Climate change: what we know, what we don't know. What to do and what not to do

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1 Introduction

The prevailing opinion among national governments and supranational institutions is that climate change science is settled and, quoting the Secretary-General of the United Nations, "we should waste no more time on that debate" (Ki-Moon, 2012). In the next few decades, drastic cuts in the emissions of CO_2 and other greenhouse gases are deemed necessary to prevent dangerous human caused climate change as foreseen by the 1992 UN Convention on climate change (Ki-Moon, 2014).

As we shall see in section 2, science is not settled. The negative impacts of climate change appear to be on a lesser scale than generally believed; moreover, the ability to adapt to extreme events appears to have increased considerably in recent decades (section 3).

Past and current policies, including the so-called Kyoto Protocol, are based on a central planning approach that defines national and sectoral targets for the reduction of emissions. These policies have been ineffective and inefficient. The reduction of emissions achieved will not have a significant effect on the climate, while the cost per ton of CO_2 avoided has been much higher than necessary and often higher than the estimated benefits (section 4).

In section 5 we analyze and discuss justifications for the actions aimed at regulating emissions from a neoclassical and a free-market standpoint.

Section 6 summarizes and concludes.

2 What we know and what we don't: "science is not settled".

2.1 Has the earth warmed up?

Yes, it has. Global temperature, calculated as an average of the readings at ground level and on the surface of the oceans, increased by about 0.7 °C between 1880 and 2014 (Figure 1).

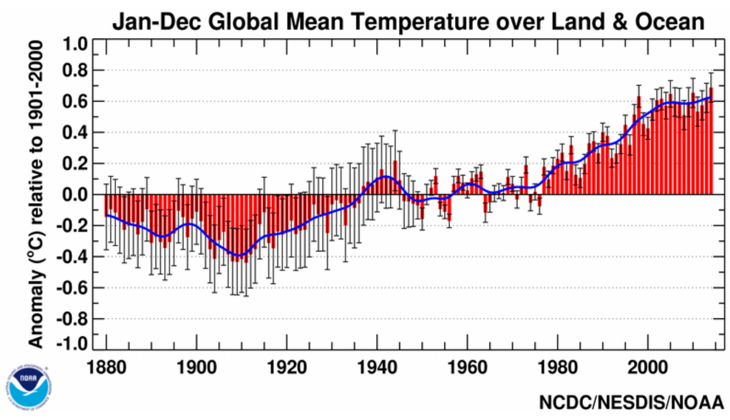

Figure 1 – Global surface mean temperature: 1880 - 2014

Source: NOAA, 2015

The historical series of temperatures can be divided into five periods. The first one (1880-1910) is characterized by a temperature decrease of about 0.2 °C. The second period, (1910–1940) corresponds to a 0.5 °C temperature increase. The third period, (1940 – 1975), shows a slight decline of about 0.1 °C while a new increase of around 0.5°C was recorded during the fourth period (1975 – 2005). Temperatures have been more or less stable in the last decade with a spike mainly due to El Niño after 2014, a spike that is likely to recede in the coming years.

Paleoclimatic reconstructions reveal a trend of rising temperatures since 1600, which followed after a decline in the preceding six centuries. However, because of the wide margins of uncertainty in the precision of the surveys it is impossible to say for sure if temperatures are higher or lower today than they were in the Middle Ages.

Most mountain glaciers are shrinking and, as climatologists foresaw, the diurnal temperature variation has shrunk; the beginning of spring is four days earlier in the Northern hemisphere today than it was in 1980.

The temperature in the Arctic region has been rising four times faster than the global average and the area covered by ice is shrinking by about 4% every decade. However, temperatures today are not significantly different from those registered in the 20's and 30's of the last century. There is still considerable discussion about the ultimate causes of the warm anomalies in the 1920s and 1930s. A recent multi-proxy 2000-year Arctic temperature reconstruction shows that temperatures during the early centuries of the first millennium were comparable to or even higher than those during the 20th century. By contrast, glacier size in Antarctica is on the rise.

According to the IPCC, "It is extremely likely that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forces together. The best estimate of the human-induced contribution to warming is similar to the observed warming over this period." (IPCC 2013). According to simulations conducted by the Intergovernmental Panel on Climate Change (IPCC), warming should have continued at an average rate of 0.21 °C per decade between 1998 and 2012. Instead, the observed warming during that period was 0.04 °C per decade (Tollefson, 2014) in spite of the fact that the amount of carbon dioxide in the atmosphere rose by about 25%; the idea that the excess heat caused by greenhouse warming has been buried in the oceans, thereby reducing heat building up in the atmosphere, remains controversial.

The historical series for global temperature calculated as an average of the ground level surveys has been repeatedly criticized, in particular because of the lack of global observations and the frequent adjustment of the raw data. Global coverage has been provided by satellite measurements since 1979.

It is clear that the objects of the satellite-based measurements and those of the thermometers at the earth's surface are different. But the theory behind the models utilized for climate-change forecasts assume that increased greenhouse gas concentration in the atmosphere initially causes atmospheric warming and then a redistribution of heat towards the Earth's surface. Therefore, it is not possible for an increase in the temperature of the Earth's surface to take place in the absence of atmospheric warming. This record shows no warming between the last two major El Niño episodes (Figure 2). The year 2016 was not statistically warmer than 1998.

