledge about the social, health, and economic consequences of the environmental impact in question, reducing the environmental impact due to the specific indicator automatically rises higher on its priority list".

The focus on institutional factors (broadly defined following Sala-i-Martin 2002),[4] rather than on the mere levels of GDP, led other economists to try and link carbon intensity, or carbon emissions, with economic freedom, as measured by such institutions as the Fraser Institute in Canada and the Heritage Foundation in the US. Broadly defined, economic freedom means the freedom of market actors to make use of the various production factors they deem most efficient, based on a reliable and stable legal framework, without being subjected to state interference. Various attempts have been made to measure economic freedom (see the next paragraph for a discussion on the concept of economic freedom hereby employed) and to correlate it with carbon emissions.

Montgomery and Bate (2005) found a significant negative correlation between economic freedom, as measured by the Fraser Institute, and carbon intensity, indicating that economically freer countries tend to be less carbon intensive, all else being equal. "There are several causal routes – they argue – through which greater economic freedom could lead to lower energy use and emission per dollar of output" (p.143). Among the others, they suggest that economic freedom is positively correlated with GDP growth, and through GDP growth it affects emissions, as well (a re-interpretation of EKC). Moreover, they suggest that freer countries tend to better and sooner benefit from technological innovation and the deployment of cleaner technologies. Economic freedom is also associated with lower barriers to investments, and hence higher investments in innovation and more competitive pressures to adopt more efficient technologies in the energy-intensive industries.

Montgomery and Tuladhar (2006) also found a negative correlation between the subcomponents of economic freedom and energy (they didn't test carbon) intensity. The provided explanation is that "the lack of a market-oriented investment climate hinders technology transfer, by discouraging foreign direct investments and use of

[4] "[V]arious aspects of law enforcement… the functioning of markets… inequality and social conflicts… political institutions… the health system… financial institutions… as well as government institutions".

most advanced technology adopted elsewhere" (p.41). In other words, according to these authors the main effect of economic freedom on carbon intensity is through technology transfer, that mostly applies to developing countries, and the ability to adopt cleaner technologies.

Carlsson and Lundström (2003) found that an increase in economic freedom, and more precisely an increase in specific subcomponents of economic freedom, may be negatively correlated with carbon emissions. That particularly applies to price stability and legal stability. The result appears to be more robust for countries with a relatively lower industrial sector as a share of GDP. Other subcomponents of economic freedom, such as freedom to trade, or measures of other freedoms, such as political freedom, are little or no significant at all. Three main reasons are provided for this: (a) an efficiency effect, i.e. competitive pressures create an incentive for businesses to invest in more efficient, less energy-intensive technologies; (b) a trade regulation effect, under which a more efficient resource allocation is expected to take place; (c) a stability effect, concerning of the higher level of investments that can result from a greater price stability.

On a different level, Cornillie and Fankhauser (2002) showed that a market-oriented regulation has contributed to the reduction of energy intensity in the Eastern European transition countries. He and Wang (2007) found a similar result for China, where economic liberalizations are negatively correlated with energy intensity. Montgomery and Tuladhar (2005) showed that economic reforms improved the carbon-efficiency in India, while Karakaya and Ozcag (2005) found similar evidence for Central Asia.

2.6. What is economic freedom and how it can affect carbon emissions?

This paper will investigate the correlation between economic freedom and carbon emissions.

Economic freedom means the freedom of market actors to make use of the various production factors they deem most efficient, based on a reliable and stable legal framework, without being subjected to state interference. Various attempts have been made to measure economic freedom. This paper refers to the index drawn up by the Heritage Foundation and the *Wall Street Journal* (Miller 2009). According to the authors: "The highest form of economic freedom provides an absolute right of property ownership, fully realized freedoms of movement for labor, capital, and goods, and an absolute absence of coercion or constraint of economic liberty beyond the extent necessary for citizens to protect and maintain liberty itself. In other words, individuals are free to work, produce, consume, and invest in any way they please, and that freedom is both protected by the state and unconstrained by the state".[5]

The Index of Economic Freedom, as defined by Heritage Foundation, is defined as the average of ten components, each of whom is also the result of the weighted average of other subcomponents. A more detailed description of the methodology employed by the Heritage Foundaion is available online at www.heritage.org/index. Below, some qualitative details are provided for the ten components of economic freedom, with some hints about how they could be expected to affect carbon intensity.

The values of the Index of Economic Freedom for 2009 are reported in Appendix A.

Business freedom

Business freedom is defined as "a quantitative measure of the ability to start, operate, and close a business that represents the overall burden of regulation, as well as the efficiency of government in regulatory process". Because of the way it is defined, business freedom is unlikely to have a powerful effect on carbon intensity. While it may be crucial to ensure a fair competition is taking place, especially between small businesses, business freedom doesn't seem to reflect any significant determinant of energy intensity, such as the incentive to invest in cleaner technologies, the competition level between energy-intensive companies and utilities, etc.

Trade freedom

Trade freedom is "a composite measure of the absence of tariff and non-tariff barriers that affects imports and exports of good and services". Being a proxy for protectionism, trade freedom might have an impact on carbon intensity, by either protecting energy-intensive companies (hence creating a lower incentive for technological improvement) or by protecting national champions in non-energy intensive sectors (which would, all else being equal, determine a lower carbon intensity). Therefore, while trade freedom may have an impact on carbon intensity, but the sign of the effect is likely to depend on exogenous variables, such as the composition of the economy, rather than the score of trade freedom itself. Moreover, some economists have argued that the increase in international trade, that would result from more trade freedom, may reduce carbon emissions in the developed

---

[5] http://www.heritage.org/research/features/index/faq.cfm

world, while increasing emissions in the developing countries, with a net effect of nearly zero (Heil and Selden 2001).

Fiscal freedom

Fiscal freedom is "a measure of the burden of government from the revenue side. It includes both the tax burden in terms of the top tax rate on incomes (individual and corporate separately) and the overall amount of tax revenue as a percentage of GDP". Likewise trade freedom, fiscal freedom is likely to have an impact on carbon intensity, but the sign of the impact may be ambiguous: all else being equal, one might expect that higher taxes result in lower investments. However, the actual size of investments in carbon efficiency may depend on factors which are part of – but are not fully captured by – the notion of fiscal freedom, such as the use of tax revenues to finance such investments. So, carbon intensity may depend on "what's inside" fiscal freedom, rather than on fiscal freedom per se.

Government size

Government size "considers the level of government expenditure as a percentage of GDP. Government expenditures – including consumption and transfer – account for the entire score". Even government consumption may have an ambiguous effect on carbon intensity: in fact, the level of carbon intensity may depend on what's the government spends upon. However, it may be argued that government size is a proxy for the broader degree of government interventionism within the society, including the fact that government runs businesses by itself rather than leaving it up to the market, and intervene through the regulatory process (Nakada 2005). Since one may expect that, where government runs businesses, competition is less effective, one may also expect a positive correlation between government size and carbon intensity, i.e., when the government size grows, carbon intensity grows as well. However, government size is defined in a way that 100% equals to the smallest government size, while 0% equals to the biggest government, so the expected correlation is negative.

Monetary freedom

Monetary freedom "combines a measure of price stability with an assessment of price controls. Both inflation and price controls distort market activity. Price stability without microeconomic intervention is ideal state for free market”. Price stability and absence of price controls are also two key variables for the willingness to invest, especially in capital-intensive businesses (Kim and Wu 1993) such as the power sector and most energy-intensive sectors. It is likely that monetary freedom is negatively correlated with carbon intensity.

Investment freedom

Investment freedom “scrutinizes each country’s policies towards the free flow of investment capital (foreign investment as well as internal capital flows) in order to determine its overall investment climate”. Investments are a key feature for technological innovation, that, in the long run, is a major driver for carbon intensity reductions (Bernstein et al. 2006). It is likely that a negative correlation exists, between investment freedom and carbon intensity.

Financial freedom

Financial freedom is “a measure of banking security as well as measure of independence from government controls. State ownership of banks and other financial institutions such as insurers and capital markets is an inefficient burden that reduces competition and generally lowers the level of available reserves”. Financial freedom can be expected to be negatively correlated with carbon intensity, because the efficiency of capital markets is quite important for the investment process in capital-intensive sectors.

Property rights

Property rights provide “an assessment of the ability of the individuals to accumulate private property, secured by clear laws that are fully enforced by the state”. Property rights is likely to be an important driver for carbon intensity: absent a clear definition and a reliable enforcement of property rights, a company is less likely to invest in capital-intensive activities that could be seized or taken by government at any time (Anderson and Leal 2001).

Freedom from corruption

Freedom from corruption is based upon Transparency International's Corruption Perception Index, and is based upon the assumption that "corruption erodes economic freedom by introducing insecurity and uncertainty into economic relationship". However important in general, freedom from corruption is unlikely to be, per se, a driver for carbon intensity and the subsequent investments.

Labor freedom

Labor freedom is "a quantitative measure that looks into various aspects of the legal and regulatory framework of a country's labor market. It provides cross-country data on regulations concerning minimum wages; laws inhibiting layoffs; severance requirements; and measurable burdens on hiring, hours, and so on". Neither of these is likely to affect carbon intensity, either in the short- or in the long-run.

2.7. Model specification

The goal of this paper is to check whether a correlation exists, between economic freedom and carbon intensity. While a correlation doesn't necessarily mean that a causality exists, nor does it tell what is the direction of the causality, the theoretical framework provided above – as well as the results from other studies and insights – seem to suggest that, all else being equal, the difference in economic freedom may explain part of the difference in carbon intensity. The focus on carbon intensity, rather than on other measures, is justified both because carbon intensity is the only term in the Kaya Identity that can be changed in the desired direction in a win-win perspective (the other terms being population and economic growth), and because it allows to overcome a number of difficulties that have so far prevented a positive outcome from international negotiations (Pizer 2005).

A number of control variables have been inserted, in order to capture factors that may affect carbon intensity.

The proposed model is the following:

$$CI = \beta_0 + \beta_1\, EF + \beta_2\, GDP + \beta_3\, Pop + \beta_4\, En + \beta_5\, Ind + \beta_6\, Veh + \beta_7\, EnImp + \beta_8\, Urb + \beta_9\, Nuke + u$$

Where CI = carbon intensity, i.e. the ratio between carbon equivalent emissions and GDP (tonCO_2 / US$2000); EF = economic freedom (the model has been tested with the Index of Economic Freedom, each of its components, and a sub-index which will be defined); GDP = Gross Domestic Product (US$2000); Pop = Population; En = total primary energy use (tons of oil equivalent); Ind = industry sector as a share of GDP; Veh = number of private vehicles; EnImp = energy imports as a share of primary energy use; Urb = urban areas as a share of the total surface of a country; Nuke = nuclear energy as a share of total primary energy consumption; u represents statistical error.

The goal of the model is to test whether (a) economic freedom is significantly correlated with carbon intensity and (b) whether the correlation is negative, as the theoretical framework provided above would suggest.

The correlation between GDP and CI is expected to be negative but loose. While there is a strong correlation between improvements in carbon intensity and GDP growth (Hanaoka et al. 2006), the absolute levels of GDP and carbon intensity may not be that much interdependent. In fact, both GDP and carbon intensity may depend on a number of variables such as institutional factors, population, the composition of the economy, etc., that may be individually significant to both, but in aggregate may have a moderate effect. However, if the Environmental Kuznets Curve hypothesis applies to carbon emissions, one should expect a negative correlation.

As to population, there is no reason to believe that it affects carbon intensity. In fact, the ratio between carbon emissions and GDP appears to have little to do with the number of people living in a country, while it might have some relationship with GDP per capita.

All else being equal, one would expect a positive correlation between energy use and carbon intensity: since almost everywhere in the world fossil fuels cover a large share of energy needs, an increase in energy demand would result in higher carbon emissions. Intuitively, the correlation might be negative between energy imports and carbon intensity, because a government has no reason to subsidize the use of foreign energy sources and therefore one would expect it to be used efficiently.

The size of industry sector as a share of the whole economy is probably positively correlated with carbon intensity, because industry is the most energy- (and hence, in most countries, carbon-) intensive economic sector.

The number of circulating vehicles, as a proxy for the people’s mobility, can be expected to be positively correlated with carbon intensity.

Nuclear power has been considered separately from other sources of energy because (a) nuclear is widely regarded as the most economically competitive, carbon-free source of energy and (b) the share of nuclear power is almost everywhere the result of specific policies adopted decades ago, and so it reflects a set of indicators which may not be fully captured by the other control variables hereby considered.

Finally, the size of urban areas as a share of a country's total surface may affect carbon intensity both positively and negatively.

Along the lines of the above-presented model, a number of other models have been developed, for example including the single components of economic freedom, a sub-index which has been built by averaging the components which might appear to be most significant (investment freedom, monetary freedom, government size and property rights) according to the above discussion. Also quadratic and cubic terms have been inserted for economic freedom and GDP, in order to consider the obvious non-linearities of the relationship that may hold between each of them and carbon intensity. Finally, the model has been explored both in its absolute form, and re-framing it in fully-log and semi-log way.

2.8. The data

A panel dataset has been built for 162 countries in the world, covering a time-period of 13 years (1995 through 2008).

The Index of Economic Freedom, as well as its components, have been derived from the Heritage Foundation's website (http://www.heritage.org/index). All the other variables have been downloaded from the World Bank's World Development Indicators website (http://publications.worldbank.org/WDI/). Not all countries are covered for all the time period, particularly for such indicators as carbon emissions and carbon intensity. Fortunately, both the extent of the dataset and the consequent solidity of the estimators enables us to level out these measurement errors, thereby eliminating them and obtaining very reliable results.

Figure 6 plots economic freedom versus carbon intensity.

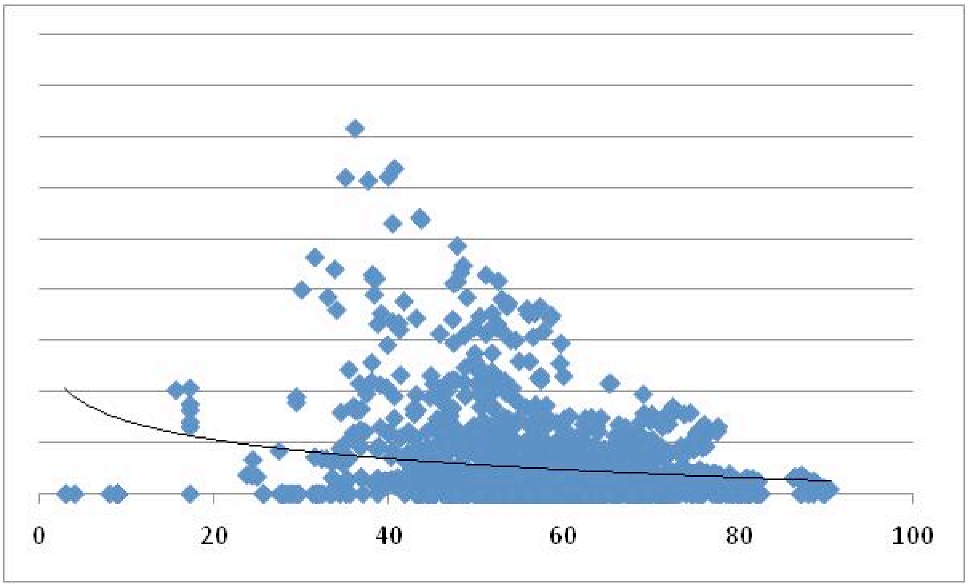

Figure 6. Economic freedom vs. Carbon intensity. Source: own elaboration on Miller (2009), WDI 2008.

Figure 6 provides an insight of what has been investigated. On the left side (economically unfree countries) both countries with very high and very low carbon intensities can be found. The latter are very poor countries, whose low energy intensity is quite a proxy for energy poverty (under the Environmental Kuznets Curve hypothesis, these countries would be on the extreme left as well). Then, as economic freedom grows, carbon intensity covers a wide range of values, but the spread tends to be reduced towards the highest scores of economic freedom. Interestingly enough, no economically free country shows a high degree of carbon intensity.

2.9. The results

A first regression has been run with a pooled OLS, in order to check whether the correlation may exist. A quadratic term for economic freedom and GDP has been included in order to consider the non-linearities of the supposed relationship. The following table summarizes the results.

(R.1)

```
. regress intensity freedom sqfreed gdp_2 sqgdp_2 urban vehicles nuclear_energy import
> s population industry energy_use

      Source |       SS       df       MS              Number of obs =     735
-------------+------------------------------           F( 11,   723) =   39.04
       Model |  9.2774e-10    11  8.4340e-11           Prob > F      =  0.0000
    Residual |  1.5618e-09   723  2.1601e-12           R-squared     =  0.3727
-------------+------------------------------           Adj R-squared =  0.3631
       Total |  2.4895e-09   734  3.3917e-12           Root MSE      =  1.5e-06

------------------------------------------------------------------------------
   intensity |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     freedom |  -2.02e-07   4.27e-08    -4.74   0.000    -2.86e-07   -1.18e-07
   sqfreedom |   8.37e-10   3.50e-10     2.39   0.017     1.50e-10    1.52e-09
    gdp_2000 |  -3.48e-19   1.62e-19    -2.15   0.032    -6.67e-19   -2.98e-20
     sqgdp_2 |   4.16e-32   1.70e-32     2.44   0.015     8.19e-33    7.51e-32
       urban |   1.79e-08   4.31e-09     4.16   0.000     9.45e-09    2.64e-08
    vehicles |  -2.98e-09   5.23e-10    -5.69   0.000    -4.00e-09   -1.95e-09
nuclear_en~y |   3.75e-09   3.37e-09     1.11   0.267    -2.88e-09    1.04e-08
     imports |   2.14e-09   4.14e-10     5.16   0.000     1.32e-09    2.95e-09
  population |   5.53e-16   3.61e-16     1.53   0.127    -1.57e-16    1.26e-15
    industry |   3.48e-08   7.27e-09     4.79   0.000     2.05e-08    4.91e-08
  energy_use |   2.50e-10   4.55e-11     5.51   0.000     1.61e-10    3.40e-10
       _cons |   8.55e-06   1.35e-06     6.35   0.000     5.91e-06    .0000112
------------------------------------------------------------------------------
```

As expected, both economic freedom and square economic freedom appear significant at a 5% level. The sign of economic freedom is negative, indicating that the correlation is negative. Interestingly enough, the sign is negative for GDP as well. All other control variables, except for the share of nuclear power and population, are significant, and the signs are as expected.

The same regression has been run under a fixed effect scheme, in order to take into account some drivers of carbon intensity that may be country-specific, and therefore may not be captured by the considered control variables. The following table summarizes the results.

(R.2)

```
. xtreg intensity freedom sqfreed gdp_2 sqgdp_2 urban vehicles nuclear_energy imports
> population industry energy_use, fe

Fixed-effects (within) regression               Number of obs      =       735
Group variable: id_country                      Number of groups   =       114

R-sq:  within  = 0.3951                         Obs per group: min =         1
       between = 0.0883                                        avg =       6.4
       overall = 0.0955                                        max =        11

                                                F(11,610)          =     36.23
corr(u_i, Xb)  = -0.4443                        Prob > F           =    0.0000

------------------------------------------------------------------------------
   intensity |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     freedom |  -2.48e-07   2.25e-08   -11.06   0.000    -2.92e-07   -2.04e-07
   sqfreedom |   1.74e-09   1.96e-10     8.86   0.000     1.35e-09    2.12e-09
    gdp_2000 |  -9.67e-19   3.69e-19    -2.62   0.009    -1.69e-18   -2.43e-19
     sqgdp_2 |   4.55e-32   1.97e-32     2.30   0.022     6.68e-33    8.42e-32
       urban |   1.69e-08   1.25e-08     1.35   0.177    -7.63e-09    4.13e-08
    vehicles |  -2.29e-09   5.13e-10    -4.45   0.000    -3.29e-09   -1.28e-09
nuclear_en~y |  -3.98e-08   8.69e-09    -4.58   0.000    -5.69e-08   -2.27e-08
     imports |   2.75e-09   1.02e-09     2.70   0.007     7.50e-10    4.75e-09
  population |   1.45e-15   2.52e-15     0.58   0.565    -3.49e-15    6.39e-15
    industry |   1.24e-08   6.16e-09     2.02   0.044     3.43e-10    2.45e-08
  energy_use |   1.35e-10   6.57e-11     2.05   0.040     5.90e-12    2.64e-10
       _cons |   9.37e-06   9.57e-07     9.79   0.000     7.49e-06    .0000112
-------------+----------------------------------------------------------------
     sigma_u |  1.748e-06
     sigma_e |  3.208e-07
         rho |  .96741251   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(113, 610) =   128.91            Prob > F = 0.0000
```

The results is fully consistent with the former regression.

In order to test the robustness of the model, a cubic term for economic freedom has been considered. As the following table, the result – economic freedom being significantly and negatively correlated with carbon intensity – still holds.

(R.3)

```
. xtreg intensity freedom sqfreed cubfreed  gdp_2 sqgdp_2 urban vehicles nuclear_energ
> y imports population industry energy_use, fe

Fixed-effects (within) regression               Number of obs      =       735
Group variable: id_country                      Number of groups   =       114

R-sq:  within  = 0.4004                         Obs per group: min =         1
       between = 0.0899                                        avg =       6.4
       overall = 0.0983                                        max =        11

                                                F(12,609)          =     33.89
corr(u_i, Xb)  = -0.4179                        Prob > F           =    0.0000

------------------------------------------------------------------------------
   intensity |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     freedom |  -4.92e-07   1.08e-07    -4.56   0.000    -7.03e-07   -2.80e-07
   sqfreedom |   6.16e-09   1.93e-09     3.20   0.001     2.37e-09    9.94e-09
    cubfreed |  -2.59e-11   1.12e-11    -2.31   0.021    -4.79e-11   -3.84e-12
    gdp_2000 |  -9.53e-19   3.67e-19    -2.60   0.010    -1.67e-18   -2.32e-19
     sqgdp_2 |   4.65e-32   1.97e-32     2.36   0.018     7.86e-33    8.51e-32
       urban |   1.54e-08   1.24e-08     1.24   0.215    -8.98e-09    3.99e-08
    vehicles |  -2.28e-09   5.12e-10    -4.46   0.000    -3.28e-09   -1.27e-09
nuclear_en~y |  -3.96e-08   8.66e-09    -4.57   0.000    -5.66e-08   -2.26e-08
     imports |   2.55e-09   1.02e-09     2.50   0.013     5.50e-10    4.55e-09
  population |   1.35e-15   2.51e-15     0.54   0.590    -3.57e-15    6.27e-15
    industry |   1.26e-08   6.14e-09     2.05   0.041     5.26e-10    2.46e-08
  energy_use |   1.58e-10   6.63e-11     2.39   0.017     2.82e-11    2.88e-10
       _cons |   .0000137   2.10e-06     6.51   0.000     9.56e-06    .0000178
-------------+----------------------------------------------------------------
     sigma_u |  1.729e-06
     sigma_e |  3.197e-07
         rho |  .96695281   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(113, 609) =   128.57           Prob > F = 0.0000
```

Still to test the robustness of the model, the same regression as above has been run with two different sets of controls. The results still hold, as the following tables show.

