Department of Economics and Finance

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ENVIRONMENTAL POLICIES: TACKLING CLIMATE CHANGE

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INDEX

Overview

Most of our economy is powered by fossil fuels, including coal, oil and natural gas. The burning of fossil fuels is the primary cause of carbon dioxide (CO_2) emissions in the atmosphere. The latter have steadily increased since the first Industrial Revolution, while dramatically booming during the last 50 years. Nevertheless, although these hydrocarbons have been considerably fueling the global economy for the past two centuries, they are not infinite resources and - most importantly - their exploitation can irreversibly harm planet Earth, with extreme repercussions on the biodiversity, natural ecosystems, human safety and welfare. As a matter of fact, carbon dioxide has been proven to be the major cause of global warming – that is – the rise in average surface temperatures, which is not just an environmental issue, but also a matter of global security. Climate change is, indeed, one of the most pressing problems of our time that the world must promptly face, despite the coterie of deniers who persistently reject the overwhelming scientific consensus. 97% of scientists, in fact, concur on the sources and threats associated to the rise in global temperatures. As they rise, many catastrophic consequences can be observed on the environment: for instance, the decline in the mass of glacial ice caps in the Arctic - acting like the air conditioning for the Northern Hemisphere - will lead to detrimental changes in currents and weather patterns; the rise in oceans' temperatures, hindering its ability to absorb carbon dioxide in the atmosphere; social and economic distresses, directly stemming from the several environmental imbalances and clearly affecting, among the other things, productivity, GDP, welfare and population distribution. Safeguarding this balance is, therefore, one of the most urgent challenges of the 21st century.

This dissertation aims at assessing the effectiveness of the economic policy instruments to tackle the question, combined with the proper international cooperation and synergy among countries. At its core, in fact, this disquisition carefully describes the key elements of major mitigation policies and how they are implemented - or scheduled for implementation - around the world, with an insight of the relationships between regulation, technological innovations and economic performances.

The paper's introduction concerns the description of the phenomenon in details with an analysis of its drivers, supporting it by sufficient scientific data to better assess the seriousness of the issue and its aftereffects. The problem of climate change will be framed in an economic viewpoint, putting the accent on the impacts on the overall world economy and understanding the linkages between growth and environmental pressure. It will be explained why climate change is a solid example of market failure, by theoretically describing the negative externalities concept and the possible solutions to deal with it.

The final part of the paper provides an overview of the major international climate negotiations, culminated in what has been decided during the 2015 United Nations Climate Change Conference. Furthermore, the most recent political developments regarding the implementation of the Paris Agreement will be discussed, accompanied to some evidences highlighting the necessity of complying with its commitments.

Chapter 1

Introduction

The problem of climate change has been proven to be a challenging long-term, large-scale issue, in spite of the several attempts to deny the plentiful evidence supporting its veracity and the urgency to take co-operative actions. This first theoretical chapter provides an overview of the phenomenon, analysing the causes of global warming and its consequences on living beings and ecosystems. The ultimate objective is to assert the effectiveness of the right environmental policies to properly tackle the problem and to foster a brand new sustainable energy system. Basing the reasoning upon the acknowledgement that climate change will deeply influence the world's economy developments, the dissertation is backed by various scientific data and several social and economic trends, capable of unveiling the most crucial aspects revolving around this complex topic. Moreover, this first chapter aims at spotting the system of linkages connecting the economic variables with the polluting emissions in the atmosphere.

Section 1.1 aims at developing a comprehensive explanation of the problem, with emphasis on its economic valence. Section 1.2 focuses on the drivers of climate change, hence on the set of factors that directly influence greenhouse gas emissions. Section 1.3 analyses, from a theoretical point of view, the concept of negative externality and the most important solutions to cope with it in order to ultimately achieve the Pareto-efficient equilibrium. Section 1.4 provides an examination of the most important instruments to tackle climate change, enriched with several practical examples about policies implemented or scheduled for implementation around the world. Section 1.5 spotlights the Porter hypothesis' path of causal links and offers some empirical evidences supporting the intuition that environmental regulation can spur innovation and assist business performances.

1.1 The problem of climate change

Climate change, often referred to as global warming, has become a crucial social and economic matter of the XXI century. It refers to the rise in average surface temperatures, primarily due to human activity. The issue is gaining increasing importance since its long-term consequences are assumed to have strong repercussions on the future of the planet Earth. Narrowing the view, climate change is also forecast to deeply influence the world economy.

It is agreed that human activity has largely impacted the climate since the first Industrial Revolution through the increase of the so-called greenhouse gases in the atmosphere (specifically, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions). The quantity of CO_2 emissions are, in fact, huge: in 2000, CO_2 emissions alone accounted for 24 billion metric tons of carbon dioxide (JSTOR). Although it is not possible to attribute the entire fault to men, a largely human contribution is unquestionable. Several natural causes can be identified which determine, albeit with lower importance, the reasons of changes in the average surface temperatures: changes in the orbital structure of our planet, solar activity and volcanic eruptions are only some of them. As a matter of fact, the United Nations Framework Convention on Climate Change (UNFCC), in its article 1, defines “Climate change” as “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods”[1]. It is particularly dramatic how, from 1880 to 2012, the average land and ocean temperatures have risen, showing an increase of 0.85 [0.65-1.06] °C (IPCC, 2013) and 2015 has been recorded as the warmest year so far (independent analyses by NASA and the National Oceanic and Atmospheric Administration (NOAA)). In that year, globally-averaged temperatures were equal to 14,79 °C (0,90 °C higher than the XX century average and 0,16 °C higher with respect to the previous year, which, indeed, held the record).

By considering the Earth as a complex system made up of factors balancing each other in a mutual equilibrium, a variation in global temperatures has a clear impact on each of these factors. This is why it is difficult to assess the real cause and effect mechanisms related to the climate change issue and furthermore it requires several interconnected studies, the conclusions of which are often presented in probability terms.
From the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2014) has emerged that it is “very likely” (with 90-100% probability) that the rise in global mean surface temperature (GMTS) is due to anthropogenic increase in greenhouse gas concentrations and, consequently, it is “extremely likely” (with a probability > 99%) that “human activities caused more than half of the observed increase in GMTS from 1951 to 2010”. Moreover, it is “virtually certain” that “internal variability alone cannot account for the observed global warming since 1951”[2].

Among the effects and consequences of the global warming, it is necessary to mention the oceans' heating (IPCC recorded an increase in the first 75 meters of 0.11 °C per decade from 1971 to 2010); the rise in sea level (between 1901 and 2010, the average global sea level increased by 0.19 m); the decline in the mass of glacial ice caps in Antarctica and Greenland (especially between 2002 and 2011); the continuing retreat of glaciers around the world and the rise in precipitations. Global warming will cause devastating consequences observable on the biodiversity and on natural ecosystems; on overall world resources; on human safety and welfare. For instance, Fankhauser (1995) has estimated the annual forestry losses to be US$1.8 billion in the OECD and US$2 billion for the world as a whole due to the climate change. An estimation of the impact on water resources is complex because of the interaction of various climate as well as non-climate factors. Hydrological models show that water availability could vary widely among nations and within nations. Based on the estimates made by Fankhauser (1995) annual losses will be about US$34.8 billion for the CECD and US$46.7 billion for the world as the whole. Moreover, a recent analysis from Michigan Technological University found that about 52,000 people die prematurely in US because of coal pollutants.

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[1] United Nations Framework Convention on Climate Change (1992), Article 1, Definitions, page 7.
[2] IPCC Fifth Assessment Report (2013), Working Group I, Chapter 10 - Detection and Attribution of Climate Change: from Global to Regional, Executive Summary, page 869.

Impacts on living beings and ecosystems are already crystal clear and could soon become irreversible, especially in the poorest areas of the world, where temperatures are usually higher than average and it is more difficult to cope with them. Research suggests that elevated temperatures reduce productivity and wages, exacerbating the already existing inequalities, and that mortality during hot periods is nearly 20% higher in India with respect to US. These disparities are likely to lead, among other things, to even more intense migration flows. Global warming will, indeed, according to a research co-authored by two University of California, Berkeley professors, widen the already existing inequalities among northern and southern countries. The former will tend to get richer while the latter, despite contributing least to climate change, will become even poorer, as the average income in the poorest 40% countries will be reduced by 70% in 2100.

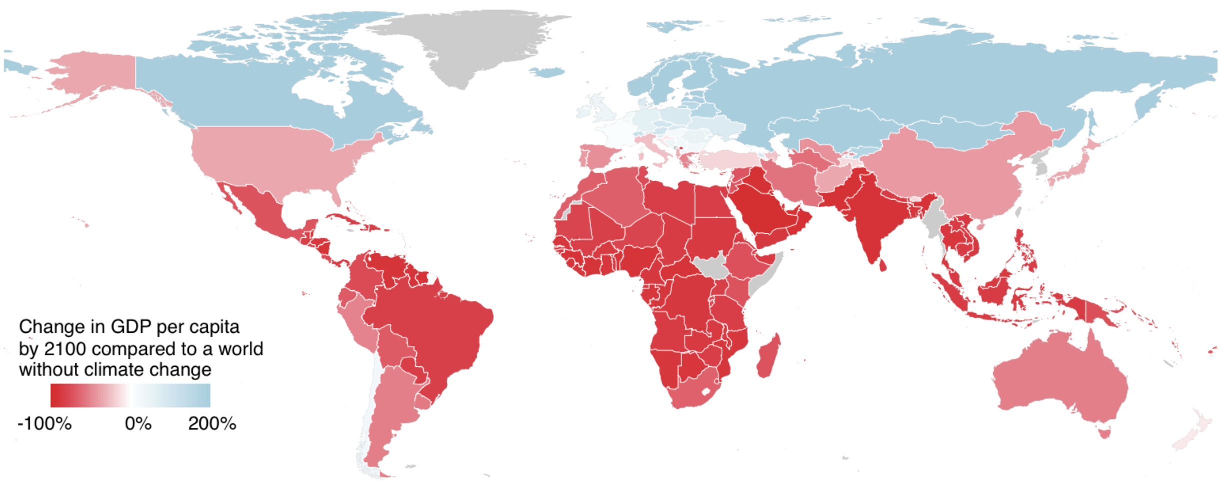


Figure 1.1 – how climate change is going to affect GDP per capita by 2100. Source: Burke, Hsiang, Miguel (Nature, 2015)

Estimations deriving from this analysis assume, in conclusion, that climate change will impact the overall global economy, reducing the world's GDP by 23% by 2100 (Figure 1.1 provides comprehensive estimations about the long-term consequences of climate change on GDP per capita in the countries of the world). Even assuming the standard forecasts about technological progress, the study finds that, because of climate change, 43% of countries are assumed to become poorer. Developing countries, being often unable to tackle the problem effectively, are likely to be threatened by global warming to a much larger extent: because of the actual and potential internal and external conflicts that these countries already face, climate change "will act as an accelerant of instability", with the potential to exacerbate disparities and resources, ethnic and linguistic issues.