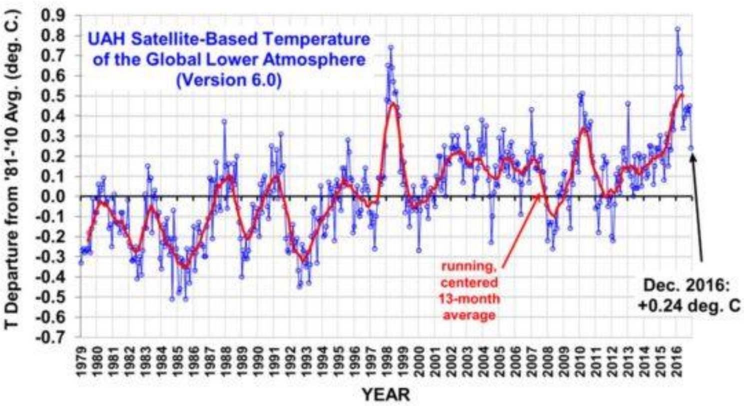

Figure 2 – Global lower troposphere mean temperature: 1979 - 2016

Source: Spencer, 2016

2.2 How much will the Earth warm up in this century?

Forecasts of temperature evolution for the coming decades (and centuries) are based on climate models that attempt to reproduce the physical phenomena that determine the behavior of the Earth's atmosphere, surface and oceans. As regards the historical evolution of temperature it must be noted that such models are unable to accurately reproduce temperature evolution in two periods (1910-1940 and 1940-1975). Moreover, most of them largely overestimate the heating in recent decades. As shown in Figure 3, the temperature increase recorded from 1979 to 2015 in the tropical zone of the troposphere – the part of atmosphere in direct contact with the surface where the greenhouse effect is amplified – is quite modest, around 0.1 °C per decade and equal to about one third of the average forecast of the simulations, both according to satellites and balloon datasets, two independent independent systems which closely agree to each other. The main limit of such models is their inadequate resolution: the elements of the "grid" that reproduces the Earth are about 100 kilometers apart; many meteorological processes, such as cloud formation or rain, develop over smaller ranges. Such processes need to be parametrized by introducing a high number of calibrating factors.

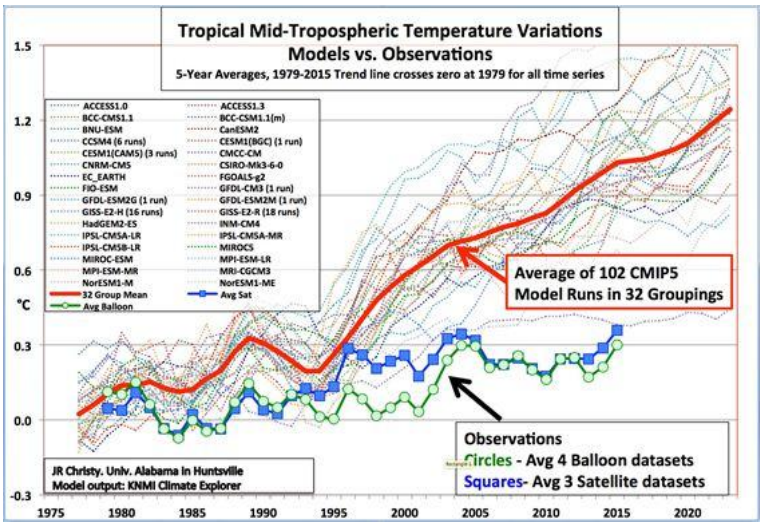

Figure 3 – Tropical mod-troposphere temperature: observations vs. models

Source: Christy, 2016

The fundamental parameter for understanding how anthropic emissions will impact on climate evolution is climate sensitivity, i.e. the size of the increase in heat caused by a doubling of the concentration of carbon dioxide in the atmosphere. In spite of the vast amount of scientific literature produced on the subject in the last thirty years, the uncertainty in estimating this factor remains roughly the same.

The second last document issued by the IPCC (2007) indicated 3°C as the best estimate for this parameter, with a lower minimum threshold (5^{th} percentile) of 1.5 °C and did not identify an upper bound at this confidence level; in the last report (2013) the minimum value was reduced to 1.0 °C and the maximum (90^{th} percentile) is estimated to be 6°C. More recent scientific contributions give lower upper bounds and best estimates around 1.5 °C, on the basis of a different valuation of the cooling effect of small aerosol particles in the atmosphere. The upper bound is especially relevant for the evaluation of the potential negative effects of climate changes.

Table 1 - Values of equilibrium climate sensitivity (ECS) (°C)

	Best Estimate	5^{th} pctile	95^{th} pctile
IPCC AR4 (2007)	3.0	1.5	-
IPCC AR5 (2013)	-	1.0	6.0*
CMIP5 models (2013)	3.22	2.1	4.7
Lewis & Curry (2014)	1.64	1.05	4.05
Lewis (2015)	1.45	1.05	2.2
US IWG	3.0	1.72	7.14

* 90^{th} pctile

Source: Curry, 2015

3 How dangerous is climate change?

3.1 The impacts

As we saw in the previous chapter, contrary to the prevailing opinion of political decision-makers, current scientific knowledge of climate change seems far from settled. An analogous divergence can be seen as regards the negative consequences of climate alterations brought about by greenhouse gas emissions. For instance, according to the former President of the United States, Barack Obama (2015):

"No challenge poses a greater threat to future generations than climate change...2014 was the planet's warmest year on record. Now, one year doesn't make a trend, but this does: 14 of the 15 warmest years on record have all fallen in the first 15 years of this century... The best scientists in the world are all telling us that our activities are changing the climate, and if we don't act forcefully, we'll continue to see rising oceans, longer, hotter heat waves, dangerous droughts and floods, and massive disruptions that can trigger greater migration and conflict and hunger around the globe."

Well: it is true that sea levels are increasing. The trend recorded during the last 25 years for which satellite altimeter observations are available, is around 3.2 mm per annum. A similar trend, though, had already been recorded in the nineteen 30s and 40s (IPCC 2013) when anthropic emissions were negligible.