(R.4)

```
. xtreg intensity freedom sqfreed gdp_2 sqgdp_2 urban imports population industry, fe

Fixed-effects (within) regression               Number of obs      =      1227
Group variable: id_country                      Number of groups   =       123

R-sq:  within  = 0.1798                         Obs per group: min =         1
       between = 0.1264                                        avg =      10.0
       overall = 0.1235                                        max =        11

                                                F(8,1096)          =     30.03
corr(u_i, Xb)  = -0.1993                        Prob > F           =    0.0000

------------------------------------------------------------------------------
   intensity |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     freedom |  -1.51e-07   1.69e-08    -8.94   0.000    -1.85e-07   -1.18e-07
   sqfreedom |   1.02e-09   1.49e-10     6.83   0.000     7.26e-10    1.31e-09
    gdp_2000 |  -1.30e-18   3.34e-19    -3.88   0.000    -1.95e-18   -6.41e-19
     sqgdp_2 |   6.53e-32   1.83e-32     3.56   0.000     2.93e-32    1.01e-31
       urban |  -6.39e-10   8.04e-09    -0.08   0.937    -1.64e-08    1.51e-08
     imports |   7.52e-10   2.49e-10     3.02   0.003     2.64e-10    1.24e-09
  population |   2.92e-15   2.04e-15     1.43   0.153    -1.09e-15    6.93e-15
    industry |   5.14e-09   3.50e-09     1.47   0.142    -1.72e-09    1.20e-08
       _cons |   6.80e-06   6.33e-07    10.74   0.000     5.56e-06    8.04e-06
-------------+----------------------------------------------------------------
     sigma_u |  1.875e-06
     sigma_e |  3.437e-07
         rho |  .96747293   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(122, 1096) =   190.45          Prob > F = 0.0000
```

(R.5)

```
. xtreg intensity freedom sqfreed gdp_2 sqgdp_2 vehicles imports nuclear_energy employ
> ment_industry , fe

Fixed-effects (within) regression               Number of obs      =       622
Group variable: id_country                      Number of groups   =       100

R-sq:  within  = 0.4806                         Obs per group: min =         1
       between = 0.0573                                        avg =       6.2
       overall = 0.0705                                        max =        11

                                                F(8,514)           =     59.44
corr(u_i, Xb)  = -0.5290                        Prob > F           =    0.0000

------------------------------------------------------------------------------
   intensity |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     freedom |  -3.21e-07   2.26e-08   -14.22   0.000    -3.65e-07   -2.77e-07
   sqfreedom |   2.31e-09   1.90e-10    12.15   0.000     1.94e-09    2.69e-09
    gdp_2000 |  -1.05e-18   3.88e-19    -2.71   0.007    -1.81e-18   -2.90e-19
     sqgdp_2 |   5.05e-32   2.12e-32     2.38   0.018     8.80e-33    9.21e-32
    vehicles |  -1.49e-09   3.96e-10    -3.77   0.000    -2.27e-09   -7.15e-10
     imports |   2.75e-09   1.07e-09     2.58   0.010     6.54e-10    4.85e-09
nuclear_en~y |  -3.79e-08   7.63e-09    -4.97   0.000    -5.29e-08   -2.29e-08
employment~y |   6.86e-09   6.28e-09     1.09   0.275    -5.47e-09    1.92e-08
       _cons |   .0000132   7.14e-07    18.46   0.000     .0000118    .0000146
-------------+----------------------------------------------------------------
     sigma_u |  1.888e-06
     sigma_e |  2.775e-07
         rho |  .97885721   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(99, 514) =   160.08             Prob > F = 0.0000
```

After this first test was passed, a subindex has been defined as the average of four components of economic freedom: government size, property rights, investment freedom, and monetary freedom. As discussed above, such components of economic freedom are those most likely to affect investments – either domestic or foreign – in capital-intensive industries, such as the power sector and energy-intensive industries. The following tables summarize the results of the regressions on the subindex, with the same set of controls adopted above.

(R.6)

```
. xtreg intensity subind sqsub gdp_2 sqgdp_2 urban vehicles nuclear_energy imports pop
> ulation industry energy_use, fe

Fixed-effects (within) regression               Number of obs      =       735
Group variable: id_country                      Number of groups   =       114

R-sq:  within  = 0.4779                         Obs per group: min =         1
       between = 0.0485                                        avg =       6.4
       overall = 0.0547                                        max =        11

                                                F(11,610)          =     50.77
corr(u_i, Xb)  = -0.4362                        Prob > F           =    0.0000

------------------------------------------------------------------------------
   intensity |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    subindex |  -2.07e-07   1.38e-08   -15.06   0.000    -2.34e-07   -1.80e-07
       sqsub |   1.52e-09   1.24e-10    12.30   0.000     1.28e-09    1.77e-09
    gdp_2000 |  -6.63e-19   3.43e-19    -1.94   0.053    -1.34e-18    9.65e-21
     sqgdp_2 |   3.29e-32   1.83e-32     1.80   0.073    -3.07e-33    6.88e-32
       urban |   1.51e-08   1.17e-08     1.30   0.195    -7.79e-09    3.80e-08
    vehicles |  -1.93e-09   4.75e-10    -4.06   0.000    -2.86e-09   -9.97e-10
nuclear_en~y |  -3.21e-08   8.08e-09    -3.97   0.000    -4.80e-08   -1.62e-08
     imports |   2.17e-09   9.48e-10     2.29   0.022     3.09e-10    4.03e-09
  population |  -2.78e-15   2.34e-15    -1.19   0.235    -7.37e-15    1.81e-15
    industry |   1.48e-08   5.73e-09     2.59   0.010     3.59e-09    2.61e-08
  energy_use |   1.09e-10   6.08e-11     1.79   0.073    -1.03e-11    2.28e-10
       _cons |   7.74e-06   7.47e-07    10.37   0.000     6.28e-06    9.21e-06
-------------+----------------------------------------------------------------
     sigma_u |  1.804e-06
     sigma_e |  2.980e-07
         rho |  .97342921   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(113, 610) =   141.98            Prob > F = 0.0000
```

(R.7)

```
. xtreg intensity subinde sqsub cubsub  gdp_2 sqgdp_2 urban vehicles nuclear_energy im
> ports population industry energy_use, fe

Fixed-effects (within) regression               Number of obs      =       735
Group variable: id_country                      Number of groups   =       114

R-sq:  within  = 0.4936                         Obs per group: min =         1
       between = 0.0498                                        avg =       6.4
       overall = 0.0637                                        max =        11

                                                F(12,609)          =     49.46
corr(u_i, Xb)  = -0.3903                        Prob > F           =    0.0000

------------------------------------------------------------------------------
   intensity |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    subindex |  -4.51e-07   5.78e-08    -7.80   0.000    -5.64e-07   -3.37e-07
       sqsub |   6.13e-09   1.07e-09     5.73   0.000     4.03e-09    8.24e-09
      cubsub |  -2.79e-11   6.42e-12    -4.34   0.000    -4.05e-11   -1.52e-11
    gdp_2000 |  -6.15e-19   3.38e-19    -1.82   0.069    -1.28e-18    4.86e-20
     sqgdp_2 |   3.16e-32   1.80e-32     1.75   0.081    -3.85e-33    6.70e-32
       urban |   1.20e-08   1.15e-08     1.04   0.296    -1.06e-08    3.47e-08
    vehicles |  -1.88e-09   4.68e-10    -4.02   0.000    -2.80e-09   -9.62e-10
nuclear_en~y |  -3.01e-08   7.98e-09    -3.78   0.000    -4.58e-08   -1.45e-08
     imports |   1.85e-09   9.38e-10     1.98   0.049     1.05e-11    3.69e-09
  population |  -2.70e-15   2.30e-15    -1.17   0.243    -7.22e-15    1.83e-15
    industry |   1.74e-08   5.68e-09     3.06   0.002     6.24e-09    2.85e-08
  energy_use |   1.28e-10   6.01e-11     2.13   0.034     9.77e-12    2.46e-10
       _cons |   .0000118   1.19e-06     9.90   0.000     9.48e-06    .0000142
-------------+----------------------------------------------------------------
     sigma_u |  1.801e-06
     sigma_e |  2.938e-07
         rho |  .97409144   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(113, 609) =   144.12            Prob > F = 0.0000
```

The subindex of economic freedom – as well as its quadratic and cubic terms – hold significance and the sign of the first order term remains negative.

In order to better interpret the results, fully-log and semi-log models have been run.

(R.8)

```
. xtreg lnintens lnfreed lngdp urban vehicles nuclear_energy imports population indust
> ry energy_use, fe

Fixed-effects (within) regression               Number of obs      =       735
Group variable: id_country                      Number of groups   =       114

R-sq:  within  = 0.5492                         Obs per group: min =         1
       between = 0.0751                                        avg =       6.4
       overall = 0.1114                                        max =        11

                                                F(9,612)           =     82.85
corr(u_i, Xb)  = -0.7405                        Prob > F           =    0.0000

------------------------------------------------------------------------------
    lnintens |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     lnfreed |  -.1082467   .0658146    -1.64   0.101    -.2374966    .0210032
       lngdp |  -.7537776   .0471546   -15.99   0.000     -.846382   -.6611732
       urban |   .0261885   .0038096     6.87   0.000      .018707    .0336699
    vehicles |  -.0005374   .0001488    -3.61   0.000    -.0008296   -.0002452
nuclear_en~y |  -.0053931   .0023187    -2.33   0.020    -.0099466   -.0008396
     imports |    .001462   .0002775     5.27   0.000      .000917     .002007
  population |   1.29e-09   5.65e-10     2.29   0.023     1.83e-10    2.40e-09
    industry |   .0103763   .0016672     6.22   0.000     .0071022    .0136504
  energy_use |    .000158   .0000182     8.68   0.000     .0001223    .0001937
       _cons |   2.842775   .9349811     3.04   0.002     1.006615    4.678936
-------------+----------------------------------------------------------------
     sigma_u |  1.2990633
     sigma_e |   .0873018
         rho |  .99550397   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(113, 612) =   371.55            Prob > F = 0.0000
```

(R.9)

```
. xtreg lnintens freed sqfreed gdp_2  sqgdp urban vehicles nuclear_energy import
> s population industry energy_use, fe

Fixed-effects (within) regression               Number of obs      =       735
Group variable: id_country                      Number of groups   =       114

R-sq:  within  = 0.3806                         Obs per group: min =         1
       between = 0.1584                                        avg =       6.4
       overall = 0.2063                                        max =        11

                                                F(11,610)          =     34.07
corr(u_i, Xb)  = -0.1918                        Prob > F           =    0.0000

------------------------------------------------------------------------------
    lnintens |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     freedom |  -.0117048    .007175    -1.63   0.103    -.0257955    .0023858
   sqfreedom |   2.63e-06   .0000626     0.04   0.966    -.0001203    .0001256
    gdp_2000 |  -4.52e-13   1.18e-13    -3.84   0.000    -6.83e-13   -2.21e-13
     sqgdp_2 |   2.00e-26   6.31e-27     3.18   0.002     7.66e-27    3.24e-26
       urban |   -.000171   .0039843    -0.04   0.966    -.0079956    .0076536
    vehicles |  -.0014124   .0001641    -8.61   0.000    -.0017345   -.0010902
nuclear_en~y |  -.0075629   .0027759    -2.72   0.007    -.0130143   -.0021114
     imports |   .0015827   .0003258     4.86   0.000     .0009429    .0022224
  population |   8.98e-10   8.04e-10     1.12   0.264    -6.80e-10    2.48e-09
    industry |    .004978   .0019674     2.53   0.012     .0011144    .0088416
  energy_use |   .0001002    .000021     4.77   0.000     .0000589    .0001414
       _cons |  -13.13527   .3058581   -42.95   0.000    -13.73594   -12.53461
-------------+----------------------------------------------------------------
     sigma_u |  .83276377
     sigma_e |  .10250789
         rho |  .98507412   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(113, 610) =   268.84            Prob > F = 0.0000
```

The results are still valid, even if they appear to lose significance – in both cases, economic freedom isn't significant at 95%, but just at 90%.

Finally, a slightly different line of reasoning has been followed. It has been argued that today's carbon intensity is unlikely to depend upon today's economic freedom. In fact, today's carbon intensity is the result of past investments, that may have a relationship with past levels of economic freedom, rather than with the current levels. To test against this phenomenon, an attempt has been done to regress carbon intensity versus the subindex of economic freedom three periods ahead. The results – that include the quadratic and cubic terms – are summarized below.

(R.10)

```
. xtreg intensit L3.(subind due) gdp_2 sqgdp_2 urban vehicles nuclear_energy im
> ports population industry energy_use, fe

Fixed-effects (within) regression               Number of obs      =       460
Group variable: id_country                      Number of groups   =        87

R-sq:  within  = 0.4063                         Obs per group: min =         1
       between = 0.0548                                        avg =       5.3
       overall = 0.0507                                        max =         8

                                                F(11,362)          =     22.52
corr(u_i, Xb)  = -0.3014                        Prob > F           =    0.0000

------------------------------------------------------------------------------
   intensity |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    subindex |
         L3. |  -1.35e-07   1.27e-08   -10.65   0.000    -1.61e-07   -1.10e-07
      duesub |
         L3. |   1.02e-09   1.19e-10     8.58   0.000     7.86e-10    1.25e-09
    gdp_2000 |  -3.00e-19   4.00e-19    -0.75   0.454    -1.09e-18    4.86e-19
     sqgdp_2 |   9.73e-33   2.04e-32     0.48   0.634    -3.04e-32    4.99e-32
       urban |   2.22e-08   1.74e-08     1.27   0.204    -1.21e-08    5.65e-08
    vehicles |  -1.01e-09   5.97e-10    -1.69   0.092    -2.18e-09    1.65e-10
nuclear_en~y |  -2.51e-08   8.05e-09    -3.12   0.002    -4.09e-08   -9.27e-09
     imports |   2.15e-09   1.05e-09     2.04   0.042     7.85e-11    4.22e-09
  population |  -1.19e-15   3.26e-15    -0.36   0.716    -7.60e-15    5.23e-15
    industry |   2.14e-08   6.82e-09     3.13   0.002     7.95e-09    3.48e-08
  energy_use |  -7.45e-11   7.06e-11    -1.06   0.292    -2.13e-10    6.44e-11
       _cons |   4.60e-06   1.08e-06     4.27   0.000     2.48e-06    6.72e-06
-------------+----------------------------------------------------------------
     sigma_u |  1.668e-06
     sigma_e |  2.163e-07
         rho |  .98344658   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(86, 362) =   170.02            Prob > F = 0.0000
```

(R.11)

```
. xtreg intensit L3.(subind due tre) gdp_2 sqgdp_2 urban vehicles nuclear_energ
> y imports population industry energy_use, fe

Fixed-effects (within) regression               Number of obs      =       460
Group variable: id_country                      Number of groups   =        87

R-sq:  within  = 0.4434                         Obs per group: min =         1
       between = 0.0645                                        avg =       5.3
       overall = 0.0536                                        max =         8

                                                F(12,361)          =     23.96
corr(u_i, Xb)  = -0.2486                        Prob > F           =    0.0000

------------------------------------------------------------------------------
   intensity |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    subindex |
         L3. |  -3.72e-07   4.98e-08    -7.47   0.000    -4.70e-07   -2.74e-07
      duesub |
         L3. |   5.58e-09   9.38e-10     5.95   0.000     3.74e-09    7.43e-09
      tresub |
         L3. |  -2.81e-11   5.73e-12    -4.90   0.000    -3.93e-11   -1.68e-11
    gdp_2000 |  -2.41e-19   3.88e-19    -0.62   0.534    -1.00e-18    5.21e-19
     sqgdp_2 |   1.06e-32   1.98e-32     0.54   0.592    -2.83e-32    4.95e-32
       urban |   1.75e-08   1.69e-08     1.03   0.303    -1.58e-08    5.08e-08
    vehicles |  -8.64e-10   5.79e-10    -1.49   0.137    -2.00e-09    2.75e-10
nuclear_en~y |  -2.83e-08   7.83e-09    -3.62   0.000    -4.37e-08   -1.29e-08
     imports |   1.76e-09   1.02e-09     1.72   0.087    -2.56e-10    3.78e-09
  population |  -1.35e-15   3.16e-15    -0.43   0.671    -7.57e-15    4.87e-15
    industry |   2.50e-08   6.65e-09     3.76   0.000     1.19e-08    3.81e-08
  energy_use |  -2.19e-11   6.93e-11    -0.32   0.753    -1.58e-10    1.14e-10
       _cons |   8.53e-06   1.32e-06     6.47   0.000     5.94e-06    .0000111
-------------+----------------------------------------------------------------
     sigma_u |  1.632e-06
     sigma_e |  2.098e-07
         rho |  .98374296   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(86, 361) =   179.78             Prob > F = 0.0000
```

In both cases, the subindex of economic freedom is significant and its sign is negative.

In order to take into account climate-related policies that might have an impact over carbon intensity, a dummy variable has been inserted. The dummy has been defined based upon the year of ratification (not just signature) of the Kyoto Protocol for Annex-B countries (i.e., the countries that have formal obligations under the Protocol), assuming the Kyoto ratification provides a reliable proxy for the adoption of climate policies. Some countries may have ratified Kyoto while not having taken any step to meet its goals, and others may not have ratified Kyoto while having adopted emissions-reducing policies. On average, though, the ratification of Kyoto suggests a commitment reasonable enough towards the target of reducing emissions (which might arguably lead to a lower carbon intensity, all else being equal). The year of ratification of the Kyoto Protocol by Annex-B countries is reported in Appendix B. The regression results are pasted below.

(R.12)

```
. xtreg intensity subind sqsub gdp_2 sqgdp_2 policy urban vehicles nuclear_energy imports po
> pulation industry energy_use, fe

Fixed-effects (within) regression               Number of obs      =       735
Group variable: id_country                      Number of groups   =       114

R-sq:  within  = 0.4827                         Obs per group: min =         1
       between = 0.0405                                        avg =       6.4
       overall = 0.0446                                        max =        11

                                                F(12,609)          =     47.36
corr(u_i, Xb)  = -0.4228                        Prob > F           =    0.0000

------------------------------------------------------------------------------
   intensity |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    subindex |  -2.09e-07   1.37e-08   -15.20   0.000    -2.36e-07   -1.82e-07
       sqsub |   1.54e-09   1.23e-10    12.46   0.000     1.30e-09    1.78e-09
    gdp_2000 |  -6.05e-19   3.42e-19    -1.77   0.078    -1.28e-18    6.72e-20
     sqgdp_2 |   3.02e-32   1.83e-32     1.65   0.099    -5.69e-33    6.60e-32
      policy |  -1.13e-07   4.75e-08    -2.38   0.018    -2.06e-07   -1.97e-08
       urban |   1.29e-08   1.17e-08     1.11   0.268    -9.98e-09    3.58e-08
    vehicles |  -1.42e-09   5.20e-10    -2.72   0.007    -2.44e-09   -3.94e-10
nuclear_en~y |  -3.03e-08   8.09e-09    -3.75   0.000    -4.62e-08   -1.45e-08
     imports |   2.05e-09   9.46e-10     2.17   0.030     1.95e-10    3.91e-09
  population |  -3.04e-15   2.33e-15    -1.30   0.193    -7.62e-15    1.54e-15
    industry |   1.36e-08   5.73e-09     2.37   0.018     2.34e-09    2.48e-08
  energy_use |   1.24e-10   6.09e-11     2.03   0.043     4.15e-12    2.43e-10
       _cons |   7.77e-06   7.44e-07    10.45   0.000     6.31e-06    9.23e-06
-------------+----------------------------------------------------------------
     sigma_u |  1.798e-06
     sigma_e |  2.969e-07
         rho |  .97345905   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(113, 609) =   142.57           Prob > F = 0.0000
```

The dummy variable "Policy", as expected, is significant with a negative sign. Nevertheless, Economic Freedom (hereby measured through the subindex above-defined) remains significant and the sign remains negative.

More controls have been inserted, while controlling for the "Policy" variable. The new controls are: foreign direct investments (FDI), whose sign is expected to be negatively correlated with carbon intensity; the amount of energy generated from coal as a share of total energy consumption (expected to be positively correlated with carbon intensity, because coal is the most carbon intensive fossil fuel); the amount of coal-related CO_2 emissions; the length of roads; state revenues from energy taxation (expected to be negatively correlated with carbon intensity, because, all else being equal, higher taxation is expected to lead to lower consumption); power consumption as a share of energy consumption; and the total surface of a country.

(R.13)

```
. xtreg intensity subind sqsub gdp_2 sqgdp_2 policy  fdi population coal_energy nuclear_ener
> gy imports co2solidfuel roads vehicles urban industry state_revenue power_consumpt surface
> , fe

Fixed-effects (within) regression               Number of obs      =       403
Group variable: id_country                      Number of groups   =        81

R-sq:  within  = 0.4879                         Obs per group: min =         1
       between = 0.0011                                        avg =       5.0
       overall = 0.0132                                        max =        10

                                                F(18,304)          =     16.09
corr(u_i, Xb)  = -0.9996                        Prob > F           =    0.0000

------------------------------------------------------------------------------
   intensity |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    subindex |  -1.39e-07   1.83e-08    -7.58   0.000    -1.75e-07   -1.03e-07
       sqsub |   9.94e-10   1.62e-10     6.14   0.000     6.76e-10    1.31e-09
    gdp_2000 |  -4.99e-19   4.12e-19    -1.21   0.227    -1.31e-18    3.12e-19
     sqgdp_2 |   2.26e-32   2.56e-32     0.89   0.377    -2.77e-32    7.30e-32
      policy |  -2.36e-08   5.98e-08    -0.40   0.693    -1.41e-07    9.41e-08
         fdi |  -7.38e-10   1.15e-09    -0.64   0.521    -3.00e-09    1.52e-09
  population |  -6.05e-15   2.98e-15    -2.03   0.043    -1.19e-14   -1.82e-16
 coal_energy |   1.90e-08   7.82e-09     2.43   0.016     3.60e-09    3.44e-08
nuclear_en~y |  -2.28e-08   1.25e-08    -1.83   0.068    -4.74e-08    1.67e-09
     imports |   2.38e-09   1.11e-09     2.15   0.033     1.97e-10    4.56e-09
co2solidfuel |   1.24e-08   1.05e-08     1.19   0.236    -8.16e-09    3.30e-08
       roads |   2.14e-13   1.77e-13     1.21   0.225    -1.33e-13    5.62e-13
    vehicles |  -5.36e-10   7.12e-10    -0.75   0.452    -1.94e-09    8.65e-10
       urban |  -8.72e-09   1.82e-08    -0.48   0.632    -4.45e-08    2.70e-08
    industry |   4.78e-08   9.05e-09     5.29   0.000     3.00e-08    6.56e-08
state_reve~e |  -1.89e-08   7.88e-09    -2.39   0.017    -3.44e-08   -3.34e-09
power_cons~t |  -1.85e-12   3.55e-11    -0.05   0.959    -7.17e-11    6.80e-11
     surface |  -3.19e-11   2.68e-10    -0.12   0.905    -5.59e-10    4.95e-10
       _cons |    .000033   .0002272     0.15   0.885    -.0004141    .0004801
-------------+----------------------------------------------------------------
     sigma_u |  .00006504
     sigma_e |  2.642e-07
         rho |   .9999835   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(80, 304) =    92.18             Prob > F = 0.0000
```

The Subindex of Economic Freedom is significantly and negatively correlated with carbon intensity, but most of the other variables (including the dummy for climate policies) lose significance.