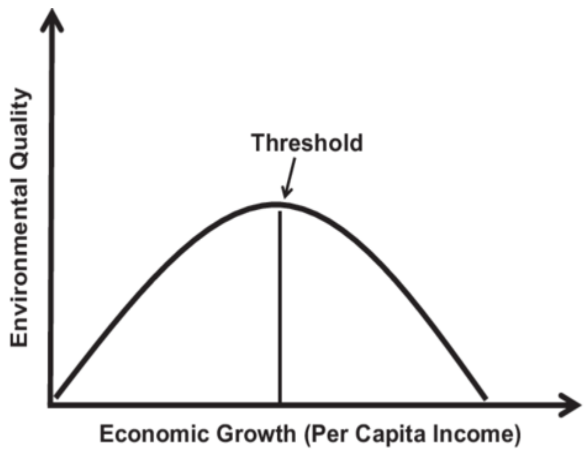


Figure 1.2 – The Environmental Kuznets Curve. Source: Richard S. Mbatu & Kefa M. Otiso

Since the last decades of the XX century we have witnessed to an enhancement in the developed countries' living standards, mainly due to technological progress and the

increase in income per capita. The rise in GDP has, unfortunately, to be coupled with a massive degradation of the environment, accompanied by a serious increasing scarcity of resources.
A possible interpretation of the underlying relationship between the environmental quality and economic growth is given by the “Environmental Kuznets Curve hypothesis” (Figure 1.2). According to this hypothesis, the environmental pressures are assumed to be more and more pronounced as GDP per capita increase until a certain point, after which they tend to decrease. However, its validity strongly depends upon governmental regulations, education and institutions, but this optimistic view is likely to be valid as long as higher incomes act as an incentive to tackle environmental damages.

Although the overwhelming evidence has ensured the scientific trustworthiness of the global warming phenomenon, there is still a minor school of thought radically denying the problem, strongly influencing the current political scenario. Its modus operandi is based upon challenging much evidence (such as claiming that temperatures are not rising at all and glaciers are not melting), attributing little or no weight to human activity and claiming that costs required to combat climate change are (and will be) much high with respect to the benefits of reducing the environmental pollution. The underlying reasons for this attitude could be linked to a tendency to protect corporate interests, especially in the case of the oil, gas and coal industries (Oreskes and Conway, 2010). An example could be ExxonMobil, one of the main American multinational oil and gas corporations, which is currently the biggest spender on the climate change denialism, paying $16 million to fund several climate change denying organization (UCS).

Since global warming awareness is a key ally in fighting the problem, it is unquestioned that climate change denial can seriously damage the environment, society and trust in science. As a matter of fact, in his book, Powell (2011) claims that “in the denial of global warming, we are witnessing the most vicious, and so far most successful, attack on science in history.”[3]

1.2 Greenhouse gas emissions and trends

The main human-produced greenhouse gases (GHG) that directly contribute to climate change are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The Fifth Assessment Report of the IPCC (2014) states that “anthropogenic GHG emissions have increased from 27 (±32) to 49 (±45) $GtCO_2eq/yr$ (+80%) between 1970 and 2010; GHG emissions during the last decade of this period were the highest in human history (high confidence)”[4]. Moreover, in the same period, about 78% of the total greenhouse gases emissions come from CO_2 emissions from fossil fuel and industrial processes. The report highlights how median per capita high income countries’ emissions greatly exceed those of low-income countries, being the former historically energy-intensive.

[3] Powell, The Inquisition of Climate Science, 2011.
[4] IPCC Fifth Assessment Report (2014), Working Group III, Chapter 5 – Drivers, Trends and Mitigation, Executive Summary, page 354.

Because of its main responsibility for global warming, it is necessary and interesting to understand the key determinants of CO_2. The Kaya Identity is an useful equation expressing the relationship between the dominant part of greenhouse gases emissions and the main contributors that directly influence it. It explains that the total level of CO_2 emissions is determined by the product of several factors: human population, GDP per capita, energy intensity per unit of GDP and carbon intensity of energy.

$$CO_2 = \text{POPULATION} \times \text{GDP/POPULATION} \times \text{ENERGY/GDP} \times CO_2\text{/ENERGY}$$

Figure 1.3 shows the decomposition of the change in annual CO_2 emissions by decade (from 1970 to 2010) measured in gigatonnes of CO_2 per year [$GtCO_2$ / yr].

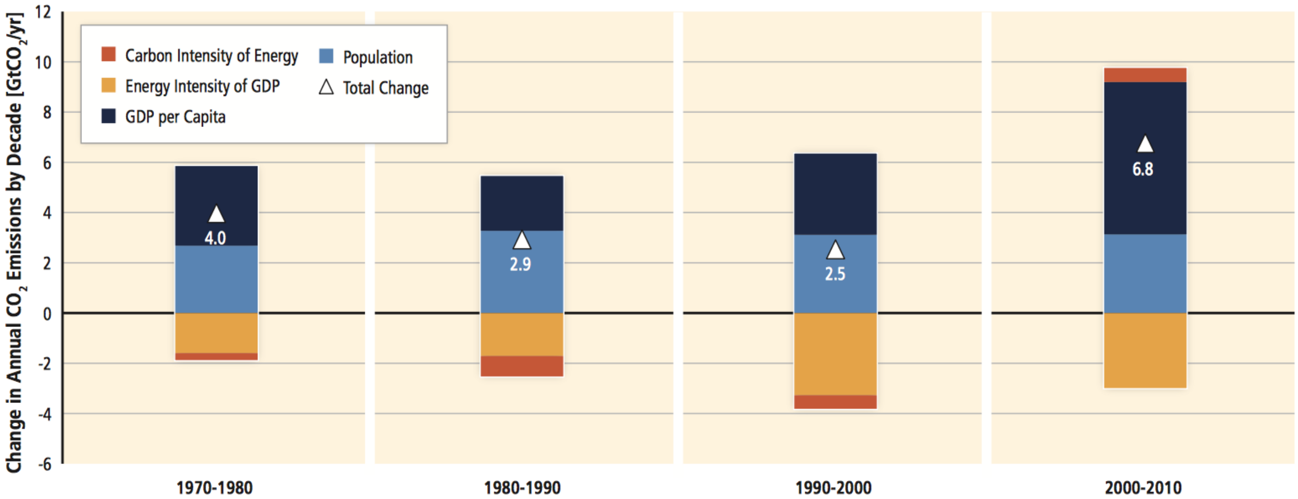


Figure 1.3 – Decomposition of the Change in Total Annual CO2 Emissions from Fossil Fuel Combustion by Decade. Source: IPCC (2014)

The elements having the stronger effect on CO_2 are the growth of world population and the economic development.

Demographic growth is an important factor determining the level of CO_2 emissions because it implies an increase in the exploitation and consumption of natural resources, higher production and more propulsive energy needs. Moreover, it is important to stress that the environmental pressure is determined by the population composition, its density and distribution. Nowadays, the world population accounts for 7,2 billion people. According to recent United Nations' estimations, it is expected to increase by 1 billion over the next 12 years and it is eventually projected to reach 9.6 billion by 2050. Although it is quite sure that the developed countries will not experience any significant rise in the population levels, the developing countries' population is forecast to greatly increase. For instance, African population level will account for more than a quarter of total world population. Nevertheless, Africa is only a small contributor of GHG emissions (in 2009, continental Africa accounted for 3,2% of world CO_2 emissions), mostly because of its low economic activity. However, taking into account the UN World Population Prospects, by 2100, African emissions could reach 5-10% of global emissions.

CO₂ emissions are positively correlated with economic growth as well, measured using GDP per capita. It directly influences the level of environmental pressure since higher income implies higher demand, leading to a higher level of production and energy consumption. Since 1970 we have witnessed a global increase in GDP per capita (mostly in developed countries). Figure 1.4 shows the relationship between GHG per capita and GDP per capita. All regions but Asia have been able to decrease emissions, reaching a convergence in the level of per capita emissions over time. This is the result of the technological improvements that were able to both increase GDP and to reduce CO_2 emissions. So, even if the Kaya decomposition suggests that economic growth should increase emissions, higher income in developed countries results in declining or stable emissions.