Referring specifically to the situation of the Pacific Ocean islands, considered as the most vulnerable, recent studies have shown that the emerged area for the vast majority of them had either stayed the same or had increased due to geological changes at local level (Webb et. al., 2010; Kench et al., 2015; Ford et al., 2015). It should also be borne in mind that such phenomena, observed over a ten-year period, are really only part of an extremely long-term scenario which has seen the average level of the oceans rise by more than 120 metres since the last ice age.

As regards the increase in severe weather phenomena, probably the consequence that the media have given most prominence, there is no evidence as of today of statistically meaningful changes in their frequency as pointed out by the IPCC itself (2013)[1]. It seems plausible that heat waves have increased their frequency in many places in Europe, Asia and Australia, but in the case of the United States, conditions that were much more critical than today's were observed in the '30s. There have been no variations in the percentage of the Earth's surface affected by drought in the last thirty years (Hou et al., 2014).

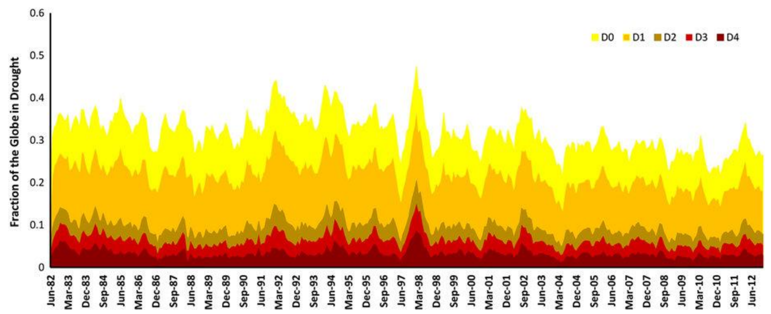

Figure 4 – Fraction of the global land in D0 (abnormally dry), D1 (moderate), D2 (severe), D3 (extreme), and D4 (exceptional) drought condition from 1982 to 2012

Source: Hao et al., 2014

While economic damage caused by severe weather phenomena from 1990 to the present day increased in absolute terms, given the higher value of goods at our disposal and the growth in the quota of population living in the riskier coastal areas, its value has remained fairly constant at around 0.17% of

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[1] "In summary, there continues to be a lack of evidence and thus low confidence regarding the sign of trend in the magnitude and/or frequency of floods on a global scale" (p. 214);
"In summary, the current assessment concludes that there is not enough evidence at present to suggest more than low confidence in a global-scale observed trend in drought or dryness (lack of rainfall) since the middle of the 20th century due to lack of direct observations, geographical inconsistencies in the trends, and dependencies of inferred trends on the index choice. Based on updated studies, AR4 conclusions regarding global increasing trends in drought since the 1970s were probably overstated. However, it is likely that the frequency and intensity of drought has increased in the Mediterranean and West Africa and decreased in central North America and north-west Australia since 1950" (p. 215);
"In summary, there is low confidence in observed trends in small-scale severe weather phenomena such as hail and thunderstorms because of historical data inhomogeneities and inadequacies in monitoring systems" (p. 216)
"Current datasets indicate no significant observed trends in global tropical cyclone frequency over the past century" (p. 216);
"No robust trends in annual numbers of tropical storms, hurricanes and major hurricanes counts have been identified over the past 100 years in the North Atlantic basin" (p. 216);
"Precipitation extremes also appear to be increasing, but there is large spatial variability" (p. 219);
"In summary, confidence in large scale changes in the intensity of extreme extratropical cyclones since 1900 is low" (p. 220)

global GDP; given all the above explanations only a modest fraction of such costs can be potentially blamed on the greenhouse effect (Figure 5).

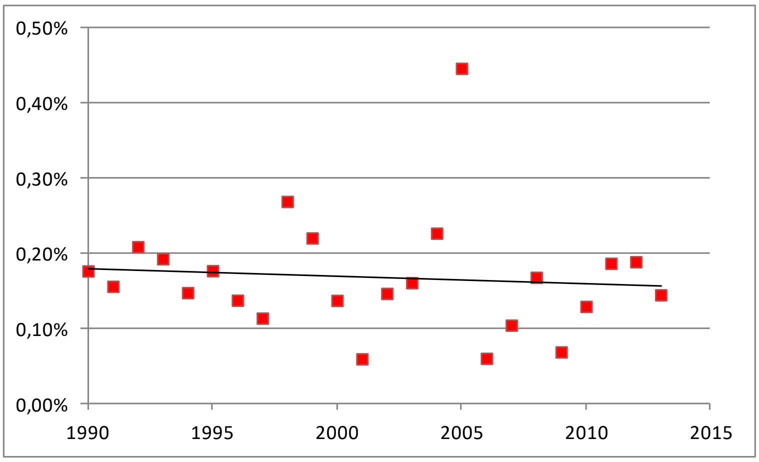

Figure 5 – Weather-related disaster economic losses as a proportion of world GDP

Source: Own calculation based on data from CRED, 2016 and The World Bank, 2016

On the other hand, the increase in temperature and in the concentration of carbon dioxide in the atmosphere has had positive impacts such as increased agricultural productivity and more efficient water usage, the reduction of mortality rates and of heating costs that are positively correlated with rigid temperature. According to FAO data, cereal production has been growing constantly for many decades also thanks to the fertilizing effect of the increasing CO_2 concentrations in the atmosphere and recorded a 30% increase between 2006 and 2016 when a new record was reached (Figure 6). Between 1992 and 2013 the number of people subject to constant hunger fell by 173 million even while the world population rose by 1.7 billion (FAO 2013).