Then, a few regressions have been performed while not controlling, alternatively, for GDP of for Economic Freedom. The results are pasted below.

(R.14)

```
.  xtreg intensity freed gdp_2 population energ industry policy urban vehicles nuclear_energ
> y , fe

Fixed-effects (within) regression               Number of obs      =       735
Group variable: id_country                      Number of groups   =       114

R-sq:  within  = 0.3015                         Obs per group: min =         1
       between = 0.0381                                        avg =       6.4
       overall = 0.0478                                        max =        11

                                                F(9,612)           =     29.35
corr(u_i, Xb)  = -0.3861                        Prob > F           =    0.0000

------------------------------------------------------------------------------
   intensity |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     freedom |  -5.22e-08   4.36e-09   -11.97   0.000    -6.08e-08   -4.37e-08
    gdp_2000 |  -8.02e-20   1.17e-19    -0.68   0.494    -3.10e-19    1.50e-19
  population |  -2.75e-15   2.29e-15    -1.20   0.232    -7.25e-15    1.76e-15
  energy_use |   2.40e-10   6.82e-11     3.52   0.000     1.06e-10    3.74e-10
    industry |   6.94e-09   6.53e-09     1.06   0.289    -5.89e-09    1.98e-08
      policy |  -3.54e-08   5.53e-08    -0.64   0.522    -1.44e-07    7.31e-08
       urban |   1.47e-08   1.33e-08     1.11   0.268    -1.14e-08    4.08e-08
    vehicles |  -2.08e-09   5.87e-10    -3.54   0.000    -3.23e-09   -9.25e-10
nuclear_en~y |  -4.57e-08   9.16e-09    -4.99   0.000    -6.37e-08   -2.77e-08
       _cons |   4.11e-06   7.96e-07     5.16   0.000     2.55e-06    5.67e-06
-------------+----------------------------------------------------------------
     sigma_u |  1.779e-06
     sigma_e |  3.442e-07
         rho |  .96394037   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(113, 612) =   117.36            Prob > F = 0.0000
```

This is what happens in the same regression while not controlling for GDP:

(R.15)

```
.  xtreg intensity freed population energ industry policy urban vehicles nuclear_energy , fe

Fixed-effects (within) regression               Number of obs      =       735
Group variable: id_country                      Number of groups   =       114

R-sq:  within  = 0.3009                         Obs per group: min =         1
       between = 0.0331                                        avg =       6.4
       overall = 0.0412                                        max =        11

                                                F(8,613)           =     32.98
corr(u_i, Xb)  = -0.3959                        Prob > F           =    0.0000

------------------------------------------------------------------------------
   intensity |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     freedom |  -5.23e-08   4.36e-09   -11.99   0.000    -6.08e-08   -4.37e-08
  population |  -3.29e-15   2.15e-15    -1.53   0.126    -7.51e-15    9.26e-16
  energy_use |   2.38e-10   6.81e-11     3.50   0.001     1.04e-10    3.72e-10
    industry |   7.57e-09   6.47e-09     1.17   0.242    -5.13e-09    2.03e-08
      policy |  -3.71e-08   5.52e-08    -0.67   0.501    -1.46e-07    7.13e-08
       urban |   1.35e-08   1.32e-08     1.02   0.307    -1.24e-08    3.93e-08
    vehicles |  -2.06e-09   5.86e-10    -3.52   0.000    -3.21e-09   -9.13e-10
nuclear_en~y |  -4.52e-08   9.13e-09    -4.95   0.000    -6.31e-08   -2.73e-08
       _cons |   4.17e-06   7.90e-07     5.28   0.000     2.62e-06    5.72e-06
-------------+----------------------------------------------------------------
     sigma_u |  1.792e-06
     sigma_e |  3.440e-07
         rho |  .96446206   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(113, 613) =   117.64            Prob > F = 0.0000
```

Economic Freedom maintains significance and the sign is persistently negative.

This is, instead, what happens in the same regression as Economic Freedom is no longer considered:

(R.16)

```
.  xtreg intensity gdp_2 population energ industry policy urban vehicles nuclear_energy , fe

Fixed-effects (within) regression               Number of obs      =       778
Group variable: id_country                      Number of groups   =       118

R-sq:  within  = 0.1307                         Obs per group: min =         1
       between = 0.0002                                        avg =       6.6
       overall = 0.0000                                        max =        11

                                                F(8,652)           =     12.26
corr(u_i, Xb)  = -0.6301                        Prob > F           =    0.0000

------------------------------------------------------------------------------
   intensity |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    gdp_2000 |  -1.58e-19   1.42e-19    -1.12   0.264    -4.37e-19    1.20e-19
  population |  -4.62e-15   2.77e-15    -1.67   0.096    -1.01e-14    8.23e-16
  energy_use |   3.19e-10   7.21e-11     4.42   0.000     1.77e-10    4.60e-10
    industry |  -2.19e-08   7.09e-09    -3.09   0.002    -3.58e-08   -7.97e-09
      policy |  -1.48e-07   6.58e-08    -2.25   0.025    -2.77e-07   -1.87e-08
       urban |   3.47e-08   1.57e-08     2.22   0.027     3.95e-09    6.55e-08
    vehicles |  -4.24e-09   6.66e-10    -6.37   0.000    -5.55e-09   -2.93e-09
nuclear_en~y |  -4.28e-08   9.40e-09    -4.55   0.000    -6.12e-08   -2.43e-08
       _cons |   9.61e-07   8.78e-07     1.10   0.274    -7.62e-07    2.68e-06
-------------+----------------------------------------------------------------
     sigma_u |  2.241e-06
     sigma_e |  4.181e-07
         rho |  .96637855   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(117, 652) =   108.99           Prob > F = 0.0000
```

Interestingly enough, GDP loses significance.

The same results are obtained, as the Subindex of Economic Freedom is employed instead of the Index:

(R.17)

```
.  xtreg intensity sub gdp_2 population energ industry policy urban vehicles nuclear_energy
> , fe

Fixed-effects (within) regression               Number of obs      =       735
Group variable: id_country                      Number of groups   =       114

R-sq:  within  = 0.3406                         Obs per group: min =         1
       between = 0.0089                                        avg =       6.4
       overall = 0.0110                                        max =        11

                                                F(9,612)           =     35.12
corr(u_i, Xb)  = -0.5518                        Prob > F           =    0.0000

------------------------------------------------------------------------------
   intensity |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    subindex |  -4.16e-08   3.04e-09   -13.72   0.000    -4.76e-08   -3.57e-08
    gdp_2000 |  -5.64e-21   1.14e-19    -0.05   0.961    -2.29e-19    2.18e-19
  population |  -6.27e-15   2.23e-15    -2.82   0.005    -1.06e-14   -1.90e-15
  energy_use |   2.02e-10   6.64e-11     3.04   0.002     7.17e-11    3.32e-10
    industry |   5.48e-09   6.34e-09     0.86   0.387    -6.97e-09    1.79e-08
      policy |  -9.15e-08   5.32e-08    -1.72   0.086    -1.96e-07    1.29e-08
       urban |   5.38e-09   1.30e-08     0.42   0.678    -2.01e-08    3.09e-08
    vehicles |  -1.42e-09   5.79e-10    -2.45   0.014    -2.56e-09   -2.83e-10
nuclear_en~y |  -3.86e-08   8.93e-09    -4.32   0.000    -5.62e-08   -2.11e-08
       _cons |   4.16e-06   7.65e-07     5.44   0.000     2.66e-06    5.66e-06
-------------+----------------------------------------------------------------
     sigma_u |  1.983e-06
     sigma_e |  3.344e-07
         rho |  .97236154   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(113, 612) =   116.38            Prob > F = 0.0000
```

(R.18)

```
.  xtreg intensity subind population energ industry policy urban vehicles nuclear_energy , f
> e

Fixed-effects (within) regression               Number of obs      =       735
Group variable: id_country                      Number of groups   =       114

R-sq:  within  = 0.3406                         Obs per group: min =         1
       between = 0.0087                                        avg =       6.4
       overall = 0.0108                                        max =        11

                                                F(8,613)           =     39.58
corr(u_i, Xb)  = -0.5532                        Prob > F           =    0.0000

------------------------------------------------------------------------------
   intensity |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    subindex |  -4.16e-08   3.03e-09   -13.76   0.000    -4.76e-08   -3.57e-08
  population |  -6.31e-15   2.08e-15    -3.03   0.003    -1.04e-14   -2.22e-15
  energy_use |   2.02e-10   6.63e-11     3.05   0.002     7.18e-11    3.32e-10
    industry |   5.53e-09   6.27e-09     0.88   0.378    -6.79e-09    1.78e-08
      policy |  -9.17e-08   5.31e-08    -1.73   0.085    -1.96e-07    1.26e-08
       urban |   5.29e-09   1.28e-08     0.41   0.680    -1.99e-08    3.05e-08
    vehicles |  -1.42e-09   5.78e-10    -2.45   0.014    -2.55e-09   -2.83e-10
nuclear_en~y |  -3.86e-08   8.89e-09    -4.34   0.000    -5.60e-08   -2.11e-08
       _cons |   4.16e-06   7.58e-07     5.49   0.000     2.67e-06    5.65e-06
-------------+----------------------------------------------------------------
     sigma_u |  1.986e-06
     sigma_e |  3.341e-07
         rho |  .97246482   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(113, 613) =   116.98            Prob > F = 0.0000
```

2.10. Comments on the results

The results obtained from the regressions primarily manifest two aspects. The first regards their robustness: however much the model is changed the coefficients for GDP per capita and economic freedom – as measured by the Heritage Foundation's Index of Economic Freedom or by the subindex hereby defined – maintain signs that are always equal and sufficiently stable values. Secondly, it appears to be preferable to use the subindex as it contains more carbon intensity-specific information than the aggregate index, which includes pieces of information that may be irrelevant or misleading. Table 3 summarizes the main results from the regressions performed above.

From the table, it appears evident that economic freedom – whether measured through the Index or the Subindex – appears consistently, negatively correlated with carbon intensity. Other variables which are consistently, negatively correlated with carbon intensity include the share of nuclear power and, to much surprise, the number of privately vehicles. Consistently, positively correlated with carbon intensity are energy use, the share of industrial sector, energy imports, and in most case the energy freedom second order term. Most of the other considered controls are generally non-significant. GDP is in most cases negatively correlated with carbon intensity, and in some cases the correlation is non-significant.

Model	Economic Freedom [Sign]	GDP [Sign]	Other significant, positive controls	Other significant, negative controls	Non-significant controls
R.1	I -	-	U, Im, In, E	V	I^2, GDP^2, N, P
R.2	I -	-	I^2, GDP^2, Im, In, E	V, N,	U, P
R.3	I -	-	I^2, GDP^2, Im, In, E	I^3, V, N,	U, P,
R.4	I -	-	I^2, GDP^2, Im,		U, P, In
R.5	I -	-	I^2, GDP^2,	V, N,	Im, Em
R.6	S -	ns	S^2, Im,	N,	GDP^2, U, P, In, E
R.7	S -		S^2, Im, In, E	S^3, V, N,	GDP, GDP^2, U, P
R.8	ln I, ns(*)	ln, -	U, Im, P, In, E	V, N	
R.9	ln I, ns(*)	ln, -	GDP^2, Im, E	V, N,	I^2, U, P, In,
R.10	S, L3, -	ns	$(S, L3)^2$, In	N,	GDP^2, U, V, Im, P, E
R.11	S, L3, -	ns	$(S, L3)^2$, In	$(S, L3)^3$, N,	GDP^2, U, V, Im, P, E
R.12	S -	ns(*)	S^2, Im, In, E	Pol, V, N	GDP^2, U, P,
R.13	S -	ns	S^2, CE, Im, In,	P, ET,	GDP^2, Pol, FDI, N, CO2C, R, V, U, PC, Sur,
R.14	I -	ns	E,	V, N	P, In, Pol, U
R.15	I -	nt	E	V, N	P, In, Pol, U
R.16	nt	ns	E, U,	In, Pol, V, N	P,
R.17	S -	ns	E,	P, V, N	In, Pol, U
R.18	S -	nt	E,	P, V, N	In, Pol, U

Table 3. Results of the 18 regressions. CE = coal as a share of energy consumption; CO2C = coal-related carbon dioxide emissions; E = energy consumption; Em = employment; ET = energy taxation; FDI = foreign direct investments; GDP = Gross Domestic Product; I = Index of Economic Freedom; Im = share of energy imports; In = industrial sector as a share of the economy; N = share of nuclear power; P = population; PC = power consumption as a share of energy consumption;Pol =

climate policies; R = roads; S = Subindex of Economic Freedom; Sur = surface of a country; U = urban surface; V = number of private vehicles. ln = natural logarithm; L3 = lagged by 3 periods (years); ns = non-significant; nt = non-tested; (*) significant at 90%.

At any rate, to the purpose of this paper and reflecting the theoretical framework that has been provided, a negative correlation seems to exist between carbon intensity and economic freedom. This is consistent with the results available in literature, although the number of previous papers that explored this kind of approach is very limited. A correlation is obviously not – and should never be confused with – a causality, but the theoretical framework presented above seems to suggest that there may be more than a mere coincidence, here. In fact, the institutional factors that are explored to define economic freedom, may have a clear impact on carbon intensity. It can be expected that, as the indicators that define economic freedom increase, a reduction of carbon intensity may occur, especially in the countries with medium or low scores of economic freedom.

While this result is far from being conclusive, it seems to suggest that promoting economic freedom – particularly with regard to the components subsumed in the subindex hereby employed – might help to achieve long-term reductions in carbon intensity, especially in the developing world. More research is needed on the issue.

Appendix A. The 2009 Index of Economic Freedom

Country	*Score*		
1. Hong Kong	90.0	28. Norway	70.2
2. Singapore	87.1	29. Spain	70.1
3. Australia	82.6	30. Lithuania	70.0
4. Ireland	82.2	31. Armenia	69.9
5. New Zealand	82.0	32. Georgia	69.8
6. United States	80.7	33. El Salvador	69.8
7. Canada	80.5	34. Botswana	69.7
8. Denmark	79.6	35. Taiwan	69.5
9. Switzerland	79.4	36. Slovak Republic	69.4
10. United Kingdom	79.0	37. Czech Republic	69.4
11. Chile	78.3	38. Uruguay	69.1
12. Netherlands	77.0	39. Saint Lucia	68.8
13. Estonia	76.4	40. South Korea	68.1
14. Iceland	75.9	41. Trinidad and Tobago	68.0
15. Luxembourg	75.2	42. Israel	67.6
16. Bahrain	74.8	43. Oman	67.0
17. Finland	74.5	44. Hungary	66.8
18. Mauritius	74.3	45. Latvia	66.6
19. Japan	72.8	46. Costa Rica	66.4
20. Belgium	72.1	47. Malta	66.1
21. Macau	72.0	48. Qatar	65.8
22. Barbados	71.5	49. Mexico	65.8
23. Austria	71.2	50. Kuwait	65.6
24. Cyprus	70.8	51. Jordan	65.4
25. Germany	70.5	52. Jamaica	65.2
26. Sweden	70.5	53. Portugal	64.9
27. Bahamas, The	70.3	54. United Arab Emirates	64.7

55. Panama	64.7
56. Bulgaria	64.6
57. Peru	64.6
58. Malaysia	64.6
59. Saudi Arabia	64.3
60. St.Vincent and G.	64.3
61. South Africa	63.8
62. Albania	63.7
63. Uganda	63.5
64. France	63.3
65. Romania	63.2
66. Belize	63.0
67. Thailand	63.0
68. Slovenia	62.9
69. Mongolia	62.8
70. Dominica	62.6
71. Namibia	62.4
72. Colombia	62.3
73. Madagascar	62.2
74. Kyrgyz Republic	61.8
75. Turkey	61.6
76. Italy	61.4
77. Cape Verde	61.3
78. Macedonia	61.2
79. Paraguay	61.0
80. Fiji	61.0
81. Greece	60.8
82. Poland	60.3
83. Kazakhstan	60.1
84. Nicaragua	59.8
85. Burkina Faso	59.5
86. Samoa	59.5
87. Guatemala	59.4
88. Dominican Republic	59.2
89. Swaziland	59.1
90. Kenya	58.7
91. Honduras	58.7
92. Vanuatu	58.4
93. Tanzania	58.3
94. Montenegro	58.2
95. Lebanon	58.1
96. Ghana	58.1
97. Egypt	58.0
98. Tunisia	58.0
99. Azerbaijan	58.0
100. Bhutan	57.7
101. Morocco	57.7
102. Pakistan	57.0
103. Yemen	56.9
104. Philippines, The	56.8
105. Brazil	56.7
106. Cambodia	56.6
107. Algeria	56.6
108. Zambia	56.6
109. Serbia	56.6
110. Senegal	56.3
111. Sri Lanka	56.0
112. Gambia, The	55.8
113. Mozambique	55.7
114. Mali	55.6
115. Benin	55.4
116. Croatia	55.1

117. Nigeria	55.1	148. Uzbekistan	50.5
118. Gabon	55.0	149. Timor-Leste	50.5
119. Cote d'Ivoire	55.0	150. Laos	50.4
120. Moldova	54.9	151. Lesotho	49.7
121. Papua New Guinea	54.8	152. Ukraine	48.8
122. Tajikistan	54.6	153. Burundi	48.8
123. India	54.4	154. Tongo	48.7
124. Rwanda	54.2	155. Guyana	48.4
125. Suriname	54.1	156. Central African R.	48.3
126. Tonga	54.1	157. Liberia	48.1
127. Mauritania	53.9	158. Sierra Leone	47.8
128. Niger	53.8	159. Seychelles	47.8
129. Malawi	53.7	160. Bangladesh	47.5
130. Bolivia	53.6	161. Chad	47.5
131. Indonesia	53.4	162. Angola	47.0
132. China	53.2	163. Solomon Islands	46.0
133. Nepal	53.2	164. Kiribati	45.7
134. Bosnia and H.	53.1	165. Guinea-Bissau	45.4
135. Ethiopia	53.0	166. Republic of Congo	45.0
136. Cameroon	53.0	167. Belarus	45.0
137. Ecuador	52.5	168. Iran	44.6
138. Argentina	52.3	169. Turkmenistan	44.2
139. Micronesia	51.7	170. Sao Tomé and P.	43.8
140. Djibouti	51.3	171. Libya	43.5
141. Syria	51.3	172. Comoros	43.3
142. Equatorial Guinea	51.3	173. Dem. Rep. of Congo	42.8
143. Maldives	51.3	174. Venezuela	39.9
144. Guinea	51.0	175. Eritrea	38.5
145. Vietnam	51.0	176. Burma	37.7
146. Russia	50.8	177. Cuba	27.9
147. Haiti	50.5	178. Zimbabwe	22.7

179. North Korea	2.0	182. Liechtenstein	N/A
180. Afghanistan	N/A	183. Sudan	N/A
181. Iraq	N/A		

Appendix B. Kyoto Protocol ratification

Note: Only Annex-B countries have been considered

Country	*Year of ratification*		
1. Australia	2007	20. Liechtenstein	2004
2. Austria	2002	21. Lithuania	2003
3. Belgium	2002	22. Luxembourg	2002
4. Bulgaria	2002	23. Monaco	2006
5. Canada	2002	24. Netherlands	2002
6. Croatia	2007	25. New Zealand	2002
7. Czech Republic	2002	26. Norway	2002
8. Denmark	2002	27. Poland	2002
9. Estonia	2002	28. Portugal	2002
10. Finland	2002	29. Romania	2001
11. France	2002	30. Russia	2004
12. Germany	2002	31. Slovakia	2002
13. Greece	2002	32. Slovenia	2002
14. Hungary	2002	33. Spain	2002
15. Iceland	2002	34. Sweden	2002
16. Ireland	2002	35. Switzerland	2003
17. Italy	2002	36. UK	2002
18. Japan	2002	37. Ukraine	2004
19. Latvia	2002	38. US	nr

References

ALDY, J.E. (2005). "An Environmental Kuznets Curve Analysis of US State-Level Carbon Dioxide Emissions", *The Journal of Environment and Development*, vol.14, no.1, pp.48-72.

ANDERSON, T.L. and LEAL, D.R. (2001). *Free Market Environmentalism*. New York: Palgrave MacMillan.

ARROW, K., DASGUPTA, P., PIMENTEL, D. et al. (1995). "Economic growth, carrying capacity, and the environment", *Science*, vol.268, no.5210, pp.520-521.

ASLANIDIS, N. and IRANZO, S. (2009). "Environment and development: is there a Kuznets curve for CO_2 emissions?", *Applied Economics*, vol.41, no.6, pp.803-810.

BERNARDINI, O. and FOTI, P. (1982). "Il risparmio energetico in Italia 1972-80: realtà e illusioni", *Energia*, no.1, pp.38-63.

CARLSSON, F. and LUNDSTROM, S. (2003). "The Effects of Economic and Political Freedom on CO_2 Emissions", *Göteborg University Working Paper in Economics*, no.23.

CARSON, R.T., LEON, Y. and MCCUBBIN, D.R. (1997). "The relationship between air pollution emissions and income: US Data", *Environment and Development Economics*, vol.2, no.4, pp.433-450.

COLE, M.A., RAYNER, A.J. and BATES, J.M. (1997). "The Environmental Kuznets Curve: An Empirical Analysis", *Environment and Development Economics*, vol.2, no.4, pp.401-416.

CORNILLIE, J. and FANKHAUSER, S. (2002). "The energy intensity of transition countries", *European Bank for Reconstruction and Development Working Paper*, no.72.

EBERSTADT, N. (2007). "Too many people?", International Policy Network – Sustainable Development Network, http://www.sdnetwork.net/files/pdf/Too%20Many%20People_%20web.pdf

EHRLICH, P. (1968). *The Population Bomb.* New York: Ballantine Books.

EHRLICH, P. and EHRLICH, A. (2008). *The Dominant Animal: Human Evolution and the Environment*. Washington, DC: Island Press.

EIA (2008). *International Energy Outlook 2008*. Washington DC: Energy Information Administration. http://www.eia.doe.gov/oiaf/ieo/index.html

GALEOTTI, M. and LANZA, A. (1999). "Desperately Seeking (Environmental) Kuznets", *FEEM Working Paper*, no.2.