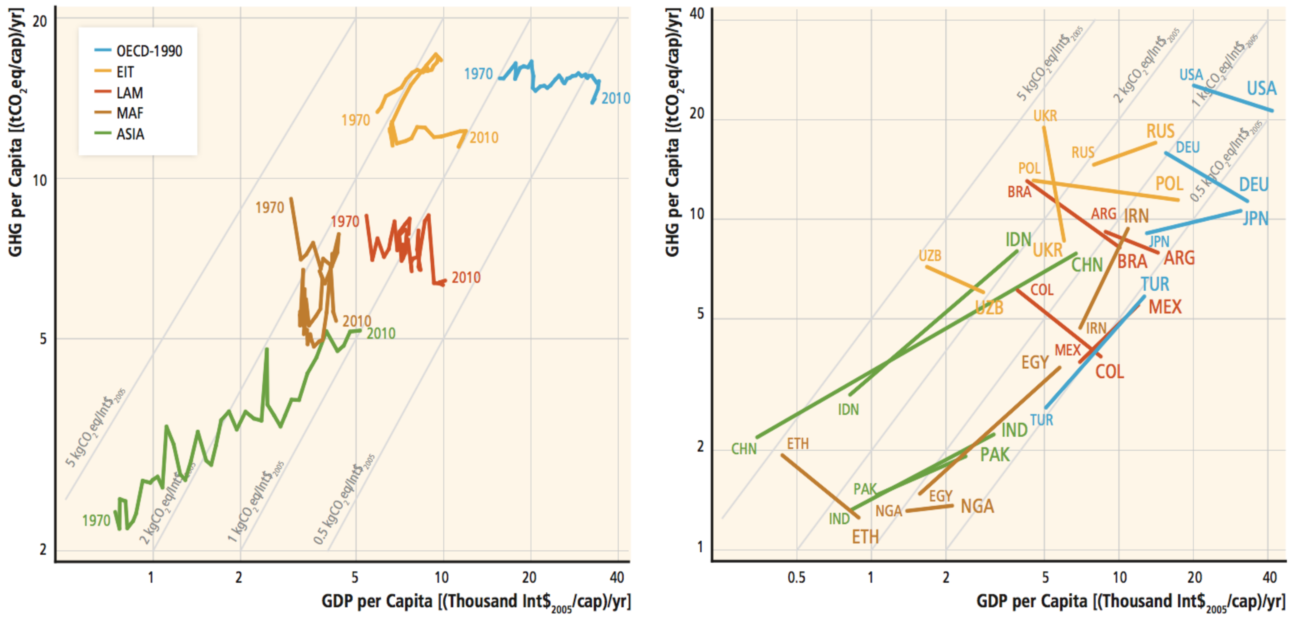


Figure 1.4 –Regional trends in GDP per capita and GHG emissions per capita (left panel) with the four most populous countries in 2010 for each region (right panel). Source: IPCC (2014).

It is important to highlight that energy intensity has declined in the wealthier countries, mainly because of changes in the economic structure and in technologies, that led to a more efficient use of scarce resources. Moreover, the rapid growth of international trade positively contributed to this trend. However, the decrease in the energy intensity of GDP from 1970 to 2010 was not sufficient to offset the effect of the increase in total GDP per capita and in world population. Furthermore, the introduction of brand new technologies allegedly able to reduce the greenhouse gases emissions could trigger behavioural or systemic responses capable of reducing - or even offsetting - the potential gains (the so-called rebound effect).

Carbon intensity, computed as the ratio of CO_2 emissions per unit of energy is the last component of the Kaya equation. We are witnessing a global decarbonisation trend, enhanced by the increase in the use of renewables, natural gases and nuclear. Anyway, this tendency is not only driven by the exhaustion of fossil fuels, but also as a result of political decisions, social attitudes and economic and technological progress. In addition, the continual development of IT technologies are a fundamental ally in decreasing the carbon intensity of energy, through a decrease of energy demand. Although this decarbonisation trend appears to be constant, the energy-efficiency improvements alone are not thought to be enough to reduce the overall emissions and a higher decarbonisation rate is, then, necessary. Moreover, data from 2000 suggest that the slight decarbonisation trends has been reversed.

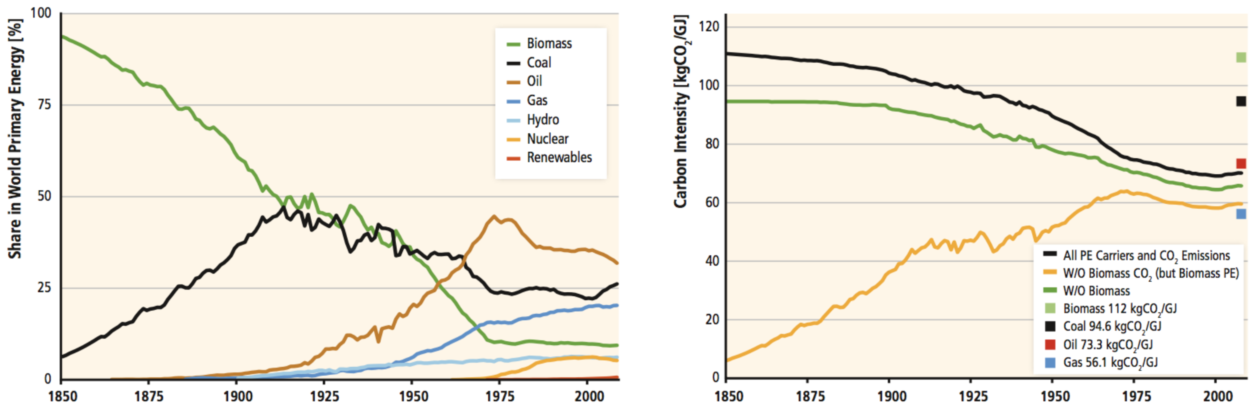


Figure 1.5 – Structural change in world primary energy over 1850 – 2008 (left panel). Decarbonization of primary energy use worldwide ove the same time period. Source: IPCC (2014).

Besides the factors making up the Kaya Identity, it is necessary to specify that assumptions about future trends, infrastructural choices and behavioural features of the societies affect the environmental pressure. Inner individuals' characteristics depend on the country's culture, lifestyle, consumption pattern, political scenario and physiological orientations. Country-level policies and strategies can be implemented to modify the individual's attitudes, but in order to achieve the desired effects, policies should be enforced and scaled up at a macro level.

1.3 Negative externalities and solutions

Tackling climate change is a worldwide complex matter. CO_2 emissions are a result of most of production processes and it is simply not possible to have cheap energy without emissions, considering that virtually every firm or households contributes to pollution. Furthermore, climate change is a long-term issue: some gases can last in the atmosphere for thousands of years. Hence, most of the effects of global climate change will not be felt in the present, meaning that future generations will be more likely to suffer their consequences. It has already been said that the minor contributors of GHG emissions - that is, poor countries - are expected to be the ones to bear the heaviest repercussions. Moreover, as a result of the rising sea level, in the worst-case scenario, countries like the Netherlands, emitting less than 1% of total CO_2 emissions, could experience serious damage even though not primarily responsible of them. Therefore, it is necessary to assert that climate change imposes damages to society as a whole caused by third parties. Since its costs do not directly fall on those conducting polluting activities but, instead, they weigh on future generations or on the least emitting countries, climate change could be certainly defined as the ultimate negative externality.

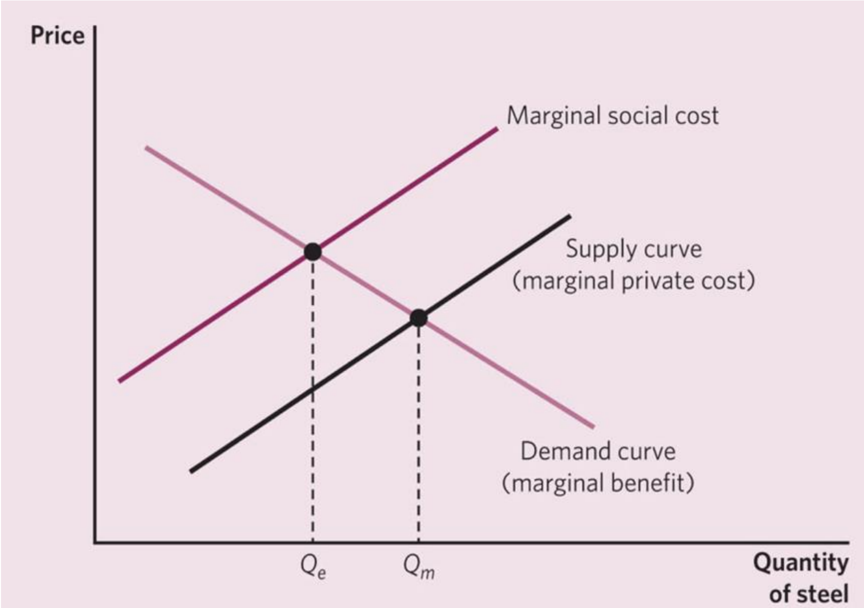


Figure 1.6 – Negative externality representation. Source: Economics of the Public Sector, Stiglitz, Rosengard (2015)

Externalities are spillover effects arising from the production (or consumption) of goods or services, falling on economic actors not directly involved in the production (or consumption) of those goods or service. Hence, they arise when the activity of a producer or a consumer indirectly influences third parties' welfare, that is, not through market prices variations. In this situation, individual actions impose costs (or benefits) to third parties without any compensation (or a payment). As a consequence, resources are allocated inefficiently since prices do not reflect the true value of goods or services. This is why positive and negative externalities lead to market failures, resulting, respectively, in under-production or over-production. Nicholas Stern (2007) claimed that "Climate change is a result of the greatest market failure the world has seen. The evidence on the seriousness of the risks from inaction or delayed action is now overwhelming."[5]

Greenhouse-gas externality is, clearly, a great example of negative externality.

Figure 1.6 shows the graphical representation of a negative externality in a competitive market, in which a generic polluting firm produces according to its maximization profit strategy, hence by setting Marginal Private Cost equal Marginal Benefit. The Social Cost curve has been introduced to account for social costs: it is, in fact, the sum of Marginal Private Cost and Marginal Social Damage.

Using this framework, the efficient output level would be, however, given by the interception of Social Cost curve and Private Benefit curve. In this way, damages caused to third parties resulting from the firm's production process would be rightfully taken into account. However, the firm has no incentive to reduce the output produced since it does not entirely bear the total costs stemming from production. The firm only takes into consideration the direct costs incurring from the production process being social costs unrevealed in the market. In conclusion, the market equilibrium will, eventually, be inefficient.