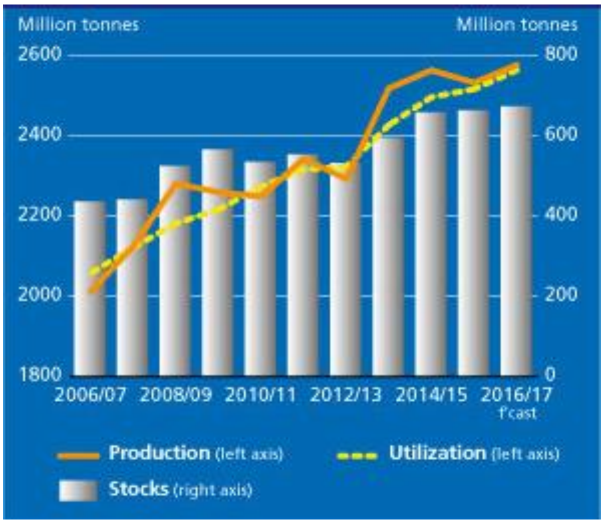

Figure 6 – Cereal production, utilization and stocks

Source: FAO, 2016

A complete look at the effects of climate change leads to the conclusion that positives and negatives broadly even out in the short-medium term, whereas in the long run the latter ones take the lead. According to the IPCC (2014): "estimates agree on the size of the impact (small relative to economic growth)"; the loss of wellbeing caused by an increase in temperature of up to 3°C with respect to 1850 – possible by 2100 if no emission-reduction actions are taken – would be equivalent to a fall in per capita income of a few percentage points with respect to the trend; in other words the cumulative effect of a century of climate change is of the same magnitude as a year of missed growth globally (Figure 7). Only one among the many analyses leads to a more pessimistic estimate, i.e. a loss above 10%; another forecasts a reduction of 6% if the temperature increased by 5.5 °C. The most negative impacts would be on low-income countries as these are less capable of adapting to climate evolutions.

According to estimates of the DICE model developed by William Nordhaus, global GDP would grow from US$76 trillion in 2015 to 510 trillion in 2100. An increase in temperature of 3.8 °C would cause a 20 trillion loss, reducing GDP to 490 trillion, equivalent to 6.5 times current value of GDP at constant prices (Cass, 2016).

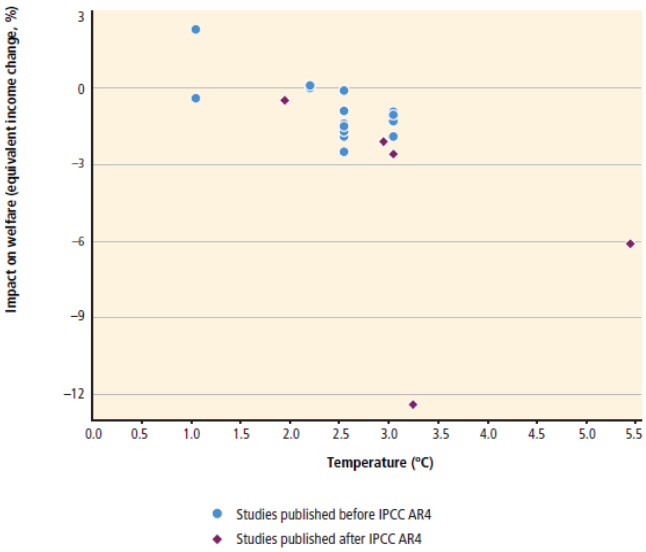

Figure 7 – Estimates of the total impact of climate change plotted against the assumed climate change

Source: IPCC, 2014

3.2 We have learnt to protect ourselves from adverse climate change

Since 1998, the Center for Research on the Epidemiology of Disasters (CRED), with the initial support of the World Health Organization and of the Belgian government, has been updating a database that collects data on the number of victims, the people involved and the damages related to severe events of either natural or technological origin; the database covers a period that goes from 1900 to the present and documents the consequences of 18,000 disasters[2]. An analysis of this data shows how the evolution during the past one hundred years has been decisively positive, both in terms of absolute

[2] For a disaster to be entered into the database at least one of the following criteria must be fulfilled:

- ten (10) or more people reported killed;
- hundred (100) or more people reported affected;
- declaration of a state of emergency;
- call for international assistance

number of deaths and of mortality rates (*a fortiori* given that the world population has quadrupled in the period of analysis) (Figure 8).

The risk of losing one's life because of a severe weather event diminished from 1920 to 2010 by a factor of fifty, from about 250 to 5 victims per million each year (Figure 9). The extraordinary economic boost and progresses made by scientific knowledge allow us to defend ourselves from the whims of climate today as never before. To understand what has happened it is sufficient to compare the effects of an identical severe event (or earthquake) on a high-income or a low-income country. In the first case the negative consequences for people are much more contained thanks to the ability to foresee the event, the availability of more resilient infrastructures and the ability to move populations away from the scene of the disaster.

A similar pattern can be seen with regard to heat waves: mortality in the United States correlated to days with temperatures above 80°F fell about 70% from 1960, almost exclusively thanks to the diffusion of air conditioning (Barreca et al 2016).