GOKLANY, I.M. (2007). *The Improving State of the World*. Washington, DC: The Cato Institute.

GROSSMAN, G.M. and KRUEGER, A.B. (1995). "Economic Growth and the Environment", *Quarterly Journal of Economics*, vol.110, no.2, pp.353-377.

GUPTA, S., HALL, S., MABEY, N. and SMITH, C. (1997). *Argument in the Greenhouse. The International Economics of Controlling Global Warming*. London: Routledge.

HANAOKA, T., KAINUMA, M., KAWASE, R. and MATSUOKA, Y. (2006). "Emissions scenarios database and regional mitigation analysis: a review of post-TAR mitigation scenarios", *Environmental Economics and Policy Studies*, vol.7, no.3, pp.367-389.

HAYEK, F.A. von (1988). *The Fatal Conceit: The Errors of Socialism*. Chicago: University of Chicago Press.

HE, C. and WANG, J. (2007). "Energy Intensity in Light of China's Economic Transition", *Eurasian Geography and Economics*, vol.48, no.4, pp.439-468.

HEIL, M.T. and SELDEN, T.M. (2001). "International Trade Intensity and Carbon Emissions: Cross-Country Econometric Analysis", *The Journal of Environment and Development*, vol.10, no.1, pp.35-49.

KARAKAYA, E. and OZCAG, M. (2005). "Driving Forces of CO_2 in Central Asia: A Decomposition Analysis of Air Pollution from Fossil Fuel Combustion", *Arid Ecosystems Journal*, vol.11, no.26-27, pp.49-57.

KAYA, Y. and YOKOBORI, K. (eds.) (1997). *Environment, energy, and economy: Strategies for sustainability*. Tokyo: United Nations University.

KIM, M.K. and WU, C. (1993). "The cross-sectional effect of inflation on corporate investment and employment", *Review of Quantitative Finance and Accounting*, vol.3, no.2, pp.203-220.

KUZNETS, S. (1955). "Economic Growth and Income Inequality", *American Economic Review*, vol.45, pp.1-28.

LOMBORG, B. (2008). *Cool it*. New York: Knopf.

MEADOWS, D.H., MEADOWS, D.L., RANDERS, J. and BEHRENS III, W.W. (1972). *The Limits to Growth*. New York: Universe Books.

MEADOWS, D.H., MEADOWS, D.L. and RANDERS, J. (2004). *Limits to Growth: The 30-Year Update*. White River, VT: Chelsea Green.

MILLER, T. (ed.) (2009). *2009 Index of Economic Freedom*. Washington, DC: The Heritage Foundation.

MONTGOMERY, W.D. and BATE, R. (2005). "A (Mostly) Painless Path Forward: Reducing Greenhouse Gases Through Economic Freedom". In M. Thorning and A. Illarionov (eds.). *Climate Change and Economic Growth: A Way Forward to Ensure Both*. Washington, DC: ICCF/IEA/IBL, pp.140-151.

MONTGOMERY, W.D. and TULADHAR, S.D. (2005). "Impact of Economic Liberalization on GHG Emission Trends in India", Climate Policy Center.

MONTGOMERY, W.D. and TULADHAR, S.D. (2006). "Econometric Evidence on the Relationship Between Institutional Factors and Energy Intensity". In W.D. Montgomery and S.D. Tuladhar. *The Asia Pacific Partnership: Its Role in Promoting a Positive Climate for Investment, Economic Growth and Greenhouse Gas Reduction*. Washington, DC, CRA International and ICCF, pp.35-44.

NAKADA, M. (2005). "Deregulation in an energy market and its impact on R&D for low-carbon energy technology", *Resource and Energy Economics*, vol.27, no.4, pp.306-320.

PANAYOTOU, T. (2003). "Economic Growth and the Environment", *Spring Seminar of the United Nations Economic Commission for Europe*, Geneva.

PIZER, W. (2005). "The Case for Intensity Targets", *Resources for the Future Discussion Paper*, no.05-02, http://www.rff.org/Documents/RFF-DP-05-02.pdf.

SALA-I-MARTIN, X. (2002). "15 Years of New Growth Economics: What Have We Learnt?", *Columbia University Department of Economics Discussion Paper*, no.0102-47.

SCHMALENSEE, R., STOKER, T.M. and JUDSON, R.A. (1998). "World Carbon Dioxide Emissions: 1950-2050", The Review of Economics and Statistics, vol.80, no.1, pp.15-27.

SCHUMPETER, J. (1975). *Capitalism, Socialism and Democracy*. New York: Harper.

SELDEN, T.M. and SONG, D. (1994). "Environmental Quality and Development: Is There a Kuznets Curve for Air Pollution Emissions?", *Journal of Economics and Management*, vol.27, no.2, pp.147-162.

SHAFIK, N. and BANDYOPADHYAY, S. (1992). "Economic Growth and Environmental Quality: Time Series and Cross-Country Evidence", *World Bank Policy Research Working Paper*, no.94.

SIMON, J.L. (1996). *The Ultimate Resource 2*. Princeton: Princeton University Press.

SMIL, V. (2003). *Energy at the Crossroads*. Boston: MIT Press.

STERN, D.I., COMMON, M.S. and BARBIER, E.B. (1996). "Economic growth and environmental degradation: the Environmental Kuznets Curve and sustainable development", *World Development*, vol.24, no.7, pp.1151-1160.

YANDLE, B., VIJAYARAGHAVAN, M. and BHATTARAI, M. (2004). "Income and the Race to the Top", in Anderson (2004), pp.83-108.

Chapter 3.

A Reassessment of European Climate Policies: Cap & Trade vs. Carbon Tax

Abstract

The European Union has unilaterally decided to implement a cap & trade scheme to contain greenhouse gases (GHGs) emissions, starting on 1 January 2005. After the First Phase of the Scheme had been concluded on 31 December 2007, emissions from the sectors covered by the European Emissions Trading Scheme (ETS) had actually increased. That is not enough to tell that the scheme didn't work: there are too little data to perform a credible assessment. The literature on the issue is not unanimous. It seems plausible, however, that some permits over-allocation occurred in 2005, that might explain the not-so-exciting performance of the scheme. In fact, to some extent some over-allocation was also acknowledged by the European Commission itself, which adopted more stringent criteria for the Second Phase of ETS (2008-2012). Now the criteria and the rules for the Third Phase (2013-2020) are being debated, with an emphasis over defining even more stringent criteria and a shift from a grandfatherin system in the initial allocation (whereby allowances are initially given free-of-charge on the basis of historical track records for emissions), towards a partial auctioning system (whereby permits are initially given to the highest bidders), with a goal of a full auctioning in 2027. At the same time, safeguard measures are being considered in order to prevent "carbon leakage" (i.e. delocalization due to higher costs of energy) in the energy-intensive economic sectors or sub-sectors that are exposed to international competition. This paper examines the guidelines for the Energy Policy for Europe by assessing its effectiveness in achieving the stated environmental targets, assuming not every country in the world will be willing to pursue similar targets. Subsequently, it identifies the major shortcomings in the European policies, that mostly depend on the complexity and possible politicization of the ETS. Finally, it reviews the possible alternatives, by emphasizing the benefits that a revenue-neutral carbon tax might deliver both in terms of reaching the environmental goals, and of the policy's efficiency and allocational efficiency. Two models of carbon tax are considered: one defined on the basis of the expected social cost from GHGs emissions, the other dependent on a state function that measures the degree of global warming in any given year.

3.1. An Energy Policy for Europe

The reduction of greenhouse gas emissions is the cornerstone of the new Energy Policy for Europe (EPE). If, at a rhetorical level, the Union aims to be and remain a global leader in the fight against climate change,[6] in practice environmental policy is the only way for the European Commission to influence the national governments' energy policies. In fact, the European Treaty doesn't include energy policy within the community's area of jurisdiction.

It is in this context that the European Council held in the spring of 2007 formulated the ambitious goals of cutting European greenhouse gases (GHGs) emissions by 20% below the reference year by 2020; increasing the share of renewable energy sources up to 20% of primary energy consumption; and reducing by 20% below the baseline the total consumption of energy.[7] Such objectives have been somehow downsized – the renewable share is to be referred to final energy consumption, will the total consumption reduction goal has been turned into a non-binding target of increasing energy efficiency by 20%. The way to achieve such goals is embodied in a package of directives that was launched by the European Commission on January 23rd, 2008. Since then, a wide debate emerged and some major changes have been made. Technical issues are being debated, too. After a long negotiation in late 2008, the Commission has proposed an amended version of the Directive, which has been passed by the EU Parliament and is now to be ratified by the member States.[8]

As far as emissions reductions are concerned, Europe plans to strengthen its Emissions Trading Scheme (ETS), a "cap & trade" mechanism that has been in place since January 1st, 2005.

This paper intends to examine the objective of emission reductions. First we will evaluate the usefulness of this objective from the point of view of its environmental impact. In the second part we will look at the performance of European climate policies, while the third part will be focused on the Emissions Trading Scheme (ETS). Although the available data refer to a relatively short period, some elements have already emerged and deserve deep reflection. Finally, in the fourth part, we will

---

[6] So said European Commission President José Manuel Barroso, who – in a statement released on December 15th, 2007 – attributed to Europe's "leadership" the "successful outcome" of Bali negotiations. See http://europa.eu/rapid/pressReleasesAction.do?reference=IP/07/1941&format=HTML&aged=0&language=EN&guiLanguage=en

[7] Initially the third target was formulated with regard to primary consumption of energy, but in the latest versions of the package it became clear that the reference was to final consumption, and the target – differently from the other two – was made non-binding.

[8] http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+TA+P6-TA-2008-0610+0+DOC+XML+V0//EN&language=EN

compare the approach that the EU currently takes – the quantitative one – with an alternative path, that is, the imposition of an environmental tax.

3.2. Are European climate policies any useful?

The objective of the European climate policies is to "adopt the necessary domestic measures and take the lead internationally to ensure that global average temperature increases do not exceed pre-industrial levels by more than 2°C". For the Commission, "this is technically feasible and economically affordable if major emitters act swiftly. The benefits far outweigh the economic costs."[9] This statement – contained in a communication of the Community's executive body preceding the 2007 Spring meeting of the European Council – rests on a previous communication of 2005 (that "demonstrated that the benefits of limiting climate change outweigh the costs of action"),[10] and also rests on the *Stern Review* (Stern 2006).

The 2005 communication "demonstrates" that the benefits exceed the costs in a succinct 12-line paragraph to which were added two annexes on the effects of climate change (two faces of a sheet of paper compiled into points without even one bibliographic reference even when long-term projections are given) and a cost-benefit analysis (less than three pages where the following quote by IPCC is reported: "comprehensive, quantitative estimates of the benefits of stabilization at various levels of atmospheric concentrations of greenhouse gases do not yet exist").[11] Another reference is the Staff Working Paper,[12] which supplies all the material behind the communication. This is a more articulate document consisting of 51 pages which, of course, "demonstrates" nothing, as it does not contain anything that is original other than a review of the literature – which, however, does not even mention less pessimistic studies – with the ambition of summing up the body of the scientific and economic knowledge on causes and effects of global warming and costs and benefits of the different policy options (including the business as usual and most ambitious scenarios). Similar considerations apply to the Staff Working Paper in support of the 2007 Communication,[13] which picks up and updates the preceding paper.

The reference to the *Stern Review* is seemingly more solid. The report was commissioned by the British government to the former World Bank chief economist,

---

[9] European Commission, "Limiting Global Climate Change to 2 degrees Celsius", COM(2007) 2, http://europa.eu/press_room/presspacks/energy/comm2007_02_en.pdf, p.2.

[10] *Ivi*, p.4.

[11] European Commission, "Winning the Battle Against Global Climate Change", COM(2005) 35, http://ec.europa.eu/environment/climat/pdf/comm_en_050209.pdf, pp.4 and 12-16.

[12] http://ec.europa.eu/environment/climat/pdf/staff_work_paper_sec_2005_180_3.pdf.

[13] http://ec.europa.eu/environment/climat/pdf/ia_sec_8.pdf.

Nicholas Stern, with the objective "to understand more comprehensively the nature of the economic challenges and how they can be met, in the UK and globally".[14] The most shocking and emphasized result of the report – some 575 pages of analysis of evidence and studies available on the economic aspects of global warming – is the forecast that, depending on the climate scenario, in the absence of countermeasures, the global mean temperatures growth could bring about economic losses ranging from 5 to 20% of the global GDP. It is a resounding result, as the previous estimates gravitated around one percent of global GDP, which is also the order of magnitude of the mitigation costs according to many authors. To get to such a figure, Sir Nicholas makes two singular hypotheses: on one hand, he assumes a discount rate next to zero (in fact, 0.1%); on the other, he refers systematically to the most alarmistic studies on the possible consequences of global warming. In all cases, by simply adopting a discount rate of 3% – a value typically employed in the literature – the estimated costs of the greenhouse effect crumble, depending on the scenario, from 5-20% to 0.4-1.1% of the global GDP (Dasgupta 2006; Galeotti and Lanza 2006; Nordhaus 2007; Tol 2006).

Tol and Yohe (2006, pp.233-234) go as far as to find six critical issues in the *Review*. Of these, four refer to technical limits of the *Review*:

- First, The *Stern Review* does not present new estimates of either the impact of climate change or the costs of greenhouse gas emission reduction. Rather, the *Stern Review* reviews existing material. It is therefore surprising that the *Stern Review* produced numbers that are so far outside the range of the previous published literature;
- Second, the high valuation of climate change impacts reported in the *Review* can be explained by a very low discount rate, risk that is double-counted, and vulnerability that is assumed to be constant over very long periods of time (two or more centuries, to be exact). The latter two sources of exaggeration are products of substandards analysis. The use of a very low discount rate is, of course, debatable;
- Third, the low estimates for the cost of climate change policy can be explained by the *Review*'s truncating time horizon over which they are calculated, omitting the economic repercussions of dearer energy, and ignoring the capital invested in the energy sector. The first assumption is simply wrong, especially since the very low discount rates put enormous weight on the other side of the

[14] http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_backgroundtoreview.cfm.

calculus on impacts that might be felt after the year 2050. The latter two are misleading;

- Fourth, the cost and benefit estimates reported in the *Stern Review* do not match its policy conclusions. If the impacts of climate change are as dramatic as the *Stern Review* suggests, and if the costs of emission reductions are as small as reported, then a concentration target that is far more stringent than the one recommended in the *Review* should have been proposed. The *Review*, in fact, does not conduct a proper optimization exercise.

But the weakness – or at any rate the selectivity of the calculations used by the European Commission – is not the most exposed flank of the Community's strategy on climate. The deepest problem concerns policy objectives, functions, and consistence.

The ultimate goal of the European policies is to contain the increase in global temperatures within the "magic" threshold of two degrees centigrade. Arguably, this is a symbolic value, because there is no reason to believe that a warming of up to two degrees is harmless, while a greater increase in temperatures, no matter how small, will bring about any kind of disasters. Furthermore, it risks becoming an unrealistic objective. Although Europe is persuaded of the human responsibility for climate changes, no one can exclude that all or part of the temperature increase is governed by natural dynamics such as solar cycles (see Fig. 1) (Soon and Yaskell 2004). Therefore, Brussels could have set a target that goes beyond the powers that mankind – leave aside Europe – has today of influencing the environment. In this sense, it would have been desirable to express the objective in terms of stabilization of atmospheric concentrations of carbon dioxide and other greenhouse gases. Furthermore, the ratio between CO_2 emissions and temperature variation (which, rather, depends on atmospheric concentrations, not on yearly emissions) is subject to great uncertainties, so there is an extremely high degree of arbitrariness in the definition of the necessary emission reductions and in their temporal displacement to the end of limiting the growth to two degrees – and not 1.99, 2.01, or 2.1 or 3°C.

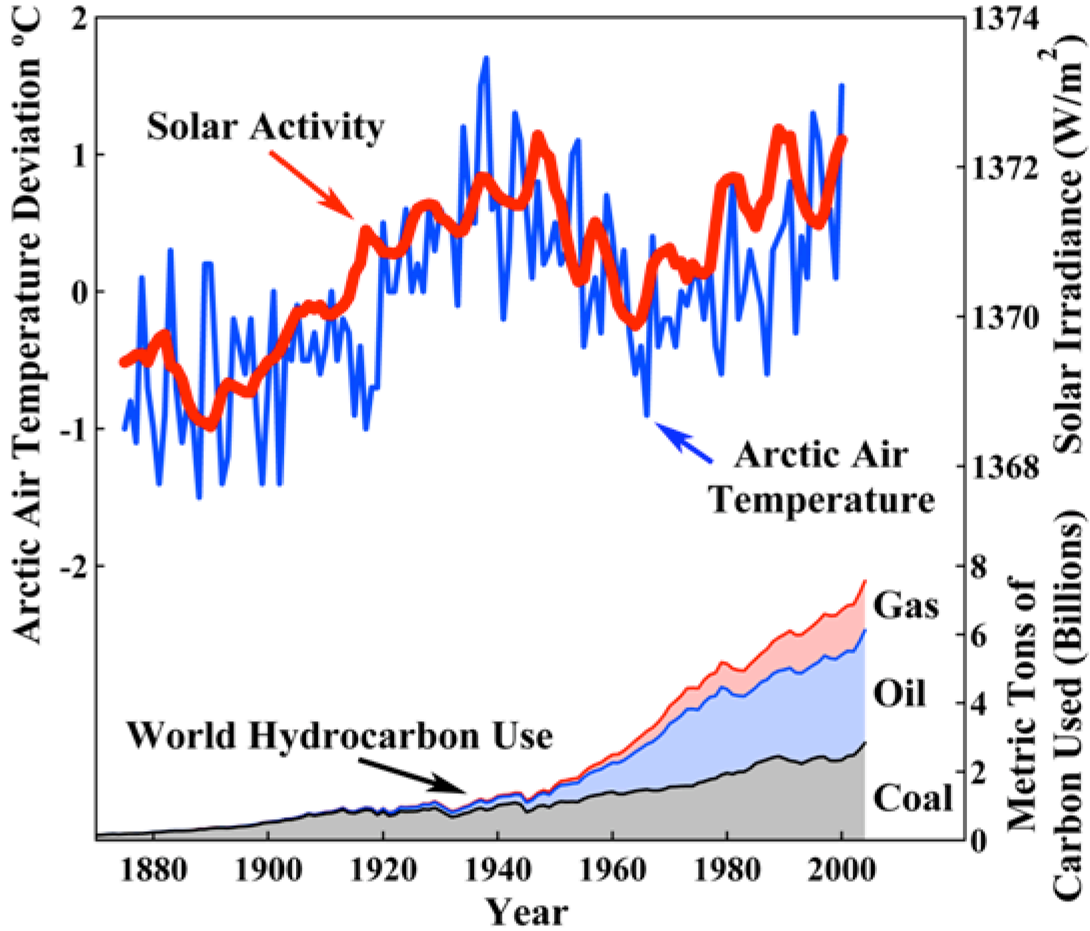

Figure 1. Artic temperature, solar activity and cumulative hydrocarbon consumption. Source: Robinson, Robinson and Soon (2007).[15]

The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC 2007) evaluates temperature increase by 2100 in the interval 1.8-4.0 degrees centigrade in the different scenarios. In six scenarios out of seven, the lower end of the fork is equal to or lower than 2 degrees, and in scenario 4 it is even smaller than 1.5 degrees.[16] That means that there is a some chance – even assuming that the hypothesis and conjectures underlying the IPCC scenarios are valid – that the increase of temperature *in the absence of any political measure* stays below the critical threshold of two degrees. This fact in itself should supply a precise policy indication: as it is possible that the European efforts are useless – one way or another – they should be conceived in such a way so as to allow for adjustments in a relatively quick and simple manner as the scientific evidence grows and allows the unveiling of at least some of the many unknowns at the basis of the global warming phenomenon.

[15] http://www.oism.org/pproject/GWReview_OISM150.pdf.

[16] Ipcc, "Summary for Policymakers", in *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report* (Cambridge, UK e New York, NY: Cambridge University Press), http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_SPM.pdf, p.13.

During the Spring 2007 European Council, the leaders of the EU member States committed to a reduction of emissions of at least 20% by 2020, but also re-launched a further commitment to reduce the emissions by 30% if it becomes possible to find an agreement between all industrialized countries.[17] This is contradictory. If the emissions cause global warming and if preventing global warming is the European political priority, then the commitment to reduce emissions should be stronger, as the participation of other countries is smaller. In fact, the presumed cause of global warming comes from global emissions; in the absence of reductions by other countries, Europe should do more, not less, so that the same result is achieved. Why is the Commission not following this simple logic? The answer, which is never given openly in the official documents of the Union, is that the Commission believes, correctly, that the reduction in emissions represents a ballast for economic growth and that it may cause a loss of international competitiveness. Europe does not want to push beyond a certain limit which is set arbitrarily, without any preliminary study, and quantified by 20%. That is obviously because it believes that the cost for the European economy would be by far greater than environmental benefits which are uncertain and at any rate remote in time. Therefore, implicitly, the EU reasons about the future with a discount rate which is quite different than the 0.1% used by Stern, and hence it demonstrates with facts that it does not believe in the studies that it nevertheless calls on to support its policies. Then how do we explain the European choices? It is not the objective of this paper to put intentions on trial, nor to investigate the ideological motivations or economic advantages of some effective and well-organized pressure groups in Brussels, Berlin, London and in other member States that have been pushing hard to set climate policies in motion. To the ends of this reflection, what is relevant is that, in fact, the European Union gives economic weight to "salvaging the climate" and that, regardless of the numbers, it attempts to reconcile the verbal extremism with a series of practical caveats. We can see that in a whole series of details – and anybody knows that the devil's right there. For example, at the same time as the EU promotes biofuels (even by adopting a specific target of a 10% the market share by 2020), and it prevents or discourages, through customs duties, the import of biofuels coming from tropical countries, which are more economical and characterized by a lower environmental impact as compared to those

[17] Council of the European Union, Presidency Conclusions, 8-9 March 2007, 7224/1/07, http://www.consilium.europa.eu/ueDocs/cms_Data/docs/pressData/en/ec/93135.pdf. Sections 31 and 32 state, respectively: "the European Council endorses an EU objective of a 30 % reduction in greenhouse gas emissions by 2020 compared to 1990 as its contribution to a global and comprehensive agreement for the period beyond 2012, provided that other developed countries commit themselves to comparable emission reductions and economically more advanced developing countries to contributing adequately according to their responsibilities and respective capabilities". Moreover, "The European Council emphasises that the EU is committed to transforming Europe into a highly energy-efficient and low greenhouse-gas-emitting economy and decides that, until a global and comprehensive post-2012 agreement is concluded, and without prejudice to its position in international negotiations, the EU makes a firm independent commitment to achieve at least a 20 % reduction of greenhouse gas emissions by 2020 compared to 1990."

produced in Europe. In this case, the EU seems to put the creation of a safety net for European agriculture (which is threatened by the reform of the common agricultural policy) before actual climate salvation (Clini 2007; Stagnaro 2007). But even this risks leading us astray. In fact, regardless of the internal contradictions or perhaps excessive ambitions of European policy, another element exists that dictates the possible irrelevance of this measure: the rest of the world.