[5] Sir Nicholas Stern (Lord Stern), in 2007, published a report about the economics of climate change. A year later, in Manchester, during its lecture in the Royal Economic Society (RES), he said: "The problem of climate change involves a fundamental failure of markets: those who damage others by emitting greenhouse gases generally do not pay. Climate change is a result of the greatest market failure the world has ever seen. The evidence on the seriousness of the risks from inaction or delayed action is now overwhelming. We risk damages on a scale larger than the two world wars of the last century. The problem and the response must be a collaboration on a global scale."

In addition to this issue, public goods (such as the natural environment), being non-rival, non-excludable and not subject to property rights, have no market price, resulting in an inefficient market. These goods will either not be supplied by the market or, if supplied, it will be done in an insufficient quantity. It occurs because of the free-riding problem, a common situation arising when the excludability is unfeasible and concerning the reluctance of individuals to contribute voluntarily to the support of public goods while still benefiting from their consumption. In the climate change context, the free-rider problem is conceived as a barrier to tackle the issue.

Dealing with externalities is difficult and requires some knowledge of the specific issue. The different solutions to deal with the negative externality problems can be either private or public.

The main private approach is the Coase Theorem.

Ronald Coase (1960) links the cause of negative externality to the absence of assigned property rights. According to the theorem, the externality will be internalized and the market will reach an efficient solution by itself if property rights are assigned and made transferable and parties can negotiate without cost. When property rights are assigned, one of the two parties will pay the other to be compensated for the damage in order to achieve the socially efficient quantity produced. The efficient quantity produced will be reached independently from who initially owns the property rights. However, the arguments proposed by Coase encounter some difficulties when facing reality. The global warming problem involves the entire world population and, as consequence, is a large-scale issue with long-run implications. Since it is virtually impossible to exclude people from enjoying the natural environment (identified as a public good), policymakers must take into consideration the possibility of facing free-riding individuals. Moreover, Coase assumes that parties can negotiate without cost, that is, the transaction costs are not significant. In reality, transaction costs incurring when the transaction occurs on a global scale are, actually, noteworthy. In addition to these problems, it is important to mention the presence of imperfect information and the difficulty in allocating the property rights when dealing with environmental issues of this magnitude.

On the other hand, government assistance is necessary to properly deal with environmental externalities. Public solutions can be divided into two groups: market-based solutions, trying to influence incentives in order to achieve economic efficiency (through fines, subsidies and marketable permits) and direct regulation (through mandatory standards). Basing our analysis that the social cost associated with a greenhouse-gas externality (assuming that people would be willing to be compensated for global warming), our aim is to weigh costs and benefits associated with CO_2 emissions in order to spot the efficient equilibrium outputs. The Pigouvian tax, named after English economist A. C. Pigou (1920), is probably the simplest type of market-based solution. It expects the government to charge properly calculated corrective taxes equal to the

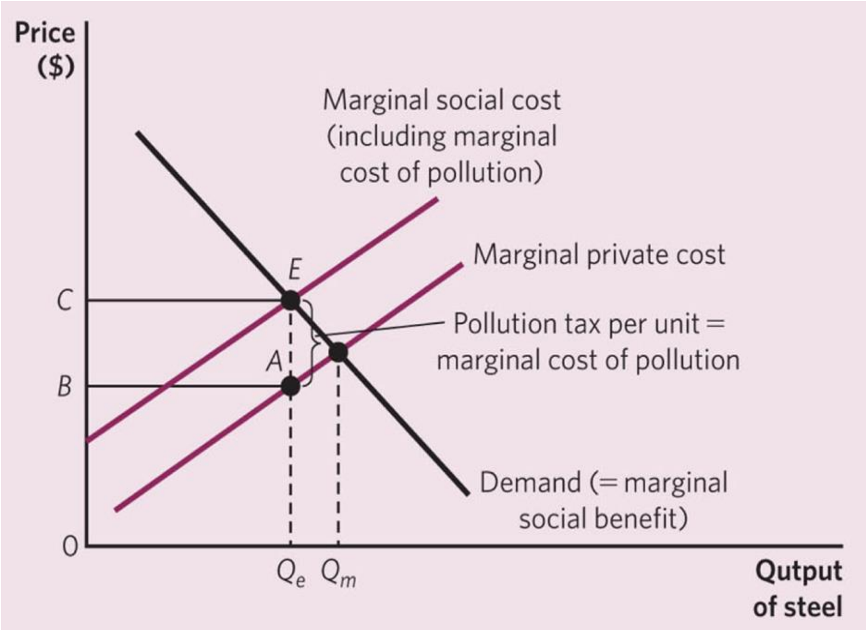


Figure 1.7 – The imposition of a generic tax to align marginal private cost with marginal social cost. Source: Economics of the Public Sector, Stiglitz, Rosengard (2015)

marginal pollution cost in the attempt to correct market inefficiencies. In our case, for instance, the Pigouvian tax should be levied on the greenhouse gas emitter, charging a fixed tax on output produced, that is:

$t^* = MD(Q^*)$

The introduction of the Pigouvian tax results in a rotation of the Marginal Private Cost curve, aligning the private and social costs and benefits, and forcing the firm to internalize the greenhouse-gas externality costs, eventually achieving the optimal output quantity.

While negative externalities can be corrected with Pigouvian taxes, positive ones can be properly adjusted with Pigouvian subsidies, acting in a specular manner.

Although these solutions appear to be effective in achieving economic efficiency, their implementation is far from easy. The main issue is weighing precisely the true externality value and quantity emitted, factors that are difficult to properly measure since it requires estimating the actual pollution social damages in monetary terms. Furthermore, the real application of this tax encounters some difficulties because of the presence of information asymmetries among the government and the polluting firm.

Despite the complications, both the Case Theorem and the Pigouvian tax have been - and still are - priceless starting points when formulating environmental policies, for instance, carbon tax and cap-and-trade system: the former are charged on each unit of polluting emission (differing from Pigouvian taxes that are instead charged on the firm's output), while the latter implies the creation of a market, in which property rights could be traded between the firms.

1.4 Environmental policies

Among the other targets to transform our world, one of the United Nations' Sustainable Development Goals is to "Take urgent action to combat climate change and its impacts"[6]. The Agenda for Sustainable Development, with its 17 objectives, was adopted by the world leaders in September 2015 and officially entered into force on 1 January 2016, expecting to achieve the desired targets by 2030. Furthermore, 2030 is a fundamental year from the climate and energy point of view. As a matter of fact, EU countries have agreed

[6] The United Nations have drawn up a list of goals for our planet's sustainability. In the Agenda one can read the 17 Goals set by the UN in which the 13th revolves around the climate action.

on a 2030 Framework to enhance sustainability and competitiveness, based on the 2020 climate and energy package and in line with the long-term perspectives outlined in the Energy Roadmap to move towards a competitive low-carbon economy by 2050. By 2030, in fact, targets to be achieved are: “a 40% cut in greenhouse gas emissions (with respect to 1990 levels); at least a 27% share of renewable energy consumption; at least 27% energy savings compared with business-as-usual scenario”[7]. The challenge is being capable of effectively encouraging the private sector to invest in new pipelines, electricity networks and overall low-carbon technologies. Nevertheless, policies for 2016 are needed in order to achieve the goals. the European Commission has proposed: “a reformed EU emissions trading scheme (ETS); new indicators for the competitiveness and security of the energy system, such as price differences with major trading partners, diversification of supply, and interconnection capacity between EU countries; first ideas for a new governance system based on national plans for competitive, secure, and sustainable energy.”[8]

As a starting point, tacking climate change requires co-operation among countries, awareness and a timely departure from business-as-usual. Solutions imply substantial changes in technologies used, in countries' economies and institutions. The issue, as already pointed out, is complex and its consequences could be perceived in the distant future, suggesting that mitigation policies should be addressed both to present and future concerns. In the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (2007), mitigation is defined as “a human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs)”[9]. In that report, it is stressed how the GHG emissions are increasing and 2010 was the year in which emissions recorded the highest reached level. To be more precise, from 2000 to 2010, the growth of GHG emissions increased to 2,2% per year and in 2010 the emission curve reached its peak with 49 billion tonnes. It is significant how much the rise of China and, more generally, the international trade, contributed to these tragic data.

The Working Group III aims at assessing the possibilities for reducing GHG emissions and hence mitigating global warming. The strategies suggested are a not mutually exclusive, but instead should be combinations of different policies, instruments and measures leading to the desired goal. Policies to be implemented by governments tend to improve the energy efficiency (and so the efficiency in coping with the reduction of pollutants) and to enhance decarbonisation. Favouring the implementation of a sustainable public transportation or the usage of more efficient light bulbs could be framed in the first category, while, on the other hand, intensifying the deployment of renewable energy sources is a form of decarbonisation strategy. The effectiveness of these plans is linked to the type of policy implemented and its success depends upon both

[7] The European 2030 Energy Strategy include targets set to support Europe in the achievement of “a more competitive, secure and sustainable energy system and to meet its long-term 2050 greenhouse gas reductions target.”

[8] 2030 Energy Strategy, Policies for 2030.

[9] IPCC Fourth Assessment Report (2007), Working Group II, Chapter 18 – Differences, similarities and complementarities between adaptation and mitigation. It has been stated that “The TAR used the following definitions of climate change mitigation […]. Mitigation: An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC, 2001a).”

the right choice mix of policy in the overall government environmental policy portfolio and whether the policy is flexible or not. A flexible policy is, in fact, capable of adapting to the different circumstances.