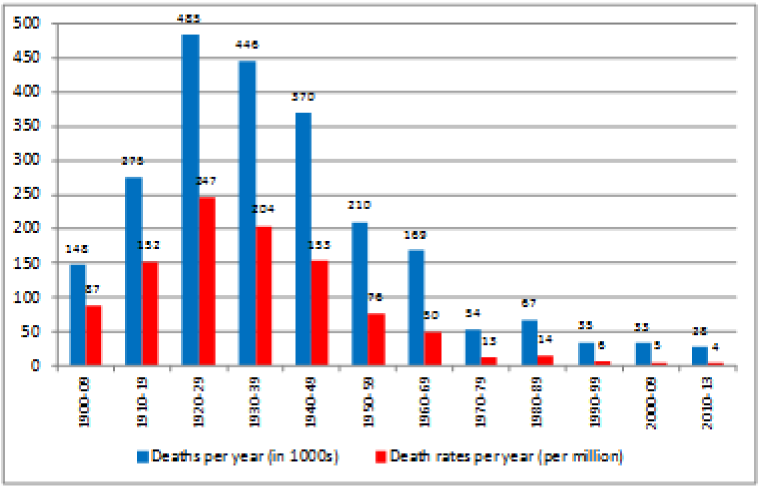

Figure 8 – Global deaths and death rates due to extreme events from 1900 to 2013

Source: Own calculation based on data from CRED, 2016 and United Nation, 2016

Even in lower-income countries there are virtuous examples: in Bangladesh, one of the countries considered most at risk due to climate change, the death rate from super cyclones has dropped by 98% thanks to the implementation of an early warning system and to the construction of temporary shelter buildings. Somewhat paradoxically, says prof. David Hulme, Executive Director of the Global Development Institute, "because few people died and the shelters were designed and built by Bangladeshis, not by aid agencies, few outsiders are aware of the striking progress that the country has made." In 1970, Cyclone Bhola with sustained winds of 150 miles per hour, killed as many as half a million people. In 2007, Cyclone Sidr killed 3,406 people. This year (2016), Cyclone Roanu killed just 30.

Mortality caused by malaria, which was feared to increase due to temperature increase, has fallen dramatically, going from 194 deaths per 100.000 people in 1900 to 9 deaths per 100.000 people in 2012 (-95.4%) (Goklany, 2015).

Since climate change alarm bells began to sound in the 90s, the number of people living in absolute poverty (below 1.90 $2011 PPP a day) has fallen from 2 billion to 700 million people (from 40% to 10% of the population). Year 2016 could turn out to be the warmest in modern history but it will be without any doubt a record year for population, per capita wealth, life expectancy and child mortality.

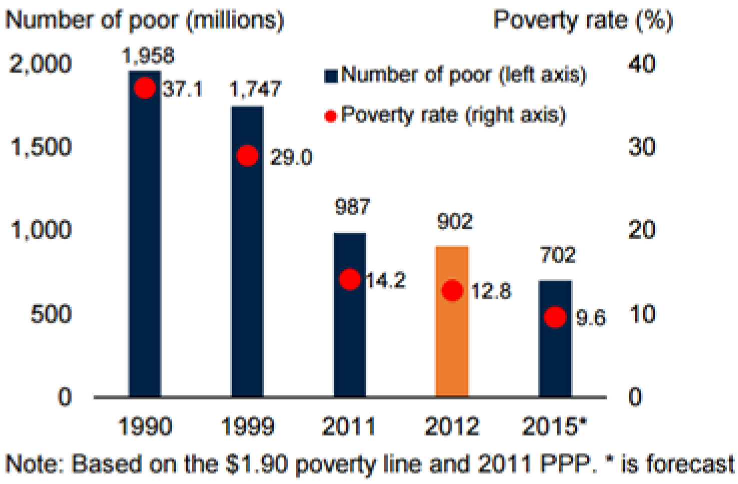

Figure 10 – Global poverty rate from 1990 to 2015 (forecast)

Source: Cruz et al., 2015

4 Policies adopted so far

Many policies to reduce greenhouse gases emissions have already been implemented, the most prominent being the so-called Kyoto Protocol. A common feature of these policies is their central planning approach with the definition of national and sectoral emission reduction targets.

This approach has been both ineffective and inefficient. The reduction of emissions achieved will not have a significant effect on the climate, while the cost per ton of CO_2 avoided has been much higher than necessary and often greater than the benefits.

In the case of the above-mentioned Kyoto protocol, the benefit/cost ratio has been reckoned to be 1/7 (Nordhaus and Boyer, 1998); if completely implemented (which has not been the case) the agreement would have led to a temperature reduction of about 0.13 °C (ibidem).

In 1998 the European Union adopted the "20-20-20 package" whose aims were the achievement by 2020 of a 20% reduction in greenhouse gas emissions, a 20% reduction of energy consumption and the sourcing of at least 20% of European energy needs from renewables. The benefit/cost ratio has been estimated as 1/30 (Tol, 2012).

Prominent in such a European strategy is the case of Italy, a country where the level of incentives for renewable energy is roughly €12 billion/year, to which another couple of billion ("capacity payments") must be added to indemnify thermal plants that have to remain in standby mode to cover demand when production from renewables drops (Ragazzi 2013).

According to data reported by a document from the CEER, the Council of European Energy Regulators, the average incentive for photovoltaic energy in Italy in 2011 was 367.2 €/MWh (Table 3). Such a figure is equivalent to 36 times the value of the total external environmental effects (including atmospheric pollution and CO2 emissions) that would have been generated if energy had been produced by combined cycle without any public incentive. According to a study financed by the European

Commission, (ExternE-Pol, 2005), in fact, such external effects amount to about one Eurocent per Kwh, i.e. 10 Euro per MWh (Figure 11)

Table 3 – Average incentives level per source of renewable energy in Europe

Member state	Hydro	Wind	Biomass	Biogas and waste	Photo-voltaic	Geo-thermal	Total (€/MWh)
Austria	1.13	21.55	81.12	98.20	263.64		46.49
Belgium	45.17	94.58	96.57		407.42		142.04
Czech Republic	57.21	106.77	55.58	112.98	484.17		214.16
Estonia	51.61	53.68	53.68	56.25			53.66
Finland	4.20	11.97	6.74	4.20			6.93
France	64.09	85.32	107.36	92.52	519.80		116.00
Germany	47.69	86.94	159.99	19.83	401.55	212.25	162.94
Hungary	71.78	111.48	112.97	108.77			107.33
Italy	70.30	69.00	119.90[38]		367.20	80.00	153.69
Luxembourg	79.33	36.38		70.46	543.43		138.21
Netherlands	103.93	68.47	75.11	41.33	385.88		70.89
Norway		11.27					11.27
Portugal	91.36	93.50	99.99	90.34[39]	342.60		97.85
Romania	59.81	65.17	63.77[40]		78.74		64.39
Slovenia	23.47	95.38	87.24	126.76	343.07		81.05
Spain	39.02	40.94	75.11	31.26	356.76		84.80
Sweden*							21.47
UK[41]	64.81	72.71	58.48	62.80	290.37		59.92