Europe, in fact, does not act in a void, but the background of its actions consists in the decisions of other nations. It is of course an ever-changing background that moves in function of a wide array of variables – social, economic and political in the first place – to which Europe itself belongs. In other words, European decisions are seen by other actors, which react in sometimes a cooperative and sometimes an opportunistic manner. When we talk about choices in energy policy, however, the influence of the EU on the rest of the world is relatively low, because the time horizon of such decisions is very long. Today, everybody is an heir of the choices made yesterday, and those choices count for more than the acceleration of a certainly important actor (but perhaps less important than European governments might wish) such as the European Union. Therefore, although one can maintain that Europe could lead other nations on the sustainability path by example, so far that does not seem to have materialized, and the EU seems to be a leader without followers. It is therefore reasonable to assume that, at least in the short to medium run, the other countries will mainly follow domestic logic, and thus, the consequences of European choices must be evaluated within a "business as usual" scenario for the rest of the world.

According to the reference scenario of the International Energy Agency (IEA 2007, p.73), "world primary energy demand is projected to grow by more than half between 2005 and 2030, at an average annual rate of 1.8%. Demand reached 17.7 billion toe, compared with 11.4 billion toe in 2005 – a rise of 55%. Global energy intensity – total energy use per unit of gross domestic product – falls by 1.8% per year over 2005-2030" (Figure 2). The growth will be dominated by fossil fuels that will confirm themselves as the heart of the world energy system: "Fossil fuels remain the dominant source of primary energy, accounting for 84% of the overall increase in global demand between 2005 and 2030". Although oil remains the most important fuel, its share next to the total mix will decrease from 35 to 32%, settling (in absolute terms) at 160 million barrels a day (37% more than 2006). The use of coal will grow by 73%, raising therefore from 25 to 28% of consumption. The share of natural gas will remain almost stable, as, according to the projections, it will moderately increase from 21% to 22% of the total. Next to the other forms of energy, the use of electricity will increase noticeably, as it will grow, next to total consumption, from 17 to 22%. Finally, the greatest part of the foreseen growth is attributed to the developing countries which, thanks to the combination of demographic and economic growth, will be responsible for 74% of the additional demand – China and India alone accounting for 45% of the global additional demand of energy. It should be noted that, in the alternative scenario of IEA (which assumes the adoption of iron-fisted and effective measures of energy savings and emissions reduction), in spite of the significant reduction of demand (11% less in 2030), the proportions are not substantially altered. The Paris-based Agency also elaborates a scenario contemplating high growth – and that can be considered pessimistic from the point of view of the European policy objectives – which is not considered here.

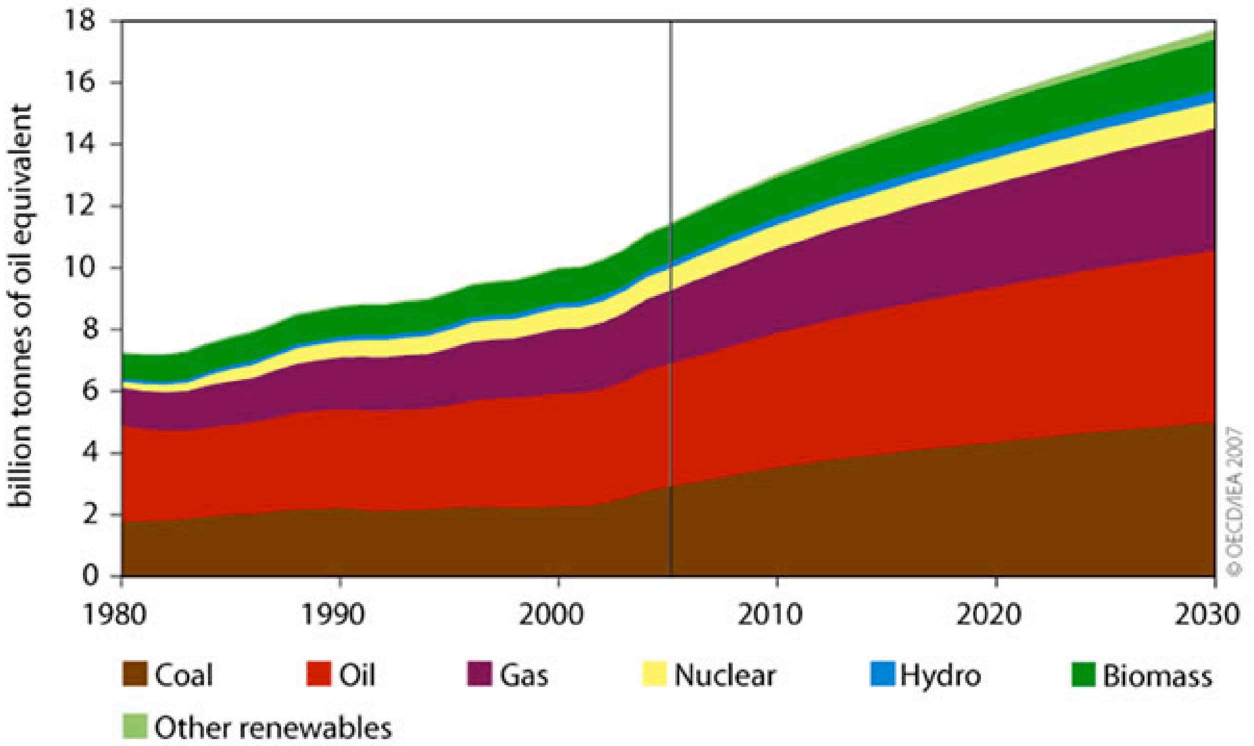

Figure 2. Global primary energy demand in the reference scenario. Source: IEA (2007)

If this is the future we are facing, the environmental implication is clear: in step with energy consumption, greenhouse gas emissions will increase. Even by limiting ourselves just to the emissions linked to energy consumption, under the IEA reference scenario, China and India will be responsible, respectively, for 42% and 14% of the emission increases, while the rest of the world (of which Europe is just a part, and not even the largest one) will be responsible for 44%. In the optimistic scenario of IEA (2007, p.98), the rest of the world will cause just 14% of the additional emissions, while China will have the lion's share with 52% and India will follow with 17%. By 2030, the total increase in emissions will be by 57% above 2005, or just 27% under the alternative scenario (IEA 2007, p.192). The European Union – which in 2005 was responsible for less than 15% of global emissions – will see its share eroded down to 12% in 2015 and down to 10% under the reference scenario, or to 11% in 2015 and 9%

in 2030 under the alternative scenario (IEA 2007, p.199). It is clear that any effort, no matter how intense, will have a relatively small impact on global emissions which, at the end of the day, are the only relevant variable for the phenomenon of global warming. Clini (2007, p.119) writes: "The advantage in terms of the reduction of CO_2 emissions – that can be measured only at the global level – is marginal. The reduction of 20% of the European emissions in 2020 corresponds to a global reduction of less than 4%".

Almost by definition, a reduction of this size is destined not to have any discernible effect on climate balances. At most, it can slow down by a modest amount the growth of emissions, acting in such a way that – in the reference scenario, and assuming for the sake of simplicity a linear path between the values of the global emissions estimated by IEA for 2015 and 2020 – we would have in 2020 a level of global emissions which, otherwise, would already have been reach in 2017. The question that arises is whether it is worth committing a significant quantity of economic and political resources – actually, *any* quantity – to achieve such a meagre objective.

3.3. Do the European climate policies work?

One could object that there is something more important than the effectiveness of the policies at the global level. By means of its own commitment, the European Union can set an example for the international community and create the conditions for which its allegedly "virtuous" behaviour is followed by others. This is the solution to the prisoner's dilemma *à la Bruxelles*: the European actor greatly publicises its actions so as to convince others that the problem is so serious that it requires common action in which all must participate, but in the absence of that action, at least something is done by someone. We are back to European leadership. However, to claim one's own leadership is not enough, as it is necessary for facts to follow words. But from this point of view, the EU does not seem very convincing or determined.

A report published by the European Environmental Agency in December 2007 (EEA 2007) states that the old continent will be able to reach, if not surpass, the Kyoto objectives – that is, an abatement of emissions of 8% below those of 1990 by 2012. That, however, is true only for the 27-member Union: the new member States are still enjoying the dubious privilege of being former Soviet countries, and as such experienced a sudden and dramatic contraction of emissions after USSR collapse. This, however, is a fact that is not destined to repeat itself, to the point that – as reported by the same EEA (2007, p.6) – "a first assessment of EU27 aggregated projections for 2020 shows that, even if the additional measures currently planned by Member States are adopted and fully implemented, greenhouse gas emissions will increase between 2010 and 2020, reaching a level approximately 2% higher than in

2005, and only 6% below their 1990 level". This is certainly not an intentional result, and a smile is irresistible when we detect the tone with which the Copenhagen-based agency hails the ephemeral result that (perhaps) will be reached in 2012 – a tone that saturates the press release informing us of the publication of the study, and the title "EU within the reach of Kyoto targets".[18]

The goal that Europe might meet is even less astonishing if we look at the results that have actually been reached by EU15, that is, by that part of Europe which has long said that it has made emissions reduction a priority and which acts accordingly. The EU15 emissions in 2007 (the last year for which official data are available) were 4052.0 MTons CO_2 equivalent, 4.3% below the baseline, or 1.6% below 2006.

A further analysis by other European Environmental Agency official documents claims that "The policies and measures in place as of today will not be sufficient for the EU-15 to meet its Kyoto target, as they are expected to push down emissions between 2006 and 2010 to an average level only 3.6% below the base-year emissions. If the additional measures planned by 10 Member States were fully implemented and on time, a further reduction of 3.3% could be obtained."[19] Moreover, the appropriate use of the Kyoto mechanisms is estimated to allow for a further 3.0% reduction, while the use of carbon sinks might induce a further 1.4% reduction. Optimistic forecasts, therefore, suggest that an aggregate 11.3% reduction below the baseline can be achieved in the 2008-12 commitment period.

Interestingly enough, last year's estimates claimed that a 4% reduction below the baseline could be achieved with existing policies (as opposed to 3.6% in the most recent estimate, a 10% downsizing), while an extra 7% reduction could be achieved by adopting the appropriate additional measures, Kyoto mechanisms, and carbon sinks. While the actual performance of the EU15 has been downsized, the ability to achieve more significant reductions by other means has been increased by 10% (from -7.0 to -7.7%).[20]

To achieve the extra 7.7% reduction, important steps need to be taken, including the following:

- Full achievement of the objectives foreseen with the existing policies;
- Quick adoption and implementation of policies and additional measures;
- Correction of the emissions by taking into account sinks and land-use changes;
- Utilization to the highest possible level of the flexible mechanisms;
- Significant overdelivery by some of the member States;

[18] http://www.eea.europa.eu/pressroom/newsreleases/eu-within-reach-of-kyoto-targets.

[19] http://www.eea.europa.eu/pressroom/newsreleases/eu-15-on-target-for-kyoto-despite-mixed-performances

[20] European Environment Agency, "Greenhouse gas emission trends and projections in Europe 2007", pp.6-7.

- Timely observation of the reduction timetable.

All that notwithstanding, at least three member states – Italy, Spain, and Denmark – will not reach the objectives, and probably this is the most accurate forecast of the whole report (EEA 2009).

Even more interesting is the way in which the Union has, so far, reduced its emissions. Table 1 reports the yearly variations declared by EEA together with the explanations that, in its annual communiqués, the agency has supplied to explain the changes. Except for one case (1999), the variation is never attributed to specific policies. In 7 years out of 9, a significant role is attributed to climate conditions – that is, to a factor completely exogenous and which cannot be politically controlled. Then, on and off, the greater or lesser use of coal in the mix is noted, and that mix depends both on industrial choices or long-term policies, and on demand, which in turn depends primarily on the temperature and on economic growth (or lack thereof), as well as on international prices of fossil fuels. It is therefore not an exaggeration to state that if Europe gets more or less close to the Kyoto target, it will depend largely on variables that are independent from climate policies; indeed the single most important variable will be... weather: the warmer (especially by Winter), the lower the emissions will be. The very analyses of the agency therefore show that regardless of the cost, European policies are ineffective, thus inefficient.

Year	Emission Variation (*)	Main reasons supplied	Real GDP Growth[21]
1999[22]	-2	• Measure against NO_2 in France and the UK; • Measures against HFCs emissions in UK; • Shift from coal to gas (Germany and the UK); • Mild winter in Germany, UK, France, and the Netherlands.	+3
2000[23]	+0.3	• Increase in electricity-related emissions; • Increase of coal in UK; • Continuous growth of emissions in Greece, Spain, Ireland, Italy, Belgium.	+3.9

[21] http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&plugin=0&language=en&pcode=tsieb020

[22] http://www.eea.europa.eu/pressroom/newsreleases/newsrelease20010423.

2001[24]	+1	• Cold winter. • Increase in transportation emissions; • Greater use of fossil fuels for heating and electricity generation.	+1.9
2002[25]	-0.5	• Mild temperatures; • Low economic growth; • Shift from coal to gas.	+1.2
2003[26]	+1.3	• Increase of the carbon share in electrical generation; • Cold winter.	+1.2
2004[27]	+0.3	• Increase in industrial emissions (iron, steel, refrigeration, air conditioning).	+2.3
2005[28]	-0.8	• Reduction in the use of coal; • Mild temperatures; • Increase of diesel next to gasoline (Germany).	+1.8
2006[29]	-0.8	• Warm weather; • High oil & gas prices.	+2.9
2007[30]	-1.6	• Warm weather; • High oil & gas prices.	+2.7

Table 1. Yearly variations of greenhouse emissions in EU15 (1999-2005). Source: EEA. Economic growth (1999-2005). Source: Eurostat.

Obviously, before the failure of European policies is assessed, a closer look at the European market for emissions rights is needed, which started operating in 2005, a year characterized by mild temperatures as well as by a reduction of emissions as

[23] http://www.eea.europa.eu/pressroom/newsreleases/greenhouse_gas_emission.

[24] http://www.eea.europa.eu/pressroom/newsreleases/ghg-2003-en.

[25] http://www.eea.europa.eu/pressroom/newsreleases/tec2-2004-en.

[26] http://www.eea.europa.eu/pressroom/newsreleases/ghg_inventory_report-en.

[27] http://www.eea.europa.eu/pressroom/newsreleases/GHG2006-en.

[28] http://www.eea.europa.eu/pressroom/newsreleases/eu-greenhouse-gas-emissions-decrease-in-2005.

[29] http://www.eea.europa.eu/highlights/eea-reports-on-progress-in-greenhouse-gas-emissions-reductions-in-2006.

[30] http://www.eea.europa.eu/pressroom/newsreleases/2009-greenhouse-inventory-report.

compared to the preceding year. Can we affirm that the European Trading Scheme (ETS) has contributed to the reduction? Or that it had no influence at all? Or that it has worked so poorly as to have slowed down the abatement of emissions? Clearly, the available evidence is bare-bone, and to make a judgement is very complex. However, it is essential to express a first evaluation because from it – and from Europe's ability to identify the limits and strengths of the existing mechanism – depends not only the outcome of the second phase (2008-2012), but also and above all the form of the policy instruments that Europe will provide itself with in view of the ambitious targets set at 2020 and, presumably, the position and credibility of the EU in international negotiations.

The ETS was created with a directive in 2003 and was enforced on January 1st, 2005, slightly over a month before the enforcement of the Kyoto Protocol. However, it helps to remember that the environment in which the Emission Trading Directive matured was profoundly sceptical towards the international climate treaty: up to mid-2004, it seemed destined to the trash bin, as it did not seem possible that the number of ratifying countries would be sufficient to exceed the required 55 % quota of 1990 total emissions. That was one of the conditions required by the protocol for its application. It happened only – and surprisingly – in the Fall of 2004, with the announcement and then the ratification by Russia, which in the past was always ferociously critical of Kyoto. The change in Russia's position was due to both the completion of an internal political revolution and external factors. On one hand, President Vladimir Putin managed to move off the main internal opponent of Kyoto, the former economic head councillor Andrei Illarionov, and managed to surround himself with a growing number of former KGB officers. That also played a role in the sudden change of energy policies, and represented the epilogue of the transition that started with the arrest in 2003 of the oligarch Mikhail Khodorkovsky, head of the private oil giant Yukos. The imprisonment of the tycoon and the dismemberment of the company (whose major assets were moved into the hands of state controlled companies including Gazprom) set off a return to direct, heavy public intervention, with the utilization of energy resources to political ends as well. From that moment on, for a western enterprise to operate in the energy sector in Russia became much more complex. In practice, as Nicolazzi (2004) wrote, Putin's design is that the state can draw "resources from the energy lever and decide whether, if and when, to address them on other sectors". On the other hand, the Kremlin was the focus of effective pressures from Brussels and some time later then president of the Commission Romano Prodi claimed the Russian adherence to Kyoto as his personal success and made it clear that it was the price to pay for European support for Moscow's participation in the World Trade Organization.[31]

---

[31] Nick Paton Walsh, "Putin throws lifeline to Kyoto as Eu backs Russia joining Wto", *The Guardian*, 22 May 2004, http://www.guardian.co.uk/international/story/0,3604,1222190,00.html.

At any rate, the fundamental point is that when the European Union designed the ETS, it was convinced that this would be a great jump ahead of the rest of the world, as Europe would place itself in the cosmic void created by the sinking of Kyoto, which did not involve a very large part of the planet, ranging from the United States to the largest emerging economies.

ETS identifies two phases of application: a first pilot phase (2005-2007) followed by a second momentum (2008-2012), coinciding with the period of application of Kyoto and during which companies and countries are called to obtain the objective of emission reductions by 8% next to the 1990 level. A large census at the European level identified 12,000 plants operating in four large sectors (energy activities including combustion installations with a rated thermal input exceeding 20 megawatts, mineral oil refineries, coke ovens; production and processing of ferrous metals; mineral industry including cement clinker, glass and ceramic bricks; and pulp, paper and board activities; from the end of the second phase, aviation will be added to the ETS sectors). At the beginning of each phase, a certain number of emission permits is gratuitously assigned to each of these. The distribution of the permits takes place on the grounds of a national allocation plan with which each member State declares the total amount of the emission quotas that it intends to distribute within itself. On April 30th each year, the plant will have to return a number of permits equal to its emissions. If it is unable to do so, or it did not have a way to buy quotas on the market, it must pay a fine of €40 per ton of CO_2 equivalent for the first phase, and €100 per ton in the second phase. The first phase covers only carbon dioxide, while in the second the other greenhouse gases identified by the Kyoto Protocol come into play.[32] Once the fine has been paid, the company's not exempted from cutting its emissions, so €40 and 100 respectively do not work as a cap on carbon price. Finally, the directive does not allow the banking of allowances and their transfer from one phase to another. If the enterprise that holds emission quotas in excess cannot sell them in useful time, their value crumbles to zero.

From this summary description, the three main elements of political arbitrariness of the ETS project emerge: the inclusion of some sectors and not others,[33] the prohibition of banking the permits, their gratuitous distribution at the beginning of each phase on the basis of the historical emission record in a reference period (the so-called grandfathering). Thus, the choice of the reference period becomes crucial to pick the winners and the losers. Keeping all this in mind is fundamental when the third phase is designed, a phase that will unfold over a longer time interval (2013-2020) and that foresees substantial changes, ranging from the inclusion of new sectors to the

---

32 CH_4, N_2O, SF_6, i PFC and HFCs.

33 Sectors covered by ETS are responsible fora round half or European total emissions. Other sectors, such as ariculture, transportations, services, and buildings are subject to specific regulations aimed at containing GHGs emissions. Finally, other broader policies aim at reducing the whole economy's emissions.

adoption of a permit auctioning rather than grandfathering system. It must be added that the negotiation between the member States and the Commission on National Allocation Plans (NAPs) becomes critical to the proper operation of the mechanism, as the difficulty of the path of emission reductions to which a country will be subject depends on it. A further problem comes from the fact that the data on emissions are made public by the European Environment Agency with about one year delay (and even two years delay for information about total emissions).

This imposes the design of the third phase without knowing how things are going in the second -- and without being able to know until mid 2013.

Furthermore, the albeit small experience accumulated so far by ETS gives rise to perplexities about how well it is operating. The price of the allowances, which at the beginning of the market went up from the initial €7 per ton to settle around €20-25, suddenly crashed. The crash coincides with the publication of the data on emissions by the ETS sectors. At the end of April 2006, eight member states (Czech Republic, Estonia, Lithuania, Netherlands, France, Spain, Sweden and Slovenia) certified to have generated cumulative emissions lower by 46.6 million tons than the available permits. Within a few weeks, the price of CO_2 fell below €20. The announcement of the data concerning other countries delivered the final blow to the value, which went down progressively starting September 2006, and settled permanently well below €1 per ton, where it stayed until the end of 2007. It then shot up again over €20 at the beginning of the year and the beginning of the second phase. The immediate growth reflects the prohibition of banking of excess permits, which couldn’t be transferred to 2008-2012.

In 2008, the price of permits showed high volatility around €20-25 per tonne. The value of allowances peaked on January 3rd at €23.54, then sharply decreased down to 18.84 on February 5th, after which began to rise again until July 1st (when allowances expiring in December 2008 were traded at €29.33). A new wave of reductions started and the next turning point was on August 1st (€21.38) when a period of very high volatility took place until October (during these months, prices stayed within the €20-25 band). Finally, as it became obvious that the economic crisis was stronger than expected and that economic performance and industrial activities were hardly hit, a rapid decrease occurred that led allowances prices below €15. With the beginning of 2009, prices had again wide volatility, but the overall trend is still decreasing, and the latest data available showed allowances being traded at or below €10. Interestingly enough, even future prices reflect the downwards trend: the forward prices at December 2012 for allowances is little above €10, well below the above-€17 that were paid in late 2008.

As a matter of fact, emissions from the ETS sector in 2007 (the last year for which verified data are available) were 0.8% higher than in 2006; and in 2006 they stood

1.1% above 2005.[34] That is particularly striking because, in the same years, total emissions in the EU decreased as compared to the previous year. Only in 2008 did emissions fall by 3% as compared to the 2007.[35]

It is particularly interesting to focus on price trends in 2005-7: What is the price trend due to, a trend that has effectively nullified the cost of the quota system? According to Stefano Clò (2007), a phenomenon of "over-allocation" in favour of the ETS sectors has taken place. Clò has defined two different benchmarks to evaluate the market – one referring to the pre-2005 period and the other to the year 2005 – and he concluded that "during the first phase the EU15 member States allocated an aggregated amount of 1,657 million permits, corresponding to the 42% of the EU15 target. This percentage is higher than both the pre-2005 EU15 ETS share (41%) and the 2005 EU15 ETS share (38%)... permits have been on average over-allocated to the ETS sectors belonging to the EU15 member States". In practice, the sectors covered by ETS would have obtained an unfairly favourable treatment, and dumped on the society as a whole the largest part of the cost of reductions. This has two consequences. In the first place, ETS has given little or no contribution to the reduction of emissions during the first phase, thus nullifying – at least in part – that first phase. So, the entire reduction effort will have to be concentrated in the five years that have just started, with a significant impact in terms of costs. In the second place, to achieve this result, ETS will have to be managed with a greater severity and the initial allocation of the quotas demands greater inflexibility. The national allocation plans approved by the Commission for 2008-12 reflect a sensitivity to these issues (Brussels has issued 1,439 permits versus the 1,570 requested), but this – and, in junction, the prices of quotas, which went back to pre-2006 levels – allows to predict that the second phase will have tangible costs for the enterprises and consequently for consumers, unless economic crisis is so long that for several years carbon prices are low as a consequence of low industrial activity and low economic growth (or recession).