Although the OECD countries are responsible of nearly 50% of global emissions, they have undertaken real initiatives only in recent years. Relevant cuts to emissions should be made in order to achieve an increase in temperatures within 2 °C, making a remarkable social and economic effort (that is deemed to be even harsher if countries delay political actions). The costs of postponing the action decision is quite significant. In the IPCC 2014 Report, different possible future scenarios have been developed according to a consistent set of socioeconomic assumptions arising from well-defined expectations about future technological, socioeconomic, demographic, political and biophysical hypotheses. About 4 Representative Climate Pathways (RCP) have been constructed describing the possible consequences of different mitigation projections for our carbon budgets - that is - the amount of emissions that we can afford to remain within the 2 °C limits. They describe the GHG concentration trajectories depending on the amount of emissions in the time to come.

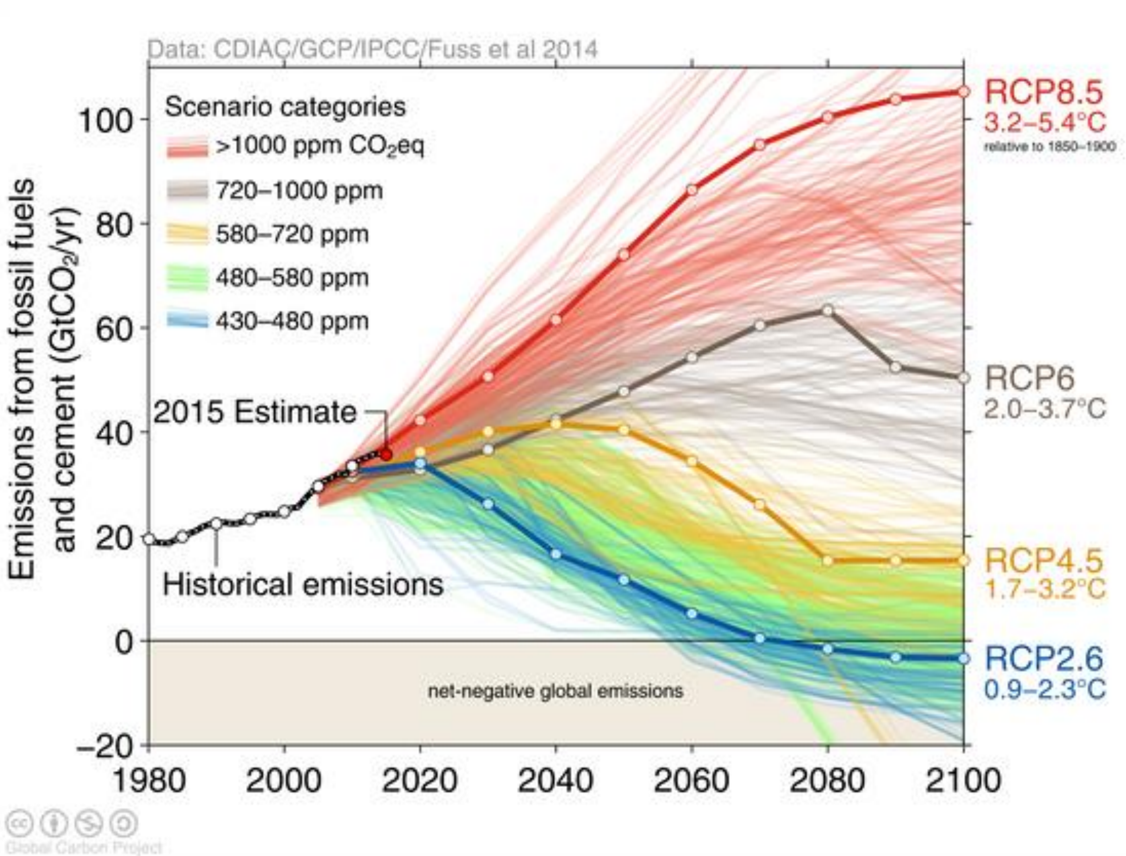


Figure 1.8 – Representative Climate Pathways. Source: CDIAC, GCP, IPCC, Fuss et al. (2014)

One can see from the figure 1.8 the four RPC projections. For instance, the more optimistic RCP 2.6 (named after the expectation of a +2.6 W/m^2 radiative forcing value in 2100 with respect to pre-industrial value) is based on the hypothesis that global annual greenhouse gases emissions will experience a peak approximately from year 2010 and 2020, with emissions declining substantially thereafter. In this scenario, according to the IPCC, there is a high probability of remaining within the 2 °C target. Because of its relevance to the environmental negotiations, we take 2030 as a benchmark for our discussion: depending on the different future perspectives, the probability of achieving the desired emissions goals in that year are drastically different. It is expected that, in case emissions continue to grow until 55 GtCO2 per year, in order to achieve the environmental targets, they should experience a decrease of about 6% per year. In the most realistic view, however, this enormous effort is quite incompatible with the historical emissions growth rate, accounting for 1,2% per year. On the other hand, staying below 55 GtCO2 per year would be result in a sensitive lower effort. In this case, the government would be required to achieve a decrease of about 3% per year. In conclusion, the more society tends to postpone the emissions reductions decisions, the higher the costs incurred to reach the desired goals. As a matter of fact, in the former scenario, the research outlines that costs would be 50% higher with respect to the latter, in which governments are assumed to take immediate action and emissions could be controlled below a specific threshold. To deepen the analysis, in order to implement policies to sustain the temperature growth below the 2 °C, the direct costs borne by the society are associated with the projections of countries' economic growth. In 2030, the study forecasts a decrease in GDP between 1 and 4% (in absolute terms) and in 2050 the decrease in GDP is expected to be between 2 and 6%. Accounting for opportunity costs leads to the obvious conclusion that policies are, indeed, necessary and need co-operative actions to be undertaken. Effective legislation and co-operation will result in several co-benefits related to societal goals, such as those related to human health, food security, biodiversity, environmental quality, energy access and equitable sustainable development.

The urgency of implementing effective environmental policies seems tragically evident. In this context, governments are required to use tools capable of cutting human-produced CO_2 emissions and reducing the incentives to employ most polluting energy sources, while encouraging the exploitation of renewables. The aim is to find the best self-reinforcing policy mix since one single instrument is not sufficient for the full achievement of the targets. As a matter of fact, environmental issues have several features and different instruments are needed to properly address each of them. Moreover, flexibility is only achieved when firms are in the position to reduce the cost of policy compliance as a result of the combination of different instruments.

Governments may implement several environmental policies, for instance:

- regulatory instruments (command-and-control systems), directly regulating the emissions and fixing the standards the firms have to comply to;
- market-based instruments, including fees, taxes, tax exemptions and tradable permits (cap-and-trade systems);
- voluntary environmental agreements among governments and economic actors;
- new technologies R&D.

Regulatory instruments are prescriptive and include emissions standards, processes or equipment requirements, limits on input and/or on output, information disclosure obligation and audits. However, they are less flexible than market-based instruments. Regulation, in fact, can potentially restrict the innovation process and consequently there is a lower probability that brand new low-carbon technologies could be deployed. On the other hand, market-based instruments do not set standards or regulate the CO2 emissions but rather seek to provide incentives (often under the form of direct or indirect taxes) to operate in the most sustainable way. Carbon pricing instruments set an adequate price to carbon dioxide through the imposition of a tax or the implementation of emission trading systems, in order to stimulate the deployment of cleaner energy forms and the sustainability of the business activities. Policies are, then, designed to influence economic actors to take into consideration the overall (private and social) costs incurring during the production process (and hence, to reduce CO2 emissions). In this scenario, firms could benefit from introducing new low-emissions technologies by facing lower fixed or variable costs. Carbon pricing instrument could, indeed, potentially support the shift towards a less polluting energy model: taxes are assumed to give incentives to reduce the pollution at a lower cost than the tax rate, while trading systems set a cap (a maximum level of emissions) and establish a market for the exploitation of environmental resources. Cutting emission can, in the latter case, be convenient because profits can be made from the sale of permits; in the former, firms can benefit from a tax relief by reducing emissions. Nevertheless, market-based solutions could be less effective with respect to regulations in reducing emissions and reaching the environmental goals. They can, however, be re-designed and adjusted to create the best possible stimulus to act sustainably, enhancing flexibility.

To examine more in depth the climate change analysis, we are going to focus primarily on market-based instruments (the key world mitigation solutions), in particular on taxes on emissions and cap-and-trade systems.

The importance of these instruments was also highlighted during the 2015 United Nations Climate Change Conference, which was saw the official launch the Carbon Pricing Leadership Coalition, a global initiative comprising public and private sector's leaders and non-government organizations, with the desired goal "to expand the use of effective carbon pricing policies that can maintain competitiveness, create jobs, encourage innovation, and deliver meaningful emissions reductions"[10].

In its 2016 report, the World Bank provided a comprehensive map (Figure 1.9) concerning the pricing carbon instruments adopted in 2016 and those about to be implemented. It makes clear that 40 countries and more than 20 cities, States or regions have implemented (or scheduled) a carbon pricing policy, either through taxes on emissions or through a cap-and-trade system. The aforesaid jurisdictions contribute to a quarter of world greenhouse gas emissions and, where implemented, initiatives are able to cover about 50% of emissions (on a global-scale level it translates in a coverage accounting for about 13% of global GHG emissions).

[10] From the Carbon Pricing Leadership's webpage one can read: "In September 2014, the idea of a Carbon Pricing Leadership Coalition formed from a groundswell of support for carbon pricing at the UN Climate Summit, where 74 countries and more than 1,000 companies expressed support for carbon pricing. The Coalition officially launched at COP21 in Paris, with the goal to expand the use of effective carbon pricing policies that can maintain competitiveness, create jobs, encourage innovation, and deliver meaningful emissions reductions."