Source: CEER, 2013

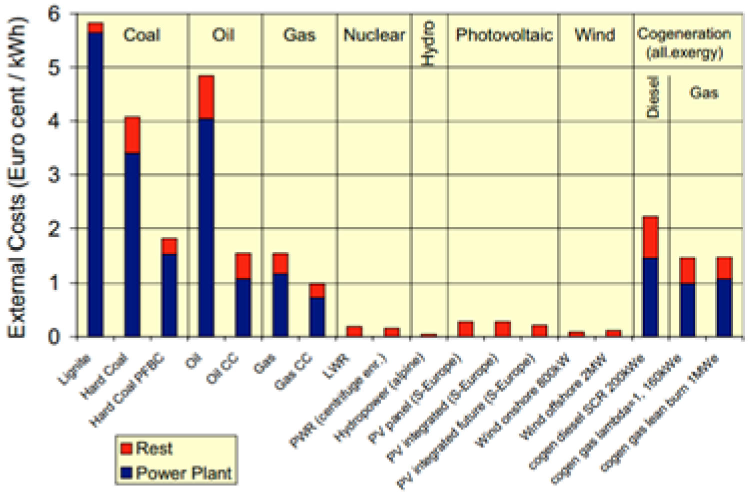

Figure 11 – External costs correlated to electric energy production

Source*: ExternE-Pol, 2005*

Carbon dioxide emissions increased by 57% between 1991 and 2014. This increase was due exclusively to areas outside the most developed blocks, North America, Europe and Japan, where the situation has remained virtually unchanged for about 40 years.

In the last twenty-five years, the share of energy not generated using fossil fuels has gone from 12.2% to 14%. In 2015 the wind and solar contribution was about 1,9%.

The cost of solar energy production has fallen dramatically in the last ten years and it is about double the price of the coal-generated equivalent today. Some estimates foresee that the cost of solar and coal energy will be approximately the same in a decade. Such estimates do not take into account the

need to maintain backup supplies that can work when the sun does not shine or the wind does not blow.
In the forecast scenario that "takes account of broad policy commitments and plans that have been announced by countries, including national pledges to reduce greenhouse-gas emissions and plans to phase out fossil-energy subsidies, even if the measures to implement these commitments have yet to be identified or announced", the IEA (2015) estimates a contribution from solar and photovoltaic energy equal to 5% of total in 2040.

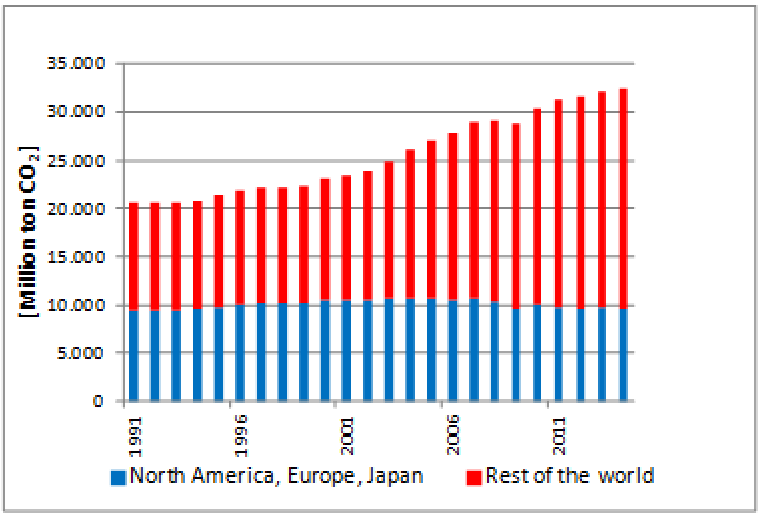

Figure 12 – CO_2 emissions from fuel combustion

Source: Own calculation based on data from OECD/IEA, 2016

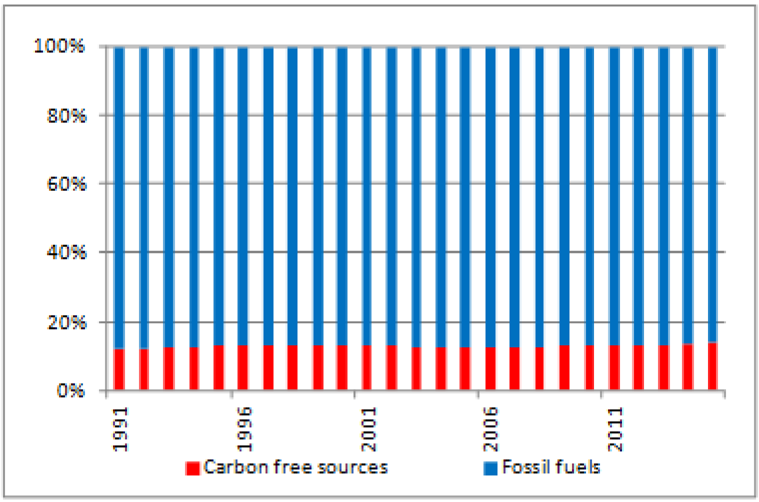

Figure 13 – Share of energy consumption from fossil fuels and carbon free sources

Source: Own calculation based on data from BP, 2016

After investing large amounts of its own resources in a project for assessing the possibility of substituting fossil fuels with renewable energy on a vast scale, Google halted it when it decided that that it was unrealistic (Koningstein and Fork 2014).