Other authors, such as Ellerman and Buchner (2006), argued on the contrary that over-allocation didn't take place. In order to reach such conclusion, they defined a benchmark on the basis of 2005 business as usual emissions, which proved to be higher than both the allocated permits, and the actual emissions. However, as Stefano Clò (2008, p.10) shows, their analysis "does not indicate how much the ETS is contributing to emissions reductions in Europe compared to the non-ETS sectors and thus to which extent the member States rely on the ETS to achieve their Kyoto emissions reduction target". By relying on a counter-factual scenario, indeed,

---

[34] http://europa.eu/rapid/pressReleasesAction.do?reference=IP/08/787&format=HTML&aged=0&language=EN&guiLanguage=en

[35] http://europa.eu/rapid/pressReleasesAction.do?reference=IP/09/794.

Ellerman and Buchner were not able to avoid possible biases due to the fact that, among other reasons, the amount of emissions produced before 2005 by the ETS installations was unknown (Grubb and Ferrario 2006).

Over-allocation may have significant, negative consequences (Stefano Clò 2008, pp.23-24). Assuming the overall reduction target will still be met, over-allocation means that part of the reduction burden will be shifted onto non-ETS sectors. Alternatively, national governments might take care of the missing allowances, by directly buying credits, or indirectly by subsidizing non-ETS sectors: in this case, part of the burden would be shifted onto tax payers. Also, over-allocation make less urgent for the ETS sectors to buy international credit, with the consequence that national governments would buy them (Neuhoff et al. 2006). Finally, the overall target might simply be missed because of over-allocation, if neither of the above was done (or not enough) – at virtually no economic cost, but at high political cost.

The inherently political nature of the allocation also shows another side, that is, a unfairness in the distribution of permits amongst the member States. Countries which are relatively less polluting such as Italy have been penalized, while other more carbon-intensive nations (above all, Germany) issued an excessive number of permits in the first phase. From this point of view, the second phase does not seem to bring about anything new. It is true that the Commission has cut the proposal of the member states; however, by fairly cutting, it has preserved the lack of fairness. All the European countries obtained the greater part of the improvement in energy intensity before 1997 (the year when the Protocol was negotiated in Kyoto) and for reasons that are independent of climate policies; but those who have done more are called to a harder commitment than those who instead achieved less. Those who have an energy mix based on gas, the cleanest fossil fuel, do not get rewarded as compared with those who massively depend on coal. And those who have a greater marginal cost of emission reduction do not enjoy any advantage, although that indicates that a piece of the path has been walked already. In this way, we get to the paradoxical situation for which those who are less energy-efficient get, in fact, favourable treatment (Table 2).

Country	Balance [Megaton]	Energy Intensity [Tep/M€2000]	Carbon Intensity [Ton C02/Tep]
Austria	-1	150	2.21
Belgium	3	203	1.97
Denmark	14.4	105	2.50
Finland	12	230	1.59
France	19.1	177	1.40
Germany	21	162	2.33
Greece	-0.1	200	3.08
Ireland	-3.1	112	3.06
Italy	-9.5	152	2.42
Luxemburg	0	184	2.64
Netherlands	6.1	183	2.17
Portugal	0.4	210	2.32
Spain	-10.8	194	2.36
Sweden	3	175	0.96
UK	-36.4	132	2.43

Table 2. Net balance 2005 (allocated emissions – verified emissions), energy intensity and carbon intensity in EU15 in 2005. Source: European Commission 2007.

Please note that amongst the countries that have recorded an important negative balance (Italy, Spain, UK), Italy is the only one that has recorded, in 2005, a near-zero economic growth rate.[36] Unless we take into account the political dynamics behind the initial allocation, the 21 million ton CO_2 excess reported by Germany is not comprehensible. It is true that, in 2005, this country reduced its emissions by 2.3% (23.5 million tons) below 2004, but that is mainly due to "a shift from coal to gas in the production of public electricity and heat" and by the reduction of "emissions from road transportation and from households and services". Furthermore, a determining element has been a mild winter and the consequent low demand during

[36] In 2005, Italy's economic growth was as low as 0.1%, as compared with Spain's 3.6%, UK's 1.8%, and an average GDP growth for the EU15 of 1.6%.

the coldest months of the year.[37] At any rate, virtually none of that can be attributed to ETS. The same can be said of France, which furthermore produces about 80% of its electricity with nuclear power, which has no emissions but which has been, and to some extent still is, strongly subsidized.

The substantial failure of the first phase, therefore, implies a greater effort – that is, cost – in the second phase. The simple fact that the value of allowances has gone back to over €20 as Phase 2 began – leaving aside the following fall, mainly due to the effects of the economic crisis, not to emissions reductions due to the ETS – brings back as valid a series of estimates on the comprehensive impact of the reductions that were implemented before or shortly after the enforcement of ETS. The Brussels-based think tank International Council for Capital Formation has estimated the cost for Italy of reaching of the Kyoto targets into a loss of GDP as high as up to 2% per year below the business-as-usual by 2010 (ICCF 2005). Furthermore, the awareness of the substantial failure of the first phase has caused the Commission to pay greater attention to the second phase and, looking ahead, to the third one. And it is on the latter that it is necessary to focus, both because it is late to intervene on dynamics that are already in motion, and because the size of the objective embraced by Europe is much more ambitious: we are talking about 20% less emissions than 1990 within 2020, in the eight years following 2012. If the Kyoto objective are to be reached and thus on December 31st, 2012 the emissions of the EU15 will be 8% lower than 1990, Europe should proceed with an average cut of -2.1% per year, which is significantly greater than the -1.1% per year needed during the period 2005-2012.[38]

To the need to set up a system of rules that is certain and stable – a need made cogent by the size of the objectives and by the short time span in which they should be reached – and to the need for equity, the observation on the high level of inefficiency of the system as a whole must be added. Stefano Clò writes: "permits over-allocation to ETS sectors implies that these sectors will have a lower need to recur to international credits to be acquired to comply with national emissions reduction target; thus Finance Ministers and tax-payers will pay for these directly, transforming the international Kyoto flexible mechanism in a largely public-funded markets". And again: "This different treatment [in the various member States] implies that, despite being subjected to the same European regulation, different firms competing in the same market have to bear different environmental costs depending on the State where they are located". This introduces a further dimension of unfairness. The last point concerns the fact that the compliance costs – very low in the first phase and, probably, very high in the second – are just a part of the picture. The administration

[37] http://www.eea.europa.eu/pressroom/newsreleases/eu-greenhouse-gas-emissions-decrease-in-2005.

[38] In the beginning of 2005, the EU15 emissions were 0.9% below 1990, so in the seven years between 2005-2012 (when the First and Second ETS Phases take place) the EU15's emissions are supposed to decrease by further 7.1 percentage points.

cost of the ETS must also be considered, and, in particular, the effect that messages that are alternatively reassuring or disturbing about the future regime have on investments. Absent certainty, companies do not invest, and the result is not only that of reducing the reciprocal competitive pressures, but also – especially from the environmental point of view – to reduce the rate of technological innovation and thus, paradoxically, to create an opposite thrust to the objective declared by the policies, that of reducing emissions. The missed or late adoption of innovative and more efficient technologies, in fact, translates into a relative increase of emissions.

3.4. The new directive

The European Commission is aware of all these criticisms but it finds itself locked by commitments made perhaps too lightly. So, in recent months, we have seen intense work of rewriting of decisions made, culminating in the change of the objective of renewable resources from 20% of *primary* energy consumption to 20% of the *final* consumption. This is no small difference. Nor is this decision without repercussions on the target of emission reductions. In fact, as Clò and Verde (2007) show, the cut of emissions by 20% beyond 1990 was a *de facto* objective implicit in the other two that concerned the energy efficiency and green energy quotas. The change of coordinates – which significantly reduce the scope of the commitment, although it still remains very ambitious – together with other frictions we have already highlighted, made a rethinking of ETS indispensable.

The new directive introduces substantial changes, some of which are questionable. Its greatest flaw is in the zone of uncertainty which the directive says it wants to eliminate but instead amplifies. Beyond the statements of principle which change little or nothing, right off the bat the directive sets fair general objectives, such as harmonizing the emission market and creating maximum predictability and stability of choices. Furthermore, it is honestly recognized that "the environmental outcome of the 1st phase of the EU ETS could have been more significant but was limited due to excessive allocation of allowances in some Member States and some sectors".[39] Notably, the Commission claims that ETS "represents the spearhead and 'one of the most important instruments' of EU climate policy due to its ability to achieve absolute emission reductions in an economically efficient manner".[40] There is, though, no agreement on this very issue (Norregaard and Reppelin-Hill 2000).

[39] European Commission, COM(2008)16, p.2.

[40] European Commission, "Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading system of the Community", COM(2008)16, 23 January 2008, http://ec.europa.eu/environment/climat/emission/pdf/com_2008_16_en.pdf, p.2.

The new directive foresees the extension of the ETS to other plants or sectors for which it is possible to monitor emissions.[41] A linear path of emissions reductions is foreseen. Starting from the medium value of the second phase, it leads to the target of 2020. Within this general criteria, the directive proposal suggests the overtaking of the national allocation plans, to be achieved by adopting a unified communitarian cap to reach in a time period longer than the five years of the first two phases. In fact, "provides a long-term perspective and increased predictability, which is required for long-term investments in efficient abatement. This can be best achieved by an 8-year trading period until 2020 and a linear reduction of the cap that continues the reduction path beyond 2020, thereby giving a clear message to investors".[42] The other fundamental choice concerning the third phase is about the passage from grandfathering to auctioning in the allocation of quotas, such as to guarantee "efficiency of the ETS, transparency and simplicity of the system and avoids undesirable distributional effects".[43]

Thus, according to the proposed directive by the Commission, starting from 2013, all quotas for the thermoelectric sector will be allocated through auctions. This choice seems to collimate with the preferences of the majority of economists, who recognise two advantages in allocation through quota auctioning: less exposure to political whim (Joscow and Schmalensee 1998), and the ability to generate tax income. In fact, the added value created by the permits does not stay with the enterprises but is made available to the collective. This last point is open to interpretation: it is not certain (in fact, the contrary is more likely) that a larger flow of resources to public finances can be considered advantageous, both from the environmental perspective and that of proper market operation. It is true that the choice of grandfathering creates, due to its very nature, an entry barrier. But, ultimately, it is clear that the barrier exists in an auctioning system as well. The cost of entrance is in any case higher than that of the "deregulation" scenario. For those who enter, there is little difference whether the expenditure must be faced at the beginning of the year, during auctioning, or at any other moment by turning to the market.

The first argument about the greater neutrality of auctioning seems to have better foundations. Such concerns disappear, however, as soon as one goes on reading the European directive on emission trading. In spite of the initial call for harmonization and predictability, the exceptions seem far more numerous than the cases to which the presumed rule is applied. One line after stating that allocation for the thermoelectric sector is to be performed through auctioning from 2013 on, the report adds that, "in order to encourage a more efficient generation of electricity, electricity generators could however receive free allowances for heat delivered to district

[41] *Ibidem*, p.4.

[42] *Ibidem*, p.7.

[43] *Ibidem*, p.7.

heating or industrial installations".[44] However, the firmness used to pass from free distribution to sale to the highest bidder ends here: for all other sectors, the passage from free distribution to auctioning will take place gradually and in function of several factors.

It should be noted that enterprises are told that, from now to the end of the third phase of ETS, a variable allowances quota will be distributed free of charge. The quota will be different from sector to sector and from year to year, and, within the same sector in a given year, it will change from case to case. But there is more: if the other industrialised countries do not commit to reducing emissions and if (but there is no doubt about this) this establishes a competitive disadvantage for some European enterprises, these will be able to enjoy special free-of-charge quota assignments. To the political uncertainties over distribution of free emission quotas is therefore added the possibility that further free quotas (subtracted from whom? Or are they to delay the reduction objectives?) are assigned to the most energy-hungry enterprises (which ones? And in which sectors?) according to the choices of other sovereign nations. The definition of "certainty" which is in vogue in Brussels apparently includes as a variable the political choices of an undefined number of foreign countries over the next 12 years.

The passage from the report which illustrates the directive proposal that "clarifies" the mechanism – so to speak – deserves to be quoted in its entirety:

> For installations in other sectors [other than thermoelectric], a gradual transition is appropriate, starting with free allocation at a level of 80 % of their share in the total quantity of allowances to be issued, decreasing by equal amounts each year, arriving at zero free allocation by 2020. In the event that other developed countries and other major emitters of greenhouse gases do not participate in an international agreement that will achieve the objective of limiting global temperature increase to 2°C, certain energy-intensive sectors and sub-sectors in the Community subject to international competition could be exposed to the risk of carbon leakage.[45]
>
> This could undermine the environmental integrity and benefit of actions by the Community. The European industry should receive a clear commitment that the Community will take appropriate action. The Commission will review the situation by June 2011 at the latest, consult with all relevant social partners, and, in the light of the outcome of the international negotiations, submit a

[44] European Commission, COM(2008)16, p.8.

[45] That is, "the risk high emitting industries are either delocalized to sites outside the EU or that competitors outside the EU take over the market share of European companies." See http://www.europarl.europa.eu/news/public/story_page/064-32904-182-06-27-911-20080627STO32878-2008-30-06-2008/default_en.htm.

> report accompanied by appropriate proposals. In this context, the Commission will identify by 30 June 2010 which energy intensive sectors or subsectors are likely to be subject to carbon leakage. It will base its analysis on the assessment of the inability to pass through the cost of required allowances in product prices without significant loss of market share to installations outside the EU not taking comparable action to reduce emissions. Energy-intensive industries which are determined to be exposed to significant risk of carbon leakage could receive up to 100 % of allowances free of charge or an effective carbon equalisation system could be introduced with a view to putting installations from the Community which are at a significant risk of carbon leakage and those from third countries on a comparable footing. Such a system could apply requirements to importers that would be no less favourable than those applicable to installations within the EU, for example by requiring the surrender of allowances.[46]

Essentially, what can be foreseen is an uncertain, unstable and unpredictable system, as the arbitrariness of the Commission is at its height, and – presumably – the clash of lobbies in future years will rise to its height as well. The Commission's design therefore nullifies yet another of the advantages of auctioning – that is, the de-politicization of at least that slice of allowances that would be put up for auction. It is not clear how all of this could be effected without distorting the internal market. It seems that the Commission is a victim of the conflict between efficiency and equity that was denounced, in connection with a completely different theme, by Rockefeller (2007, p.52), who wrote on "the impossibility of encouraging winners and protecting losers at the same time". By the same token, it is not possible to pursue efficient allocation – where the permits actually go to those willing to pay more – which is fair at the same time. By fair, we mean being careful to not allow excessive growth (whatever that means) in the costs for some less substantial actors, whether these are relatively less developed countries or consumers with less available income.

A similar uncertainty concerns the destination of the cash flow from auctioning. Although it remains available to the member states (and is therefore considered normal tax income), "a certain percentage of the proceeds from the auctioning of allowances should be used to reduce greenhouse gas emissions, to adapt to the impacts of climate change, to fund research and development for reducing emissions and adapting, to develop renewable energies to meet the EU's commitment to using 20% renewable energies by 2020, for the capture and geological storage of greenhouse gases, to contribute to the Global Energy Efficiency and Renewable Energy Fund, for measures to avoid deforestation and facilitate adaptation in developing countries, and for addressing social aspects such as possible increases in electricity prices in

[46] European Commission, COM(2008)16, p.8.

lower and middle incomes".[47] Each of these destinations, as well as the relationship between them, implies a huge question mark, as there is a very ample definition which leaves enormous room for political arbitrariness. In some cases, such as incentives for renewable energy resources or the financing of social tariffs – this overlaps existing programs, introduces further distortions to the electricity market, and potentially creates conflicts with liberalization, since it limits price competition between electricity service suppliers.

It is not the case here to go further into the complex – and, needless to say, arbitrary – mechanisms of the recognition of credits matured through the flexible mechanisms of Kyoto. The Commission states its intention to discourage free riding by companies that operate in nations which have not concluded an international agreement, except for those companies which have their headquarters in third nations or administrative entities connected to the European emission exchange system. Here too, what this means *specifically*, and which behaviours are and are not legitimate, is not and cannot be clear.

In general, there is no indication of effort in the proposed directive to put together a system which is what the Commission says it wants, and which is a clear and predictable mechanism. The very choice of auctioning, with its function of the depoliticising of the initial allocation eliminated or at any rate limited, seemingly reduces itself to an infernal mechanism. On the one hand, the mechanism acts as a pre-emptive tax on enterprises, who obviously will attempt to pass the costs onto consumers, in a total absence of transparency. On the other hand, it represents a formidable – as well as invisible to consumers, who rightfully do not care about the costs of the manufacturers – source of income that can be destined to both general taxation, and to a series of public expenditures which interfere with the projects in progress and with the good functioning of the market. All that with a further aggravation: as the price of the emission quotas has been and probably will be volatile, the public proceeds of the initial allocation can hardly be forecast. Consequently, governments from time to time will find themselves with a sort of unexpected treasure in their hands, which can be freely expended, virtually without any criterion – a veritable windfall profit for public finances.

The only true – and well questionable – advantage of such a system is that, because of its complexity, it will hardly be able to become the object of true public debate. Paradoxically in view of the premises, this allows an extremely high degree of politicization of the system in each of its stages: in the initial allocation of permits, in the possible additional allocations, in the concession of exemptions or facilitated conditions, and in the use of the revenues. Clearly, the supporters of a restrictive policy of control of emissions have a good game in favouring policies the costs of which are not visible to consumers (Stavins 1998). It is however natural to ask

[47] European Commission, COM(2008)16, p.9.

ourselves whether all this is in the public interest – that is, whether this is effective in the reduction of emissions, and efficient in pursuing this end at a contained cost and with the induction of few or no distortions in the internal market (under the non obvious assumption that emissions reductions are in the public interest, in the first place). All in all, the impression is that the Commission is designing a sort of mechanism which is strongly bureaucratic and politicized, and which has the undeclared purpose and the fundamental function of generating a fiscal income and to create opportunities for rent-seeking for the countries, the industries and the firms that are politically stronger and more aggressive.

3.5. The final compromise

After the presentation of the proposed directive by the Commission in January 2008, a wide debate emerged between member States and industrial sectors, who found several flaws in the proposed plan. Two issues have been emphasized: (a) the risk of carbon leakage and (b) the high costs of the plan. At one point, a wide coalition of countries – including Italy and ten Eastern European member States – threatened to veto the proposal, if their objections had not been considered. In order to achieve the necessary consensus, a number of concessions have been made. A version of the Directive amended accordingly has been advanced by the Commission and approved by the European Parliament in December, with a strong support of the French rotating Presidency (second semester 2008). The new Directive will reform Directive 2003/87/EC, that created ETS.

The relevant changes are the following:

- A Community-wide quantity of allowances will be defined by 30 June 2010, that will decline in a linear manner from the mid point of the period 2008-2012 by 1.74 % per year (Article 9);
- Allowances will be either auctioned or allocated free of charge (Article 10.1);
- Of the total allowances to be auctioned, 88 % will distributed among the member States proportionally to past verified emissions; 10 % will be distributed between some member States for the purpose of solidarity and growth; 2 % will be distributed to member States "whose GHGs emissions in 2005 were at least 20 % below the reference year" (Article 10.2);
- The use of the revenues from auctioning will be freely determined by member States, provided that at least 50 % of the revenues will be used for at least one between the following (Article 10.3):

- to reduce greenhouse gas emissions, including by contributing to the Global Energy Efficiency and Renewable Energy Fund and to the Adaptation Fund as operationalised by UNFCCC COP 14 in Poznan , to adapt to the impacts of climate change and to fund research and development as well as demonstration projects for reducing emissions and adaptation , including participation in initiatives within the framework of the European Strategic Energy Technology Plan and the European Technology Platforms;
- to develop renewable energies to meet the commitment of the Community to using 20% renewable energies by 2020, as well as to develop other technologies contributing to the transition to a safe and sustainable low-carbon economy and to help meet the commitment of the Community to increase energy efficiency by 20% by 2020;
- for measures to avoid deforestation and increase afforestation and reforestation in developing countries that have ratified the future international agreement ; to transfer technologies and to facilitate adaptation to the adverse effects of climate change in these countries;
- for forestry sequestration in the EU;
- for the environmentally safe capture and geological storage of carbon dioxide , in particular from solid fossil fuel power stations and a range of industrial sectors and sub-sectors, including in third countries;
- to encourage a shift to low emission and public forms of transport;
- to finance research and development in energy efficiency and clean technologies in the sectors covered by the scope of the directive;
- for measures such as those intended to increase energy efficiency and insulation or to provide financial support in order to address social aspects in lower and middle income households;
- to cover administrative expenses of the management of the Community scheme;

- Member States "may also adopt financial measures in favour of sectors or sub-sectors determined to be exposed to a significant risk of carbon leakage due to costs relating to greenhouse gas emissions passed on in electricity prices, in order to compensate for those costs and where this is in accordance with state aid rules applicable and to be adopted in this area" (Article 10a.6);
- The amount of allowances allocated free of charge will be as high as 80 % of the total in 2013, and will gradually be reduced down to 30 % in 2020 and zero % in 2027 (Article 10a.11);

- Every 5 years the Commission shall determine which sector or sub-sectors are exposed to significant risks of carbon leakage, but the Commission may also add a sector or sub-sector at its own initiative (Article 10a.13).

While some of the shortcomings of the earlier version of the Directive have been apparently fixed, most of them still remain (Stefano Clò 2009). Particularly, the high level of uncertainty regarding which sectors and subsectors will enjoy the allocation of free of charge allowances is not reduced. This will comparatively reduce the amount of investments in innovation or measures that might actually reduce emissions. The fact that not just the Commission, but also member States are allowed to put in place measures as to address the risk of carbon leakage – or, more broadly, of competition from firms based in non-restrained markets. Here the paradox emerges: if no protective measure is taken, a risk of delocalization (which would at best leave total emissions unchanged) arises; if carbon-intensive sectors or subsectors are partly or totally sheltered from the effects of ETS, either the reduction burden will be shifted onto other subjects, or targets will be missed.