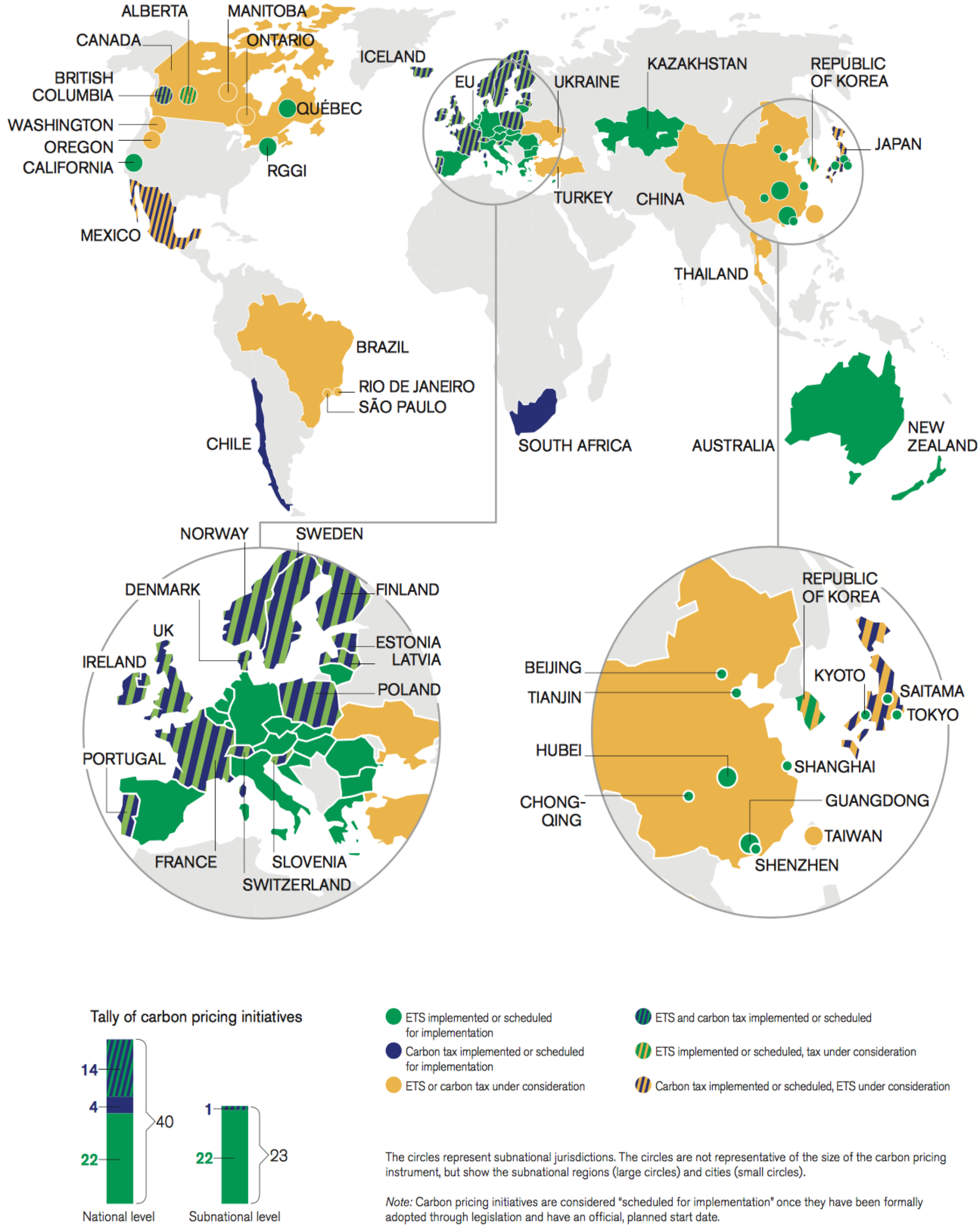


Figure 1.9 – Summary map of existing, emerging and potential regional, national and subnational carbon pricing initiatives (ETS and tax). Source: World Bank (2016)

Recalling that China is the world's leading emitter, in 2015, the Chinese President Xi Jinping announced that the national emission trading system will start in 2017. As a matter of fact, it has already launched seven pilot regional ETS, with the commitment to enlarge the scheme to a national-scale level later this year, forcing eight industrial sectors to buy permits covering GHG. As a consequence, China's ETS is expected to become the world's biggest system pricing GHG emission, creating a strong stimulus for firms to reduce the CO2 spillovers in the near future. From 2015, the country's carbon emissions have declined and the number of new coal power projects approved decreased by 85% in 2016. Furthermore, the country has greatly increased the deployment of solar, wind and nuclear power (in 2015 wind capacity grew by 33,5% while solar-generation capacity grew by 73,7%), and is planning to invest $360 billion in renewables within 2020. Estimations about future projections say that, if correctly implemented, Chinese initiatives to tackle climate change could permit the achievement of an extraordinary 23% global emissions' coverage (Figure 1.10).

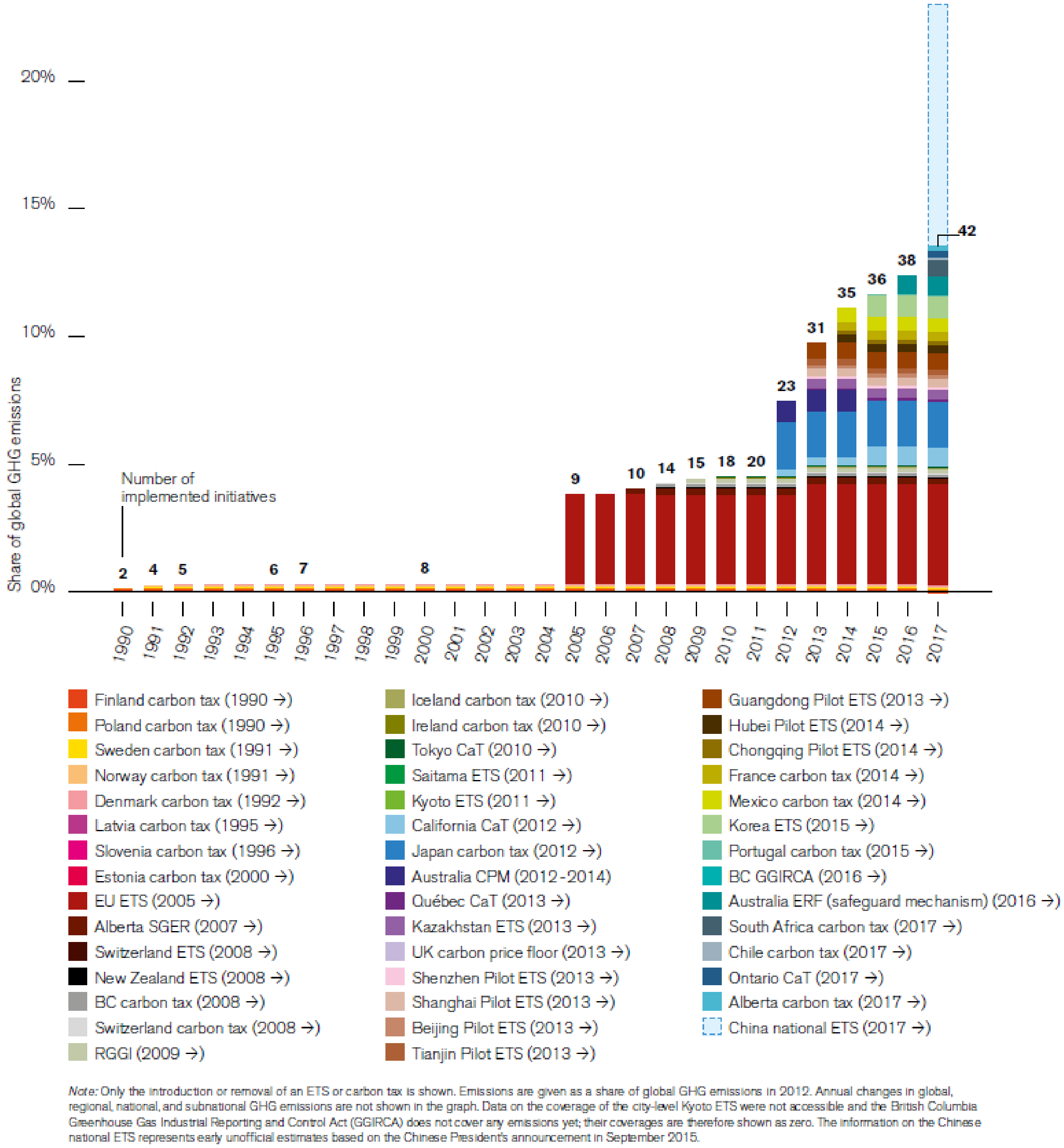


Figure 1.10 – Regional, national and subnational carbon pricing initiatives: share of global emissions covered. Source: World Bank (2016)

The World Bank report outlines that, in 2015, governments raised about US$26 billion from carbon pricing initiatives (a 60% increase with respect to the revenues raised during 2014, estimated to be equal to US$16 billion). Unofficial estimations forecast that Chinese action could potentially lead to a great increase in total revenues, accounting for US$100 billion.

Among the jurisdictions considered, the EU is a major contributor of GHG mitigation mainly thanks to the European Union Emission Trading System (EU ETS), the biggest cap-and-trade program in the world. America, just like China, only shows sub-national initiatives. However, the American case is becoming more and more complex with the new administration

In 2016, Obama and Xi Jinping jointly declared that climate change is a “pillar of the U.S.-China bilateral relationship”[11] and engaged in a cooperation to reduce emissions and stimulate the employment of clean energy. The Sino-American relationship concerning global warming has been a revolution in the GHG emissions context: after years of frictions between the countries, they ultimately managed to find a common ground and work together to mutually solve internal and external environmental and social issues. The new Trump administration, however, has removed the climate change issue from the executive agenda, engaged in a US Clean Power Plan annihilation, cut down the funds available to tackle the problem and reduced the emphasis on environmental prescriptions. This has led to a deterioration of the US-China relationship, although Chinese mitigation strategy looks not to be undermined.