Notable among the unintentional consequences of the policies adopted in Europe were a relative deterioration of the air quality (in a progressively improving environment), attributable to greater diffusion of diesel engines, and increased mortality plausibly resulting from cold as a consequence of increased energy costs.

5 Why and how to intervene

5.1 A carbon tax to avoid the worst scenario?

As shown in previous sections, current knowledge of the problem of climate change is far from conclusive: the anthropic impact on the climate has turned out to be much more limited than the one forecast according to the most alarming scenarios, the resiliency to adverse climate conditions – be it of natural or of anthropic origin – has very much improved. By contrast, the policies implemented to date have turned out to be inefficient and ineffective. Considering all of this, are there valid reasons for adopting some forms of regulation of emissions and, if so, what are the most suitable intervention features?

Some scholars (Weitzman 2009; Pindyck, 2013; Taylor, 2015) argue that action is required as a form of guarantee that a low probability catastrophe will not occur and consider a uniform global carbon tax to be desirable, an opinion held even by other scholars in a "neo-classical" perspective of maximizing collective well-being (Tol, 2013).

As Taylor put it:

> *"The key observation here is that catastrophic climate change — that is, low-probability, high-cost climate events such as the sudden disintegration of the Greenland or West Antarctic ice sheets, shutdown or reversal of large-scale oceanic circulation systems like the Gulf Stream, major disruptions of largescale weather patterns, and runaway warming due to the release of immense amounts of greenhouse gases sequestered in arctic permafrost or offshore methane hydrates is a non-diversifiable risk that threatens irreversible harm. The best evidence we have about how society regards non-diversifiable risk is the equity risk premium: the long-run return on equity relative to bonds. Investors demand much higher returns from stocks than from bonds because the value of the latter will not be devastated by a steep economic downturn (an uninsurable risk) whereas the value of the former will. Investors willingly pay a large opportunity cost (the returns they could have received from stocks over a sufficiently long period of time) to buy safety (the more dependable but lower returns associated with bonds). What this tells us is that, in financial markets, non-diversifiable risk concerns us. We pay extra to avoid it. And because catastrophic climate change is a non-diversifiable risk, we should logically be willing to pay extra to avoid climate risks as well."*

Such reasoning does not appear groundless but can be countered with two arguments: on the one hand, sensitivity estimates have emerged that tend to reduce the maximum temperature increase threshold resulting from anthropic emissions (see 2.2 above) and, therefore, the probability of catastrophe. Moreover, as the economist D. Henderson has underscored (2013), even if it is unlikely, it is not possible today to exclude future cooling of the climate with effects that are more catastrophic than those of warming, and that greenhouse emissions could contribute to alleviate. In such a perspective a "wait-and-see" stance could paradoxically be judged to be more prudent than ones that call for radical action immediately. On the other hand, in light of what we have seen in chapters 3 and 4 above, a swift reduction of emissions in the short term would inevitably have direct or indirect negative consequences for economic growth in lower income countries and therefore for their ability to adapt to severe climate events and natural disasters: at the very least such policies appear doubtful from a moral standpoint.

The adoption of a uniform worldwide carbon tax and the simultaneous suppression of any other form of regulation or subsidy would achieve a reduction of emissions at the minimum attainable cost and would avoid the adoption of measures whose costs would exceed the expected benefits. Considering the persistent uncertainty regarding the impacts of anthropic emissions, defining the amount of such a tax would be a largely arbitrary exercise; as observed by Pindick (2013): "[the] models can be used to obtain almost any result one desires". To make up, at least partially, for such a limitation, the tax amount should be correlated to the actual evolution of temperature (McKitrick, 2014). According to Tol (2016):

> *"A modest carbon tax can be justified based on conservative assumptions about people's preferences, and imposing such a carbon tax would avoid the worst of climate change without imposing much economic damage in the short run." (p. 9)*

The efficiency and effectiveness of a carbon tax are strictly correlated with the area of enforcement: if some countries do not charge the tax, the reduction of emissions will not be achieved at minimum cost; according to Nordhaus (2008):

> *"We preliminarily estimate that a participation rate of 50 percent, as compared with 100 percent, will impose an abatement-cost penalty of 250 percent. Even with the participation of the top 15 countries and regions, consisting of three-quarters of world emissions, we estimate that the cost penalty is about 70 percent" (p. 19)*

To date, the countries that accounted for most of the increased emissions in the last decades and whose weight is bound to increase further in the future have not shown any intention to adopt such forms of regulation.

In order to overcome the free-riding problem Nordhaus (2015) proposed the idea of a "Climate club": a top-down treaty with penalties for nonparticipants.

In the light of experience so far, it also appears very unlikely that adopting a carbon tax would be coupled with the suppression of all other forms of regulation. For instance, this has not happened in Australia (Murphy et al. 2015). Regarding the European outlook, it can be pointed out that even if the tax in the transportation sector is such that environment externalities are internalized (IMF, 2014), no political decision maker has manifested the intention to remove other means of public intervention such as the vehicle consumption standards or the various forms of collective transportation incentives.