The most relevant change with respect with the earlier version of the directive is that the transition towards a 100% auctioning system is significantly delayed. Instead of reaching the target of 100% auctioning in 2020, the target will be reached in 2027, 7 years later than originally planned as well as 7 years after the policy will be expired. In 2013 – the first year of application of the directive – only 30% of the allowances will be auctioned. Despite the numerous calls for fairness and non-distorsive measures, the difference between sectors such as electricity, that are required to buy allowances from the very beginning, and others that will be exempted from buying permits might create disparities of treatment that may not be fully justified.

Moreover, and perhaps even most importantly, the potentially distorsive effect of the use of the revenues from auctioning is still in place. The very effect of a cap & trade scheme is supposedly to create a levelled playing field, whereby carbon-based energy sources and carbon-intensive industrial processes are made more costly, and low-carbon or carbon-free technologies are subsequently advantaged. Theoretically, *if* the overall cap is sufficiently stringent and *if* not too many sectors or subsectors are recipient of free of charge allowances, there would be little or no need for further incentives or subsidies. In fact, the latter might even distort the well functioning of the electricity market or other markets, by inducing a political allocation, rather than an economically efficient allocation, of resources. On the top of that, renewable energy sources and other low-carbon or carbon-free technologies are already strongly subsidized through a number of policy measures, including (but not limited to) green certificates, white certificates, feed-in tariffs, mandates, etc.

3.6. An alternative proposal: the carbon tax

The choice of a system of tradable permits, made by Europe at the moment when it launched ETS, responds to many reasonable considerations. The old instruments of command and control proved themselves to be inefficient and often even ineffective. That is even more true in a case such as that of greenhouse emissions, which are created by an extremely high number of sources (virtually any living being emits greenhouse gases and even when we limit ourselves only to human activities, every production process creates CO_2 and other GHGs). The costs of information, and with them those of control and enforcement, are therefore very high. And not only that: to define technological or performance standard, in this case, is very complicated. That is because not all processes can obtain the same results. In some cases, it is technologically and economically possible to pursue consumption or emission reductions, and alternatives are available. In other cases, that does not happen. The number of scientific uncertainties and the necessarily long-term projection of policies – which should take technological progress into account – multiply the risks that regulation will fail.

In such a situation, powers of discretion are indispensable, and they represent a strong temptation for rent-seekers, and make it almost certain that regulators will be captured.

The alternatives to command and control are economic instruments, which "provide an explicit price signal to regulated firms and individuals" (Hepburn 2006, p.228). These instruments consist of instruments based on price and those based on quantity. Because a regulation of quantities assigns an implicit price to the goods subject to regulation – generally, a polluting substance, the emissions of which are the target of reduction – in ideal conditions the result of the two instruments would be identical. It is also possible to conceive hybrid forms, for example, regulation of quantities with a price cap, a price floor, or both.

In theory, and in the abstract, there is no reason to prefer one instrument over the other (Requate 1993). This is because they are equivalent under ideal conditions. However, when we descend from theory to practice, things change. There are several issues to confront that can direct the choice in either one or the other direction. The main themes concern the efficiency of the policies in the real world, the relative risk of regulatory capture, the extension of uncertainties, and also more general questions such as transparency, the distorting effect of the market, and political acceptability. Finally, considerations concerning transaction costs underlying the creation of an explicit market within a regulation of quantities are of importance. To this end, we will consider here two options: the ETS on one hand – which assigns a cap to greenhouse emissions and allows a market for emission quotas – and the carbon tax on the other, which should reduce consumption (and thus emissions) through an increase of the prices of products or services which are suspected of contributing to global warming, that is, fossil fuels.

From a theoretical point of view, little can be said, especially in terms of the incentive to innovate that different policies can create. Apparently there is no a priori reason to prefer either one (Downing and White 1986; Milliman and Prince 1989). Requate (1998) argues that, while both policy instruments can be preferable under different conditions, a tax system might prevent a real competition between non-polluting technologies. On the contrary, Weitzman (1974) shows that – in a situation of uncertainty about marginal costs – a price instrument is more, or less, efficient than an instrument of quantity when the curve of marginal benefits is relatively less, or more, steep than that of marginal costs. In the case of global warming, as Hepburn (2006, p.232) observes, "suppose the marginal cost of reducing emissions increases quickly as we move from eliminating the cheap, 'low hanging fruit' on to more difficult sources of emissions (e.g. aviation transport). Suppose also that, because damages from climate change are a function of the stock of greenhouse gases in the atmosphere, they are only a weak function of emissions over short periods (e.g. 5 years), so that the marginal benefit from abatement is relatively flat. In such circumstances, a price instrument – a carbon tax – is the appropriate instrument to use." These assumptions are consistent with the available evidence.

In fact, the marginal costs of emission abatement are clearly growing with a relatively steep curve. In the more energy-efficient countries, such as Italy, to cut the emissions is far more expensive than in countries that are less energy-efficient, such as Germany, let alone countries that are far less efficient such as the emerging economies, including China and India. Think, for example, that the efficiency of a coal-powered plant in Europe exceeds 40%, while in China the average efficiency is around 20%. If it were possible to export European technology to China for all new installations, it would be possible to obtain, at a relatively low cost, a much more substantial result of the objectives of the Kyoto protocol, assuming that they are reachable and that they are actually materializing later. According to the projections of Montgomery and Tuladhar (2006, p.4), the adoption of an American technology (less efficient than the European technology) for the new investments in the electric sector in China and in India could determine, in 2012, an emission savings more than four times greater than the domestic objectives of the European Union.

Conversely, the marginal benefit of emission reduction grows with a very mild curve, as the forcing of climate grows logarithmically next to the atmospheric concentration of greenhouse gases.[48] Nordhaus (2007, p.126) writes: " the structure of the costs and

[48] Once a very low threshold is passed (about 50 ppm in volume), each doubling of the concentrations determines an equal increase of the forcing, about 3.7 watts per square meter. Thus, if we move from a CO_2 concentration of 280 ppmv (that of the pre-industrial era) to 560 ppmv – double – the forcing grows by 3.7 watts per square meter; if we go from 560 to 1,120 ppmv, the increase of forcing is still 3.7 watts per square

damages in global warming gives a strong presumption to price-type approaches. The reason is that the benefits of emissions reductions are related to the stock of greenhouse gases, while the costs of emissions reductions are related to the flow of emissions. This implies that the marginal costs of emissions reductions are highly sensitive to the level of reductions, while the marginal benefits of emissions reductions are insensitive to the current level of emissions reductions".

In these conditions, an instrument of price regulation seems preferable to one of quantity regulation.

To these considerations on efficiency we can add one concerning the proper operation of the policies. From the institutional point of view, the creation of a market for emission quotas such as ETS – destined to have a growing level of complexity and inclusiveness – implies a commitment, that is, a mobilization of resources for the managing and the maintenance of the necessary administrative infrastructures which is far superior to that of a carbon tax (Helm 2005). That indicates a criticality in the European structure: the Union has decided to give birth to a new bureaucracy that administers a system from which the destiny of a large part of European productive activity depends. The decisions never have an exquisitely technical nature, but come from political evaluations or from difficult and unstable balances of power between lobbies and member States, and within each of these groups. What is worse, the boundaries between these components of the decisional process are fuzzy and hardly distinguishable. All in all, it is virtually impossible to know whether a certain decision – for example, to include a sector in the ETS, allocation of free-of-charge allowances, distribution of binding objectives – comes from the work of one or more technical study groups, or from the persuasive arguments presented to policy-makers in smoke-filled rooms.

This uncertainty about the future – and about the decisions that will ensue – provides a valid argument in support of a carbon tax as opposed to a cap & trade scheme. Because of its nature, a carbon tax guarantees top transparency. Everyone knows that for each ton of CO_2 produced, they will have to pay, say, €25 (just to indicate an amount in line with the forward prices of the emission quota on ETS which is consistent as we shall see with the suggestions of climate economists). To obtain maximum transparency it would be appropriate to imagine a system of transferability, so that the tax is (or at least may be) entirely passed on to the consumer. That meets the need to give the consumer the function of allocating the emission reductions in the most efficient way, that is, a way that responds on one hand to a cost criterion and on the other to the relative replaceability of products at greater emission intensity. In this way, the market would be free to operate, although

meter (today, the concentrations are about 380 ppmv). It follows that, no matter the complexity of relation between emissions (a flux) and concentrations (a stock), each emission unit saved determines a smaller increase of the forcing less than was due to the previous unit, which instead was sent into the atmosphere.

under a substantial bond turned to penalize those productive processes that are the most energy intensive and, upstream, the fossil fuels. The transferability of the tax demands, of course, the traceability of the emissions. But that is possible with relatively low costs, as almost all the reducible emissions come from fossil fuels combustion. Thus, the monitoring must concern only the fuels and the path that they follow to reach the final consumer.

Apparently, the transferability of the tax lends itself to a substantial objection: it could discourage innovation in processes or products that cut the emissions. In fact, the cost of innovation falls on the enterprise, while the saving (the tax that is reduced or cancelled because of the effective reduction of emissions) goes to the advantage of the consumer. In part, this problem solves itself: although the direct advantage goes to the consumer, the ultimate result is that the retail price of the product in question is lower and thus – all other conditions being equal – the demand increases and the market share of the innovative enterprise grows as a consequence. But even if this were not enough – that is, if the additional profits from the greater sales were not sufficient to cover, in a reasonable amount of time, the cost of investments – the system could be reinforced by recognizing a tax credit or other forms of write-offs of the investments employed to reduce emissions. It is obvious that this foresees a spread and sharing of information especially concerning benchmarking to evaluate the innovative contents of the investments, but it certainly defines a more linear, predictable and certain system than that which is strongly bureaucratic and built around ETS.

By the same token, a carbon tax seems less distorting of the market than the current cap & trade, because of a smaller administrative structure and greater predictability. It is true that a tax, just like the emissions ceiling, can be reviewed at any time and increased, thus nullifying the projects of enterprise that were based on the earlier tax. In the case of ETS, however, to the possibility of more or less occasional changes in the structure of the system, we can add a *certain amount of uncertainty* on how the ETS will be applied, which sectors will be actually called to contribute, in what way the gratuitous quota will be allocated, etc. To all that, two further elements must be added. In the first place, a system like ETS required the assignment of sectoral targets, and thus not only does it imply a significant degree of arbitrariness, but also, due to its own nature, it creates continuous clashes of lobby groups. In the second place, and more importantly, a carbon tax is the only way to call all sectors to contribute in the most efficient way to emission reductions. Besides its internal limitations, ETS is also limited to a few sectors, and therefore covers only part of the parties involved in emission reductions. As a result, ETS adds itself to other public policies – which can be of the command and control type but also subsidies or regulatory incentives of various kinds – which in turn induce distortions and high costs. Conversely, a carbon tax because of the way it works would substitute for all that and require, if not a total cancellation (which would be desirable nevertheless), at least a process of resizing, rationalization and simplification of the subsidies, particularly as concerns renewable energy sources.

This leads to another, two-fold basic theme: what is the purpose of a tax? It is obvious that, in a realistic perspective, and beyond the reasons that justify its imposition, a tax has the sole purpose of creating public revenues. In this case, however, as Albrecht (2006, pp.89-90) explains, "Environmental taxes can, however, be installed with the purpose to change behavior or with the purpose to collect revenues… Consequently, the tax revenues will also shrink with the tax base". It is probable, however, that the consumption reduction will take place slowly, given both the scarce elasticity of the demand for energy products in a broad sense (transport included), and the long times of the investments return in capital-intensive industries. Thus, the concerns for the reduction of income should not lead to any particular decision in the short term. Albrecht suggests (and this is consistent with the proposal here advanced on transferability of the tax) inserting environmental tax (including a carbon tax) in a general reform of consumption taxes. In the second place, what is to be done with the income of the carbon tax? Should the member States use it, as the European Commission would like to do with a part of the income from the auctioning of permits, to finance environmental programs (whatever could be included under this label, read: anything) does not seem a reasonable solution, as it causes distortions. Furthermore, the carbon tax assigns an implicit advantage to sources and technologies that are "clean", but also puts them all on the same level. Conversely, incentive programs assign differentiated subsidies, further misrepresenting the operation of the market. Since one of the effects of a carbon tax – and the main one from the point of view of consumers – is the increase in the prices of consumption goods including some that are widely used and considered indispensable, such as electricity and transportation fuels, it seems that the request to cut the reform of environmental taxation to fit the principal of fiscal neutrality makes sense. Table 4 shows the increase that some products would undergo in the absence of a reform of the environmental tax if a €25 per CO_{2eq} ton carbon tax were imposed (in line with the ETS prices, but much greater than that which Nordhaus (2007, p.23) considers to be the optimal short-term tax in the event of global participation).[49] The choice of such a high tax is justified both by the coherence with the indications from ETS (which does not reflect the optimal objective, but the administrative one of reducing the emissions by 8% below the 1990 level by 2012), and by the fact that Europe is alone in its effort is not and probably will not be part of an inclusive global strategy.

[49] "In the ideal world, the carbon price or carbon tax would be $27 per metric ton in 2005 in 2005 prices. (If prices are quoted in prices for carbon dioxide, which are smaller by a factor of 3.67, the optimal tax is $7.4 per ton CO_2)", Nordhaus (2007), p. 23.

Product	Emissions	Carbon tax €25/ton CO_2
Transportation	[kg CO_2/litre]	[Euro cent/litre]
Green gasoline(*)	2.35	5.87
Diesel(*)	2.60	6.5
Electric generation	[kg CO_2/kWh]	[Euro cent/kWh]
Natural gas(#)	0.40	1
Oil(°)	0.73	1.82
Coal(§)	0.91	2.27

Table 4. Simulation of price increases of some energy products with a €25/ton CO_2eq carbon tax in the absence of an environmental tax reform. (*) Emissions due to combustion alone; 7-10% should be added to take into account the emissions concerning refining and transport. (#) Combined cycle with 50% efficiency. (°) Steam turbines, counterpressure/condensation/conventional with 38% efficiency. (§) Steam turbines, counterpressure/condensation/conventional with 37% efficiency. Source: own elaboration from various sources.

Clearly, we are talking about significant figures, which must be handled with extreme caution. The double observation that, on the one hand the carbon tax erodes the buying power of income and that on the other hand it is appropriate that the tax is transmitted to the end consumer so as to obtain the most efficient allocation of the reductions, supplies us with an indication as to how to utilize the "little treasure". It can be profitably employed to reduce the income tax rates, which in turn is a strongly distorting tax. Nordhaus (2007, p.129) argues: "If the carbon constraints are imposed through taxes, and the revenues are recycled by reducing taxes on other goods or inputs, then the increased efficiency loss from taxation can be mitigated, so that there is no necessary increase in deadweight loss".

The reduction of income taxes (personal and corporate) is, in a country such as Italy, a priority regardless of climate policies (Giannino 2007).If this road could be pursued, the impact of European climate policies would be more tolerable. And not only that: a (difficult) strategy of comprehensive overhaul of the fiscal system that puts together the introduction of carbon tax with the reduction of the income tax and the rationalization and significant reduction of subsidies of renewable energy sources could, paradoxically, and although the causes are certainly debatable, determine an improvement of the fiscal and normative environment in Europe, and certainly in Italy. At least the deadweight loss would be reduced, which is due to the co-existence of several taxes, all of which more distorsive than a carbon tax. This would be done by introducing certainty and transparency and by truly delegating to the market –

although altered by an emission tax – the task of allocating emission reduction. Furthermore, by inducing general relief of fiscal pressure, the carbon tax could represent an important element in the restoration of competitiveness on the old continent. Of course, such a restoration would not be absolute, but it would be effective if part of a comprehensive project and related to the current situation.

Both the carbon tax and a cap & trade system have the effect of increasing the final prices of a series of products. But, while the cap & trade seems to proceed down mysterious paths, the tax acts in visible mode. This visibility establishes two consequences. In the first place, it allows greater price transparency and gives less grounds for vaguely populistic protests, while offering fewer reasons for policies heavily oriented towards price control in moments when, for the most disparate reasons, the prices go beyond a level that is arbitrarily considered too high. In the second place, even the regressive effects of the carbon tax – which are, in substance, the same as the cap & trade – are more visible. The impact on society becomes, therefore, equally visible, and the need to upgrade the fiscal system becomes more felt even from the political point of view.

3.7. Would a carbon tax work?

The simple simulation above, provides little information about the real extent of a price-based policy. More information are required in order to assess its usefulness.

As it was recalled, a carbon tax of 25 € / TonCO_{2eq} would impose an extra-cost of c€ 5.87 and 6.5 per litre of gasoline and diesel, respectively. As to electricity, the average increase on the generation cost per kWh would be c€1.39. The contribution of each single carbon-based source of energy has been weighed for its own share of 2007 generation (in 2007, 7.2% of the gross electricity generation in Italy came from oil-fuelled plants, 55% from natural gas power plants, and 14% from the combustion of solid fuels – see Terna 2008). It is assumed that, in the short run, such price increases shall not induce changes in the Italian generation mix, as most of the existing power plants are not yet fully amortized, the life cycle for this kind of capital asset is relatively long, and anyway the time for licensing, authorizations, and construction of new plants is at least a few years long.

In 2007, the average price for electricity in the IPEX (the Italian electricity exchange) was some 71 € / MWh (GME 2009), equal to 0.71 € / kWh or 71 c€ / kWh. The average price of gasoline and diesel was, respectively, 1.343 and 1.204 € / litre (UP 2009). As a consequence, the average increase in prices would have been by 2% for electricity, and 4.4 and 5.4%, respectively, for gasoline and diesel.

To understand what consequences might follow, one should look at the demand elasticity for energy. Price elasticity for electricity is generally found relatively low in empirical studies, especially in the short run. Elasticity in the long run might, however, be more significant. A review of the most recent studies, performed by Lijesen (2007), shows that short run elasticity ranges from -0.04 (Al Faris 2002) to -1.113 (Woodland 1993), with an average value of -0.32. According to the same source, estimates for long run elasticity range from -0.09 (Boonekamp 2007) to -3.39 (Al Faris 2002), with an average value of -0.57. This means that a price increase by 2%, might be expected to determine a short run demand reduction of 0.64%, and a long run reduction of 1.14%.

As far as the demand for motor fuels is concerned, Liu (2004) estimates a short run elasticity of -0.191 for gasoline, and -0.094 for diesel. Long run estimate are, respectively, as high as -0.318 and -0.516. A review of the most recent studies performed by Goodwin, Dargay and Hanly (2004) found an average elasticity for motorfuels of -0.25 in the short run (in the range between -0.01 and -0.57), and of -0.64 in the long run (with a range that varies from 0 to -1.81). This means that a price increase between 4.4 and 5.4% would result in a reduced demand by around 1.1-1.35% in the short run, and by 2.8-3.5% in the long term.

Emissions would be reduced accordingly. Some caution is needed, though. Estimates for price elasticity of energy consumption are extremely diverse – because, among the other reasons, the data tend to be relatively poor, and changes in prices get mixed up with changes in demand due to changes in income (and viceversa). Also, technological progress and public policies may affect energy consumption in several ways, which may not be fully captured in models trying to estimate demand elasticities. As a consequence, the estimates tend to have a very wide confidence interval.

This makes it more difficult to make reliable forecasts of the demand variations in response to a price increase, which exactly what a carbon tax (as well as a cap & trade system, from the consumer's perspective) would result in.

3.8. Which tax?

The above-mentioned problem can be overcome if a further question is correctly answered. The question is: What is the policy goal? If the goal is to reduce emissions (or energy consumption) by a given amount, *at any cost*, then cap & trade (or even more stringent "command & control" policies) is probably the better choice. If, instead, the goal is to achieve the most efficient setting from an allocational point of view, i.e. to internalize the external costs, then the real issue is, in the first place, to correctly estimate what are the external costs. In this perspective, the only metric that can be employed to measure the external costs is money (Pearce et al. 1996; Smith et al. 2001). After that complex task has been pursued, it will be possible to compare the cost of global warming's impact with the costs of mitigation measures that are adopted today. It will also be possible to appropriately set prices or quantities, depending on the kind of policy which is implemented. Naturally, such comparison should be made at the margin. Tol (2003) reviewed the most recent studies on the issue. The findings are the following: "the best guess for the marginal costs of carbon dioxide emissions is $5/tC, but the mean is $104/tC. This difference reflects the large uncertainty combined with the notion that negative surprises are more likely than positive ones". Tol et al. (2001) and Pearce et al. (1996) also argue that estimates exceeding $50 per ton of CO_2 rely on pessimistic and unlikely scenarios for climate change, impact sensitivity and economic values. Subsequently, it can be stated that the marginal costs of climate change are most unlikely to exceed $50 per ton of CO_2, and they are very likely to stand much below that threshold, with a best guess around $5 per ton of CO_2. Climate change impacts are also likely to increase as time passes and atmospheric concentrations of CO_2 rise.

Under the present state of knowledge, there are many ways to design a carbon tax. Two will be presented.

Nordhaus (2007, p.22) proposes a "policy ramp", whereby a carbon tax is imposed which gradually increases. According to Nordhaus, "policies involve modest rates of emissions reductions in the near term, followed by sharp reductions in the medium and long term. Our estimate of the optimal emissions-reduction rate for CO_2 relative to the baseline is 15% in the first policy period, increasing to 25% by 2050 and 45% by 2100. This path reduces CO_2 concentrations, and the increase in global mean temperature relative to 1900 is reduced to 2.4°C for 2100 and 3.4°C for 2200". The advantage of such an approach is that it would create a predictable policy path in the future, under which businesses and consumers might make the most efficient choices as to which technologies should be employed, and which would be the most efficient rate of turnover for those technologies. On the other hand, the policy would rely on early estimates for the marginal costs of CO_2 emissions, so it might be not enough responsive to the new evidence. True, it might be revised periodically, but this would (a) reduce its predictability and (b) require a continue re-assessment of the best science by national governments or other international bodies concerned with climate change. While some degree of policy change is necessary, as scientific understanding of global warming provides more information, a continual revision of the policy might not be the best possible solution. In fact, it would require policy-makers to follow the scientific debate up to an extent they are not possibly qualified, and might determine an even stronger politicization of science, which would make the political debate between scientists as much vocal as the scientific debate between policy-makers (Pielke 2006; Lindzen 2008).

The policy would require modest costs to be undertaken immediately, but an increasing cost in the future, as the consequences of global warming become more severe. A gradual increase would be a reasonable compromise between the request to address global warming as soon as possible, and the need to implement policies that do make not too much harm to GDP growth. One might argue that, all else being equal, a faster economic growth implies an increase in emissions, while when GDP slows down, emissions fall too. So the economic impact of the policy would be such that it parallels economic growth, rather than curbing it.

A different proposal can be developed, that allows a built-in correction rule for the tax as evidence becomes clearer. Kelly and Kolstand (1999) and Leach (2007) suggest to test the policy ramp by observing the response of a state variable to the policy itself, as well as to other factors which may or may not be known. A Bayesian learning routine allows such information to be incorporated in the policy, which would be corrected in both direction – that is, becoming more or less stringent – as its goals become more or less close. Their own research, however, show that in the case of climate change evidence may take a lot a of time before it is properly understood, so that corrections may not be applied on time or may respond to wrong information or to a poor understanding of the processes.