With Figure 1.10, World Bank managed to illustrate the growth of carbon pricing instruments in the world relative to the share of global emissions covered. From 1990 to 2005, the only carbon pricing initiatives were carried out by north European countries, covering a small percentage of global emissions. In 2005, with the Kyoto Protocol, the world witnessed a great increase of environmental policies, mainly due to the enactment of the EU ETS. From 2012, the figure shows, again, an expansion in carbon pricing instruments implemented: the number of instruments doubled and the coverage impressively rose. It is important to stress how much the coverage increased, moving from 4% to about 13%, concerning the period from 2006 and 2016.

We now start analysing these two major policy instruments in detail, since they are the most useful instruments in tackling climate change for several reasons.

Carbon tax

The so-called polluter pays principle, clearly finding its main application in the carbon tax, was officially adopted by the OECD in 1972 and aims at implementing a full cost accounting to internalize the negative externalities. In the context of eco-taxes, it can deter and decrease GHG emissions by making the party responsible for the emissions’ production through a tax payment for the damage caused to the environment. The tax on emissions - or carbon tax - is a tax levied on the carbon content of fuels (and on CO_2 emissions, expressed in tCO_2e). The implementation of a carbon tax forces the polluter to take into account the social costs, which are assumed to be summed to production/consumption private costs, leading to a strong incentive

[11] Obama White House Archives, U.S.-China Climate Change Cooperation Outcomes, 2016.

to reduce the GHG emissions. The intention is, actually, to change behaviour rather than raising revenues: through a strong price signal and market forces, in fact, both the polluting firm and the consumers are assumed to change their attitude and focus on more sustainable alternatives, redirecting and encouraging private investments towards "greener" technological innovations capable of decreasing the environmental pressure. From the consumers' point of view, on the other hand, the carbon tax would induce them to shift their preferences towards cheaper and less polluting products and services. The decrease polluting products/services demand will then lead to a reconsideration about the production process, orienting the firms towards new business models. Forcing the polluter to internalize the greenhouse gas externality is only possible after having considered the social cost of carbon. From the policymakers' point of view, this is a crucial issue: evaluating the social cost of carbon means estimating the CO_2 value in monetary terms by summing the costs and benefits of emitting one additional tonne of carbon dioxide. Therefore, the higher the social cost of carbon, the larger the benefits of a carbon tax and, consequently, even expensive policies can be supported. Since the GHG emissions will last for thousands of years, the social cost of carbon requires the estimations of the residence time of CO_2 in the atmosphere and its impacts on global warming. This is possible through a comparison of the impacts over time using future costs, discounted at present. Among other things, the discount rate used depends on the emissions' future weigh on the environment. The question, however, is how to weigh future costs and benefits today. One approach is to evaluate the discount rate according to the social time preference, which depends on the population impatience. A second way to measure it is through the social opportunity cost of foregoing alternative investments. Nevertheless, these approaches can overestimate the discount rate, meaning that people alive today are worth more than future world population. This is why the Stern Review (2006) adopted a 1,4% discount rate, which is low and takes into consideration the ethic concerns of setting a higher discount rate. Indeed, it is important to consider the principle of fairness and intergenerational equity when setting the right social discount rate. Countries like the UK and France, for instance, have understood the importance of time-varying discount rates in long-term policies implementation. Uncertainty about the future results in declining discount rates over time and, for public projects appraisal exceeding 30 years, a lower rate should be used.

Although not of primary concern, the carbon tax clearly generates revenues for the government and one important issue regards the optimal allocation of these tax revenues. The choice depends on the countries' specific economic situation, environmental issues, fiscal urgencies and governments' short and long run objectives, depending on the extent of the resistance/support of the policy appraisal. The carbon tax revenues can be used, for instance, to favour low-income population segments, to reduce the so-called distortionary taxes and hence to reduce losses in efficiencies, to finance public projects (among them, one can mention public investments towards R&D and renewables) and to reduce budget deficit. The various possibilities must be tailored according to the political countries' scenario, which can be inconsistent with the policy goals. Authorities can mitigate these issues by designing a revenue-neutral carbon tax, so that every dollar generated is returned to the citizens through, for instance, reductions in personal or corporate income tax rates.

In 1967 Tullock advanced the hypothesis of the double-dividend, concerning the multiple benefits that a tax can bring. First, an eco-tax can reduce the pollution level on environment; the second dividend, on the other hand, is about the reduction in the distortions of the revenue-raising tax system, ultimately achieving a higher overall welfare. Although the debate about the validity of the double-dividend hypothesis is still in progress, many governments have started to use the tax revenue generated from eco-taxes to decrease other tax rates.

The question, however, is how to define the optimal eco-tax rate. The choice of tax rate has, clearly, environmental consequences. Since the government sets the tax rate a priori, the effectiveness of the carbon tax in tackling climate issues depends on whether the a priori estimation of the tax rate is consistent with the environmental standards. As we have already seen, the carbon tax directly stems from the Pigouvian tax, although its real implementation encounters some difficulties: it is difficult to measure the marginal damage monetary value and, despite the estimations, it is actually challenging to ascertain the right marginal cost and benefit functions of any firm. These issues are further exacerbated when dealing with the climate change long-run phenomenon, concerning the entire world population. This is why, in 1971, William Baumol and Wallace Oates proposed a different approach for policymakers in the choice of optimal taxation. Basing their research on the drawbacks of Pigouvian solution stemming from the fact that the current scientific knowledge is insufficient to determine the right marginal pollution cost, they argued that the government should determine the acceptable level of pollution and set the tax according to that level, in the attempt to achieve the pollution targets, and eventually adjust the rate as necessary. Hence, having once set the target in terms of environmental quality, the policymaker imposes a tax capable of respecting the standard, instead of implementing a tax based on external marginal damages. In this context, adjusting the tax rate makes the correct estimation of the optimal taxation rate possible. This solution, however, does not imply the Pareto-efficient allocation of resources, since the Pigouvian tax still remains the only one capable of achieving this result. Baumol and Oates advocate that the socially sustainable level choice linked with the environmental degradation is up to the environmental policy arena. On the other hand, economists are entitled to suggest the best cost-effective instrument to reach the aforesaid level. As a matter of fact, reducing the emissions is always costly and the same environmental standard can be reached with different environmental policies, having different costs for the overall society. In order to demonstrate that the solution proposed by B&O is actually cost-effective let's assume we are dealing with a country where different firms operate facing different abatement costs and in which a standard has been set. If the policymaker were to require uniform emissions' reduction, the standard would be met but the costs would be higher than necessary. It is, instead, more convenient to demand higher emissions reduction shares from the firms facing lower abatement costs: in this way, the standard would be met less expensively and the overall wealth would benefit. It is important to stress that this redistribution of the burden of tax is possible as long as firms face different abatement costs. The overall policy cost is eventually minimized when every firm faces the same marginal cost from pollution reduction, finally achieving the efficient allocation in terms of cost. The introduction of the carbon tax can automatically lead to the aforesaid allocation since it causes firms to reduce the emissions until the marginal cost of the pollution abatement is equal to the tax rate.

Consequently, since every firm will be subject to the same tax rate, marginal costs will be equal for every polluting firm and the final allocation will ultimately be cost-effective.

Despite the advantages, carbon tax can potentially experience some drawbacks. The hurdles of its implementation are, essentially, two: the effects on firms' competitiveness and equity and regressive impacts issues. When policymakers attempt to introduce an eco-tax, in fact, they need to take into consideration the consequences on the competitiveness on national firms, especially when they face international competition as well. As a matter of fact, any tax reduces firms' revenues through an increase of the marginal cost of production; this situation is particularly acute in the case of energy intensive companies (facing the highest distress) and in the case of above-average severity of environmental policies. Because of these repercussions, we often witness the carbon leakage phenomenon, stemming from the effect that the environmental emissions' regulation in one nation has on the emissions in another nation which is not subject to the same standard. For instance, if the tax rate in country A is lower than the one in country B, firms operating in country B face great incentives in outsourcing, moving the production towards country A. Authorities usually deal with this problem by reducing the tax rate in energy intensive sectors, despite the fact that this solution undermines the market efficiency. What is really necessary to tackle carbon leakage is a strong cooperation and synergy among countries to coordinate environmental policy and ultimately enhance market efficiency.

The second issue is about the tax regression, since the burden of the tax usually falls on the low-income groups, which are more vulnerable to price changes. Equity is always a core topic when designing the optimal tax: in this case, a possible solution could be the use of the tax revenues to "repay" the poorest segments (through, for instance, tax reliefs), thus enhancing the overall tax system progressiveness.

Cap-and-trade

Other market-based approaches to managing GHG emissions by providing economic incentives for reducing polluting compounds are the emissions trading systems (one of them being the cap-and-trade system), implemented with tradable permits. The cap-and-trade system works through the allocation (or sale) of a limited number of the aforesaid permits from the government body, and it defines the cap (maximum level of emissions) to which firms must comply. Hence, polluters are required to hold tradable permits in the number equal to the amount of emissions produced. With ETS, companies must, in fact, hold a permit to cover each unit of CO2 emitted. Concerning the allotment mechanism, when tradable permits are freely allocated, it is often referred to as "grandfathering"; on the other hand, when permits are sold to the market, the method used by the authority is auctioning. The latter results in several advantages, stemming from the fact that the government raises revenues from the sale of permits, usable to finance other projects, improve efficiency or decrease distortionary taxes. As a matter of fact, the OECD, in analysing and promoting the use of market-based instruments to mitigate the climate change, advices the use of auctions to assign tradable permits in order to avoid rents associated to the environmental policy being captured by the polluting firms, ensuring the perfect compliance with the polluter pays principle. As a matter of fact, in this way companies are endowed with a valuable market asset for free, improving the shareholders' financial position. Therefore, the government revenue that would have been generated under the auctioning mechanism is transformed into a capital gift given to the polluters, which is distorting in efficiency terms. Nash (2000) carried out the most complete study on the issue: he distinguished the weak form of PPP (requiring that the authorities avoid the subsidization for polluting firms) and the strong form of PPP (requiring that polluters internalize the emissions costs). He concluded that, since the grandfathering method violates the weak form of the principle, it must violate the strong form as well, and eventually be incompatible with the polluter pays principle. Nonetheless, it ensures a cheaper compliance with the emissions' standards in the early stage of the policy appraisal, allowing firms to work under business-as-usual since they have to pay only for extra permits bought. In practice, however, permissions are almost always given out for free, probably because this approach ensures the political support to implement the ETS.