5.2 Climate change and property rights

The aim of a free-market approach to the problem of climate change is not the maximization of a social welfare function. Moreover, the free-market approach denies validity to cost-benefit analyses, since most of the costs and benefits involved are actually subjective. Rather, the fundamental principle characterizing this approach is respect for property rights. According to M. Rothbard (1973):

> *"The vital fact about air pollution is that the polluter sends unwanted and unbidden pollutants—from smoke to nuclear radiation to sulfur oxides—through the air and into the lungs of innocent victims, as well as onto their material property. All such emanations which injure person or*

> *property constitute aggression against the private property of the victims. Air pollution, after all, is just as much aggression as committing arson against another's property or injuring him physically. Air pollution that injures others is aggression pure and simple. The major function of government—of courts and police—is to stop aggression; instead, the government has failed in this task and has failed grievously to exercise its defense function against air pollution." (p. 319)*

> *"The remedy against air pollution is therefore crystal clear, and it has nothing to do with multibillion-dollar palliative government programs at the expense of the taxpayers which do not even meet the real issue. The remedy is simply for the courts to return to their function of defending person and property rights against invasion, and therefore to enjoin anyone from injecting pollutants into the air." (p. 322)*

Such an approach can be viewed as a solution to the "Tragedy of the Commons" (Hardin, 1968), according to which natural resources that do not belong to anybody, and that are therefore exploitable by anyone, will inevitably be over-utilized and depleted.

According to Anderson and Leal (1991):

> *"The free market environmental approach to pollution is to establish property rights to the pollution disposal medium and allow owners of those rights to bargain over how the resource will be used."(p. 132)*

As shown in chapter 2 and 3 above, notwithstanding the impossibility of gauging the significance of the impact of anthropic emissions of greenhouse gases with precision, there is a general consensus on the fact that they have altered the way the climate system is working. The resulting impacts are realistically bound to be amplified in coming decades when the concentration of gases in the atmosphere will increase. Such effects, e.g. rising sea levels with the consequent flooding of dry land, should be looked upon as damage to someone's else's property and be sanctioned accordingly (Adler 2009) following the decision of a court if a causal relationship between gas emissions and damage suffered can be established (Dawson 2013). The damaged person / company must be compensated and the emitters cannot be allowed to further violate the rights of third parties unless an agreement that envisions compensation for the injured party is reached.

An obstacle to such an approach that is difficult to overcome is the high number of potential injured parties (several billions of people). Then, as regards those responsible for the emissions, while it is possible on the one hand to attribute most of the emissions to a relatively limited number of companies (little more than one hundred) (Burges Salmon 2005) on the other hand there is a lesser but though growing component, particularly inked to mobility, for which several billions of people are responsible.

Another limit to such an intervention approach is represented by the fact that the time scale for CO_2 warming potential is as far as 500 years, the potential negative effects will manifest themselves in the long run and partially influence people yet to be born.

6 Conclusion

In contrast with the prevailing opinion among political decision-makers, current scientific knowledge does not allow either the current or, most importantly, the future impact of anthropic greenhouse gases emissions on climate to be determined with a good degree of approximation. Most of the economic assessments made to date estimate a worldwide negative impact of around a few percentage points of GDP should the increase in the average temperature of Planet Earth be 3°C compared to the pre-industrial world. Negative and positive fallouts differ depending on geographic position and economic sector. It is a fact that as of today the negative effects on climate and the correlated phenomena potentially attributable to human activity have been more than compensated for by the increased ability to adapt to the most adverse climate conditions: there is probably no country that has not witnessed a reduction of the number of victims of severe events in recent decades and, more generally, has not achieved advancements in economic and human terms (increase in life expectancy, reduction of infant mortality, malnutrition, child labour, etc.). The poorest and potentially most vulnerable countries enjoy life conditions better than those enjoyed a few decades ago by today's rich countries (Goklany 2007).

This highly welcome dynamic - a vast majority of the world's population enjoys better conditions even in terms of ability to cope with adverse climatic conditions - would have been all but impossible without resorting to fossil fuels. In such a scenario there appear to be two reasons that justify intervention to reduce emissions: a) the consequences that anthropic activiries could have in the very long term; b) the fact that anthropic emissions have plausibly infringed the property rights of individuals and could further violate them in the future. An approach based on the protection of such rights in court would appear to be superior from a moral standpoint, as no one would be worse off because of others' emissions. Yet, it could be very difficult to implement, given the peculiar nature of the problem.

Be that as it may, it appears that the policies that have been undertaken so far have involved significant increases in production costs, but have failed to achieve meaningful results. In fact, we would be better off if those policies had never been enacted.

The available figures lead to the conclusion *that renewable sources, particularly solar and wind* which receive high public subsidies today, cannot bring about a reduction in consumption of fossil energies in the coming decades on a scale that could modify their impact on the Earth's climate meaningfully. Provided that Governments were sufficiently committed to maintaining it for a long period of time, the adoption of a uniform, revenue-neutral - meaning other taxes should be lowered to offset the impact - and temperature-indexed carbon tax worldwide and the contemporary suppression of other forms of regulation and subsidy would theoretically make it possible to reduce emissions at the lowest possible cost and give individuals, producers or consumers the incentive to act by resorting to different production technologies, the reduction of CO_2 related consumption (electricity, gas, fuel, etc.) and the "sequestration"[3] of emissions. Considered that the richest countries are so far responsible for the larger share of greenhouse-forcing emissions, part of the resources - around 1% of GDP in some countries - now spent to subsidize renewables energies may be transferred to the poorer ones where the marginal cost of abatement is lower but the opportunity cost of climate policies is higher.

However, there is plenty of evidence documenting that such kinds of regulation have always not replaced other means of public intervention. Rather, they have become and additional burden. It is very unlikely that a reasonable carbon tax will ever eliminate previous forms of regulation: a growing

[3] Carbon dioxide sequestration is a three-step process that includes: capture of CO_2 from power plants or industrial processes, transport of the captured and compressed CO_2 (usually in pipelines) and underground injection and geologic sequestration (also referred to as storage) of the CO_2 into deep underground rock formations. Overlying these formations are impermeable, non-porous layers of rock that trap the CO_2 and prevent it from migrating upward.

number of bureaucrats have a vested interested in a "complicated" climate policy which also serves the interests of rent seekers and policy makers (Tol, 2016).

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