In taking advantage of these arguments, McKitrick (2008) propose a pricing rule which is designed in a way that it, so to speak, corrects itself, as a reaction to a state function which is easily observable. The real issue, in this perspective, is not the pricing rule per se, but to find an agreement over the state function. In fact, assuming that temperature (or average temperature) can provide the relevant information, it makes a lot of difference, both in temperature levels and in temperature trends, where you take the measure. Surface temperature data's quality has been questioned, both with regard to land temperature (de Laat and Maurellis 2006; McKitrick and Michaels 2007) and over oceans (Thompson et al. 2008; Christy et al. 2001). Measures from weather balloons are also disputable (Lanzante and Free 2008). McKitrick suggests that weather satellites may provide the most stable and reliable metric since when they collect tropospheric data (1979) (Spencer and Christy 1990; CCSP 2006; Randall and Herman 2008). Subsequently, it should be decided where to take temperatures: following IPCC (2007) and CCSP (2006), McKitrick proposes to take reference temperatures in the tropical region, from 20 degrees North to 20 degrees South.

McKitrick, hence, suggests that the mean temperature as measured by weather satellites in the tropical troposphere may provide a workable definition of the state function, that is the input of a pricing rule for a carbon tax policy. Remarkably, "if the present trend continues the Nordhaus path and the state-contingent path would closely coincide" (McKitrick 2008, p.12). The most compelling aspect of such proposal, is that it provides a policy instrument that deals with uncertainty. At the same time, it doesn't need too much of an information exchange between policy-makers and scientists, except for the obvious need to keep correcting the policies if it become clear that anthropogenic emissions are less (more) responsible for climate change, or that climate change impacts are less (more) severe than expected.

A possible objection would be that, by progressively updating the tax according to the temperature measurements in the tropical troposphere (which are subject to a relatively wide natural variability, independent from climate change), one benefit of the carbon tax over a cap & trade scheme (more predictability) might be lost.
Several responses can be provided. First, even Nordhaus' policy ramp would be updated, based upon a less objective variable – climate forecasts vs. actual climate. This is a key point, in terms of limiting the interaction between policy-makers and scientific debates they may not be able to fully understand. Moreover, a consensus might not emerge even within the scientific community, with regard to which projections are to be considered more likely.
Secondly, carbon tax corrections may be scheduled in a way that they do not result in too rapid changes – for example, the carbon tax level may be updated every three to five years, instead of annually, and by doing so it would provide an acceptable level of certainty to energy companies or energy-intensive businesses.
Third, companies themselves may (and in most cases do) have their own scientific experts, who provide the management with an assessment of the best available science. So, companies would have their own expectations regarding climate, and based upon these they can have their own forecasts about the future levels of a carbon tax. A probability level might be attached to any possible scenario, so that companies do have a range of possible alternatives for the future policy paths that depends upon a pricing rule which is known in advance.
Fourth, such process would generate a less politicized, more informed debate on the issue, because from the expectations regarding future temperatures, the future investment strategies would derive. So, any party would have an interest in assessing the *most likely* outcome, not the outcome that would be *most likely to yield the desired policies*. By the same token, it is likely that more information would be generated and made available, and the understanding of global warming would be improved.
Fifth, it is true that Nordhaus policy ramp relies on projections (so it incorporates some knowledge about the future) while McKitrick pricing rule relies on actual temperatures (thereby responds only to the past). At the same time, however, projections for future temperatures rely on the past record too, and the current temperatures are part of a trend that began long time ago and is expected to continue for a long time in the future. It will take time, in fact, for emission reductions to produce a sufficient reduction in the stock of GHGs in the atmosphere, that will in turn slow down the warming process. So there is a lag – that can't be avoided – between the moment policies enter in force, and the moment when results are delivered. There is a degree of arbitrariness, hence, that can be better filled by relying on objective measures than by adopting questionable – however complex – forecasts about the future.

Finally, the McKitrick's pricing rule for a carbon tax has four major advantages over a cap & trade system:

(a) It links the observed temperature – that is, the past temperature trend – with an estimate of the social costs of today's emissions. Its aim is to internalize the external costs, not to "save the world:" it is therefore likely that it would result in the most efficient mix of present consumption, investments in carbon-saving existing technologies, and innovation. On the contrary, a cap & trade scheme requires an assessment on what is the optimum amount of emissions today (a flow) to reduce atmospheric concentrations of GHGs tomorrow (a stock) in order to achieve the goal of containing temperatures increase. Several uncertainties and confounding factors are involved, that might induce misunderstandings or misconceptions. In fact, a major possible (if not probable) shortcoming of a cap & trade scheme lies exactly in the determination of the cap, which is subject to far greater uncertainties and risks of being politically derailed than the determination of the tax in a price-based policy. The problem would be made even bigger by the above-mentioned policy instruments that the European Union and/or other actors are considering in order to put in motion a cap & trade scheme.

(b) Under a cap & trade scheme where the cap is set with regard to ambitious environmental goals (e.g., keeping global average temperatures below 2 degrees more than the pre-industrial levels) that may not be completely controlled and that are subject to a number of uncertainties and confounding factors, the scientific debate may tend to become more politicized. In fact, privately-owned companies, rent seekers and national governments may have an interest in promoting one specific scientific view, that might lead to setting a cap more or less stringent, according to their own convenience. Under such a scheme, there would be little room for finding an agreement over an objective, non-politicized indicator.

(c) The price attached to emitting one ton of CO_2 would be far more certain under a carbon tax, whose level is established through a simple, well-known rule, than under a cap & trade system. That is generally true, and even more so as one considers that a number of exemptions and loopholes are created in order to save endangered companies. Price predictability over the medium-long run is a fundamental feature of a policy which aims, among the other goals, at creating a framework for innovation. If uncertainty relative the carbon price adds to "normal" market uncertainties, the payoff as well as bankability of investments might become less uncertain, too. And, again, more resources might be devoted to lobbying activity and to pay for the price of permits (that, differently from a carbon tax, might be hardly transferred onto consumers), and less resources might be made available for innovative or carbon-saving investments.

(d) An international agreement over a carbon tax following a simple, predictable rule may be easier to reach, than an agreement creating a complex cap & trade scheme, that national governments can (and most probably will) manipulate in order to meet requests from interest groups. Because of its simplicity, a carbon tax leaves less room for opportunistic behaviors, and might help to fill the lack of mutual trust between the parties.

As an addendum, the revenues from a carbon tax – being more easily predictable – might be employed in reducing income or labor taxes, or other taxes. Therefore, a carbon tax may well be made revenue-neutral. That is far more complex in the case of a cap & trade scheme, both because its revenues would be more uncertain, and because consumers wouldn't perceive it as clearly as they would do with a tax. This makes it more likely that a suboptimal use of the proceedings is made, as in the case of European Union that requires the member States to spend money from auctioning in subsidizing technologies or behaviors, and by doing so is probably going to distort the markets for products and services. In turn, a carbon tax would make irrelevant any other kind of subsidies or mandates, by creating a leveled playing field and by internalizing the external (expected) costs from the use of fossil fuels. In practice, a cap & trade system where part or all the permits are auctioned would be more costly to the consumers and businesses, and more distorsive of the market, than a carbon tax.

3.9. Conclusions

This paper has critically looked at the European system of emissions trading, attempting to evaluate its effectiveness, efficiency, and sustainability. By doing so, it has highlighted some shortcomings or risks in the present and future policies.

The first aspect has to do with the posture of ETS in the third phase (2013-2020). In particular, the choice of assigning quotas through auctioning, which in theory may be a reasonable choice, has been translated into a system of regulations that is confused, unstable, and ultimately such as to leave a great discretionary power to the Commission and to the governments of the member States. It is not possible to understand how this can be compatible with the objectives of the Lisbon strategy to bring Europe back on the path of an innovative growth that can be sustained, given that political arbitrariness is perhaps the main deterrent of growth (Stagnaro 2005; Sechi and Stagnaro 2006). Nor can it be understood where it is that Europe wants to go, given that the targets that it has assigned to itself are – in the almost unanimous judgement of the experts – extremely difficult if not impossible to realize.

The second aspect, which is a direct consequence of the first, concerns both the definition of the binding objectives and the ways those objectives are implemented. In this paper, the objectives concerning renewable resources and energy efficiency have not been examined, but in substance the considerations on the reduction of the greenhouse gases apply to them as well. The quantification of the objectives has not been preceded by an evaluation of how much was possible to obtain, nor by an estimate of the costs and impacts on the European energy and economic system. By the same token, a discussion of the possible alternatives is missing. Not so much and not just to replace ETS *now*, but to judge its operation through time as compared to other instruments that could have been adopted and which, in spite of the little attention they have received in Brussels, could perhaps have obtained better results at lower costs. Specifically, the carbon tax option has a series of practical and theoretical advantages, not last the fact that, if the total impact on the European economy is in principal the same as the cap & trade, the administrative costs and the political risks are lower.

As to the third aspect, thinking about the costs of climate strategies means thinking about their benefits as well, and therefore the opportunity of imposing binding domestic targets. This is particularly important in light of both the scientific uncertainties that still remain and are quite substantial – on the global warming phenomenon and on the high probability that will remain politically isolated in the short term in the effort to reduce emissions. From this stems the substantial practical uselessness of the European policies, even if they were justified, effective and efficient, because Europe represents an important but nevertheless minority and decreasing (in relative terms) fraction of global emissions,.

Strictly connected to these questions is the issue of the political feasibility of climate policies. There is virtual unanimity amongst the experts that, from the political point of view, a cap & trade system is easier to launch than a carbon tax, and the European story provides further evidence about that. However, the price of the lesser political resistance is a system that is both opaque and arbitrary. On the contrary, a carbon tax would be more easily implemented, more stable, more predictable, and more responsive to the actual changes in the climate. From a certain point of view, therefore, the lesser political feasibility, due to the difficulty of harvesting consensus on a tax and the need to substantially reformulate the fiscal system, is a further advantage of the carbon tax. The lesser political feasibility guarantees, in fact, not only that the measure will be taken only when a truly large portion of the population is openly willing to pay more to obtain a certain environmental goal. For the same reason, it will be easier to abrogate the tax – a move that is politically less difficult than cancelling regulations as encrusted with lobby activities as they are obscure to most people – when and if it becomes evident that the European strategy is not sustainable, or that the global warming is a less severe problem than what is believed today.

References

ALBRECHT, J. (2006). "The use of consumption taxes to re-launch green tax reform", *International Review of Law and Economics*, vol.26, pp.88-102.

AL FARIS, A.R.F. (2002). "The demand for electricity in the GCC countries", *Energy Policy*, vol.30, no.2, pp.117-124.

BOONEKAMP, P.G.M. (2007). "Price elasticities, policy measures and actual developments in household energy consumption – a bottom up analysis for the Netherlands", *Energy Economics*, vol.29, no.2, pp.133-157.

CCSP (2006). *Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences*. Washington, DC: CCSP, http://www.climatescience.gov/Library/sap/sap1-1/finalreport/sap1-1-final-all.pdf.

CHRISTY, J.R., PARKER, D.E., BROWN, S.J. et al. (2001). "Differential trends in tropical sea surface and atmospheric temperatures since 1979", *Geophysical Research Letters*, vol.28, no.1, pp.183-186.

CLINI, C. (2007a). "Energia pulita pronto uso", *Limes*, no.6, pp.139-144.

CLINI, C. (2007b). "I pro e i contro dell'unilateralismo europeo", *Aspenia*, no.38, pp.111-122.

CLO', A. and VERDE, S. (2007). "20-20-20: il teorema della politica energetica europea", *Energia*, no.4, pp.2-14.

CLO', S. (2007). "Assessing the European Emissions Trading Scheme Effectiveness in Reaching the Kyoto Target: An Analysis of the ETS 1st and 2nd Phase Cap Stringency", *Working Paper,* Università di Bologna.

CLO', S. (2008). "Assessing the European Emissions Trading Scheme Effectiveness in Reaching the Kyoto Target: An Analysis of the Cap Stringency", *RILE Working Paper Series*, no.14.

CLO', S. (2009). "The ETS Reform and Carbon Leakage: Economic Analysis of the New ETS Directive", http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1375544.

DASGUPTA, P. (2006). "Comments on the Stern Review's Economics of Climate Change", 11 November 2006, http://www.econ.cam.ac.uk/faculty/dasgupta/STERN.pdf

DE LAAT, A.T.J. and MAURELLIS, A.N. (2006). "Evidence for influence of anthropogenic surface processes on lower tropospheric and surface temperature trends", *International Journal of Climatology*, vol.26, no.7, pp.897-913.

DOWNING, P.B. and WHITE, L.J. (1986). "Innovation in pollution control", *Journal of Environmental Economics and Management*, vol.13, no.1, pp.18-29.

EC (2005). "Winning the Battle Against Global Climate Change", COM(2005) 35, http://ec.europa.eu/environment/climat/pdf/comm_en_050209.pdf

EC (2007). "Limiting Global Climate Change to 2 degrees Celsius", COM(2007) 2, http://europa.eu/press_room/presspacks/energy/comm2007_02_en.pdf.

EEA (2007). "Greenhouse gas emission trends and projections in Europe 2007", *Technical Report*, no.5, http://reports.eea.europa.eu/eea_report_2007_5/en/Greenhouse_gas_emission_trends_and_projections_in_Europe_2007.pdf

EEA (2009). "Gaps between 2010 projections and Kyoto targets", http://dataservice.eea.europa.eu/atlas/viewdata/viewpub.asp?id=3895.

ELLERMAN, D. and BUCHNER, B. (2006). "Over-Allocation or Abatement? A Preliminary Analysis of the EU ETS Based on the 2005 Emissions Data", *FEEM Nota di Lavoro*, no.139.

GALEOTTI, M. and LANZA, A. (2006). "Il rapporto Stern tra allarmi e allarmismi", *Lavoce.info*, 12 December 2006, http://www.lavoce.info/articoli/pagina2485.html

GME (2009). "Dati di sintesi", su www.mercatoelettrico.org.

GRUBB, M. and FERRARIO, F. (2006). "False confidences: forecasting errors and emission caps in CO_2 trading systems", *Climate Policy*, vol.6, no.4, pp.495-501.

GOODWIN, P., DARGAY, J. and HANLY, M. (2004). "Elasticities of Road Traffic and Fuel Consumption with Respect to Price and Income: A Review", *Transport Reviews*, vol.24, no.3, pp.275-292.

HELM, D. (2005). “Economic Instruments and Environmental Policy”, *Economic and Social Review*, vol.36, no.3, pp.205-228

HEPBURN, C. (2006). “Regulation by Prices, Quantities, or Both: A Review of Instrument Choice”, *Oxford Review of Economic Policy*, vol.22, no.2, pp.259-279.

ICCF (2005). “Kyoto Protocol and Beyond”. http://www.iccfglobal.org/research/climate/index.html

IEA (2007). *World Energy Outlook 2007*. Paris: IEA.

IEA (2008). *World Energy Outlook 2008*. Paris: IEA.

IPCC (2007). *Fourth Assessment Report*, Cambridge: Cambridge University Press.

JOSCOW, P.L. and SCHMALENSEE, R. (1998). “The Political Economy of Market-Based Environmental Policy: The US Acid Rain Program”, *Journal of Law and Economics,* vol.41, no.1, pp.89-135.

KELLY, D.L. and KOLSTAD, C.D. (1999). “Bayesian learning, growth, and pollution”, *Journal of Economic Dynamics and Control*, vol.23, no.4, pp.491-518.

LANZANTE, J.R. and FREE, M. (2008). “Comparison of Radiosonde and GCM Vertical Temperature Trend Profiles: Effects of Dataset Choice and Data Homogenization”, *Journal of Climate*, vol.21, no.20, pp.5417-5435.

LEACH, A.J. (2007). “The climate change learning curve”, *Journal of Economic Dynamics and Control*, vol.31, no.5, pp.1728-1752.

LIJESEN, M.G. (2006). “The real-time price elasticity of electricity”, *Energy Economics*, vol.29, no.2, pp.249-258.

LINDZEN, R.S. (2008). “Climate Science: Is it currently designed to answer questions?”. Paper presented at a meeting sponsored by Euresis and the Templeton Foundation on “Creativity and Creative Inspiration in Mathematics, Science, and Engineering: Developing a Vision for the Future”, San Marino, 29-31 August, http://arxiv.org/ftp/arxiv/papers/0809/0809.3762.pdf.

LIU, G. (2004). “Estimating Energy Demand Elasticities for OECD Countries”, *Discussion Papers*, no.373, http://www.ssb.no/publikasjoner/DP/pdf/dp373.pdf.

MCKITRICK, R. (2008). "A Simple State-Contingent Pricing Rule for Complex Intertemporal Externalities", http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1154157.

MCKITRICK, R. and MICHAELS, P.J. (2007). "Quantifying the influence of anthropogenic surface processes and inhomogeneities on gridded global climate data", *Journal of Geophysical Research*, vol.112, no.D24.

MILLIMAN, S.R. and PRINCE, R. (1989). "Firms incentives to promote technological change in pollution control", *Journal of Environmental Economics and Management*, vol.17, no.3, pp.247-265.

MONTGOMERY, W.D. and TULADHAR, S.D. (2006). "The Asia-Pacific Partnership: Its Role in Promoting a Positive Climate for Investment, Economic Growth and Greenhouse Gas Reduction", International Council for Capital Formation, http://www.iccfglobal.org/pdf/APPsummary.pdf

NEUHOFF, K., MARTINEZ, K. And STATO, M. (2006). "Allocations, incentives and distortions: the impact of EU ETS allowance allocations to the electricity sector", *Climate Policy*, vol.6, no.1, pp.73-91.

NICOLAZZI, M. (2004). "I poteri del petrolio", *Limes*, no.6, pp.67-78.

NORDHAUS, W.D. (2006). "The Stern Review on the Economics of Climate Change", 3 maggio 2007, http://nordhaus.econ.yale.edu/stern_050307.pdf.

NORDHAUS, W.D. (2007). *The Challenge of Global Warming: Economic Models and Environmental Policy*, Yale University, 24 July, http://nordhaus.econ.yale.edu/dice_mss_072407_all.pdf

NORREGARD, J. and REPPELIN-HILL, V. (2000). "Taxes and Tradable Permites as Instruments for Controlling Pollution: Theory and Practice", *IMF Working Paper*, no.13, http://www.imf.org/external/pubs/ft/wp/2000/wp0013.pdf.

PEARCE, D.W., CLINE, W.R., ACHANTA, A.N., FANKHAUSER, S., PACHAURI, R.K., TOL, R.S.J., and VELLINGA, P. (1996). "The Social Costs of Climate Change: Greenhouse Damage and the Benefits of Control". In IPCC Working Group III, *Climate Change 1995: Economic and Social Dimensions*, Cambridge: Cambridge University Press, pp.179-224.

PIELKE, R.A. Jr. (2006). “When Scientists Politicize Science”, *Regulation*, vol.29, no.1, pp.28-34.

RANDALL, R.M. and HERMAN, B.M. (2008). “Using limited time period trends as a means to determine attribution of discrepancies in microwave sounding unit-derived tropospheric temperature time series”, *Journal of Geophysical Research*, vol.113, no.D5.

REQUATE, T. (1993). “Pollution Control in a Cournot Duopoly via Taxes or Permits”, *Journal of Economics*, vol.58, no.3, pp.225-291.

REQUATE, T. (1998). “Incentives to innovate under emission taxes and tradeable permits”, *European Journal of Political Economy*, vol.14, no.1, pp.139-165.

ROCKEFELLER, E.S. (1997). *The Antitrust Religion*. Washington, DC: The Cato Institute.

SECHI, M. and STAGNARO, C. (2006). “Climate. Americans Do It Better”, *IBL Briefing Paper*, no.28-29, http://brunoleonimedia.servingfreedom.net/BP/IBL_BP_28_Stagnaro_Sechi_en.pdf.

SMITH, J.B., SCHELLNHUBER, H.-J., MIRZA, M.Q. et al. (2001). “Vulnerability to Climate Change and Reasons for Concern: A Synthesis”. In IPCC, *Climate Change 2001: Impacts, Adaption, and Vulnerability*, pp.913-967.

SOON, W.W.H. and YASKELL, S.H. (2004). *Maunder Minimum and the Variable Sun-Earth Connection*. London: World Scientific Publishing Company.

SPENCER, R.W. and CHRISTY, J.R. (1990). “Precise Monitoring of Global Temperature Trends from Satellites”, *Science*, vol.247, no.4950, pp.1558-1562.

STAGNARO, C. (2005). “Kyoto and/or Lisbon”, *IBL Briefin Paper*, no.18, http://brunoleonimedia.servingfreedom.net/BP/IBL_BP_18_Kyoto_en.pdf,

STAGNARO, C. (2007). “Biocarburanti: energia pulita o inefficienza agricola?”, *Energia*, no.1, pp.52-55.

STAVINS, R.N. (1998). “What Can We Learn from the Grand Policy Experiment? Lessons from SO_2 Allowance Trading”, *Journal of Economic Perspectives*, vol.12, no.3, pp.69-88.

STERN, N. (ed.) (2006). http://www.hm-treasury.gov.uk/sternreview_index.htm

TERNA (2008). "Dati statistici", http://www.terna.it/Default.aspx?tabid=418.

THOMPSON, D.W.J., KENNEDY, J.J., WALLACE, J.M. and JONES, P.D. (2008). "A large discontinuity in the mid-twentieth century in observed global-mean surface temperature", *Nature*, vol.453, no.7195, pp.646-649.

TOL, R.S.J. (2003). "The Marginal Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties", *Hamburg University Working Paper*, no.FNU-19,

TOL, R.S.J. (2006). "The Stern Review of the Economics of Climate Change: A Comment", 2 novembre 2006, http://www.fnu.zmaw.de/fileadmin/fnu-files/reports/sternreview.pdf

TOL, R.S.J., DOWNING, T.E., FANKHAUSER, S., RICHELS, R.G. and SMITH, J.B. (2001). "Progress in estimating the marginal costs of greenhouse gas emissions", *Pollution Atmosphérique*, special issue, pp.155-179.

TOL, R.S.J. and YOHE, G.W. (2006). "A Review of the *Stern Review*", *World Economics*, vol.7, no.4, pp.233-250.

UP (2009). *Data Book 2009*. Roma: Unione Petrolifera, su www.unionepetrolifera.it.

WALSH, N.P. (2004). "Putin throws lifeline to Kyoto as Eu backs Russia joining Wto", *The Guardian*, 22 May, http://www.guardian.co.uk/international/story/0,3604,1222190,00.html

WEITZMAN, M.L. (1974). "Prices vs. Quantities", *Review of Economic Studies*, vo.41, no.4, pp.477-491.

WOODLAND, A.D. (1993). "A micro-econometric analysis of the industrial demand for Energy in NSW", *The Energy Journal*, vol.14, no.2, pp-57-89.