The cost asymmetries among firms explains why the trade takes place. Emissions trading systems are effective mitigation instruments since they contribute to economic efficiency by supporting the reduction of emissions where it is cheapest to achieve them. Since permits are tradable in the market, polluters who would encounter difficulties in reducing emissions to meet the ceiling set by the government could buy emission allowances from firms that, having achieved a reduction in emissions because of lower abatement costs (or, simply, emit less), are willing to sell them. Although the cap is set in advance, the price at which firms trade the permits fluctuates: permits are more expensive when demand is high with respect to the current supply and become cheaper when demand decreases. The ETS promotes the research and development in the field of green and sustainable innovations because emissions' reductions translate into higher revenues from the sale of unused permits.

Although both are carbon pricing methods potentially able to achieve the same environmental standards, tradable permits and carbon taxes differ substantially, particularly on the level on uncertainty linked with the price and on the degree of emissions reduction. Since it depends on the countries' economic situation and on the demand and supply of available permits, ETS market price is subject to a higher extent of uncertainty. So, if on one hand carbon taxes ensure the certainty of the carbon price which is set a priori, a system of tradable permits ensures the certainty of emissions ceiling (since the government fixes the number of permits on the basis of the socially sustainable level of emissions in the atmosphere) but leaves to the market the determination of prices.

Nonetheless, both the market-based instruments are cost-effective, allowing the achievement of the environmental objective in the most flexible and cheapest way. In perfectly competitive markets, the ultimate equilibrium will be achieved when every firm equalizes the marginal abatement cost. Since permits are marketable, firms have the possibility to carry out mutually beneficial transactions in order to reduce total costs. As long as marginal costs across firms differ, there are incentives to trade permits and, hence, make some revenues from them (e.g. if the marginal abatement costs are higher than the price, there is an incentive to buy permits). Hence, the burden of the emissions' reduction is distributed across firms within the ETS in a way such that those with the lower abatement costs manage to reduce emissions to a higher extent with respect to those facing higher abatement costs. Moreover, since what really matters is the marginal abatement cost, the initial distribution of permits does not influence the ultimate achievement of the environmental goal (Hahn and Stavins, 2011).

As already discussed, the EU ETS is currently the largest emission trading system in the world. It is a joint-cap-and-trade scheme of 27 EU member states, Norway and Liechtenstein. When examining theoretically this kind of ETS it is important to understand the achievement of the partial equilibrium, considering that each country covered by a joint-cap-and-trade scheme aims at complying with its emissions level objective. The compliance with the emissions standards are considered in aggregate, so that if country A reduces GHG emissions below the target, country B can increase its GHG emissions above the aforesaid target. The difference among targets is accounted for by marketable permits that country A and country B buy and sell. Just as in the case of ETS implemented at national level, the joint-cap-and-trade equilibrium is achieved when marginal abatement costs are equal across countries, so that there is no possibility to further decrease the cost of producing the public good. Country A and country B manage to abate $q_i \geq 0$ at a cost c_i, such that

$c_i = c_i(q_i, \theta_i)$, where θi is a random variable influencing the country's abatement cost.

Since permits are, as already specified, tradable in the market, we assume that countries can fully comply with environmental targets by producing an aggregate supply equal to QA + QB. In absence of distortions, the aggregate production equals the required quantity.

$$q_A + q_B = Q_A + Q_B$$

By considering α as the amount of permits that country A sells to country B, then the equilibrium market price for permits is

$$p^* = c'_A(q_A + \alpha, \theta_A) = c'_B(q_B + \alpha, \theta_B)$$

In this case, costs are minimised across countries and the allowance price equals the marginal valuation of permits by the countries. As in the context of ETS implemented at national level, now a country will sell allowances if the marginal revenue from the sale is higher than marginal abatement cost. If both countries choose the emissions abatement cost-minimizing quantities, the cost they will face will be

$$C_i(\theta_A, \theta_B) = c_i(q^*_i, \theta_i) - p^*\alpha$$

Cap-and-trade systems will eventually achieve the efficient level of emissions abatement independently from the initial permits allocations and, in the absence of distortions in the market, the allowances prices will not be influenced from the authority's allocation mechanism, as it does not influence the marginal abatement cost functions. The ultimate permits allocation will be such that there will be no firm which could benefit from trading one permit more (Hahn & Stavins, 2011).

This why the ETS appears substantially similar with the Coase solution.

1.5 Porter hypothesis

After having examined in detail the main market-based instruments, it is important to highlight one of the principal issues in the analysis of mitigation solutions. The question that policymakers advance concerns whether environmental policies can be privately profitable, in the sense that they can potentially generate benefits to producers/consumers that are higher with respect to the cost incurred in complying with the environmental standards. In 1995, the Harvard Business School economist Michael Porter and the co-author van der Linde published an article in which they attempted to formulate the hypothesis that well-designed environmental regulations can spur innovation and efficiency and ultimately enhance the competitive position vis-a-vis rival firms. Prior to its time, the traditional perspective held by the economists until that time included the acknowledgement that demanding firms to reduce the GHG emission required the firms' profit to decrease, basing the theory upon the assumption that if profitable sustainable opportunities existed then businesses would have already taken advantage of them. To this extent, Porter directly questions the belief that firms are profit-maximizing entities because of the existence of imperfect information and market failures by stating that "The possibility that regulation might act as a spur to innovation arises because the world does not fit the Panglossian belief that firms always make optimal choices".

Environmental policies require firms to divert capital away from productive investments by allocating some inputs to reduce emissions instead of employing them in profitable business investments. For instance, environmental regulations impose firms to shrink the wide choice of inputs and market-based instruments force firms to modify their profit-maximization strategy because of the additional costs they incur. On the other hand, Porter and van der Linde's point of view is that pollution can be regarded as a waste of resources. It follows that softening the environmental pressure through a reduction in pollution can result in an improvement in the firm's productivity. However, some empirical conflicts arise when proving the validity of the hypothesis, even though sometimes the core issue happens to be the misunderstanding of the Porter Hypothesis' principles.

The Porter hypothesis is constructed following a path of causal links, that sees as a starting point the implementation of strict but flexible environmental regulation that finds its best application in market-based solutions. The kind of instrument is fundamental in order to validate the hypothesis. One can read from the article published by Porter and van der Linde that "If environmental standards are to foster the innovation offsets that arise from new technologies and approaches to production, they should adhere to three principles.

First, they must create the maximum opportunity for innovation, leaving the approach to innovation to industry and not the standard-setting agency. Second, regulations should foster continuous improvement, rather than locking in any particular technology. Third, the regulatory process should leave as little room as possible for uncertainty at every stage."[12]

The aforesaid well-designed regulation will consequently lead to innovation, bringing two positive effects to the society:

- they will generate environmental benefits because of the achievement of the environmental targets,
- they offset the cost of regulation compliance.

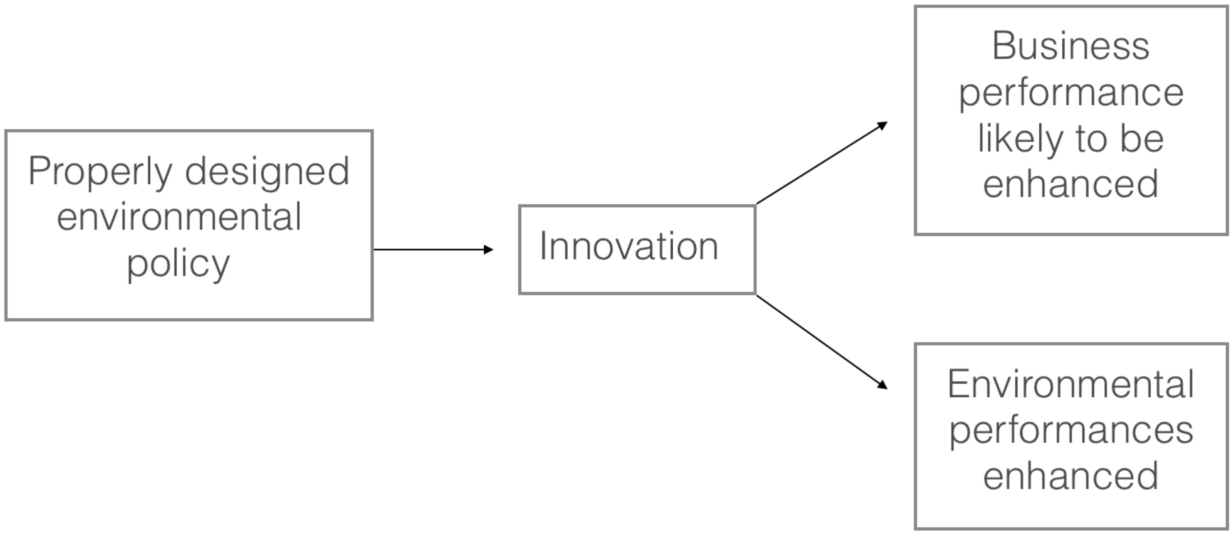
These innovation offsets result, as a consequence, in win-win situations, in which both environment and the company benefit from the government policies. Strict and flexible regulations can provide greater innovation and innovation offsets than lax regulation, since compliance requires deep and extreme solutions (for instance, product and process reconfigurations through the introduction of product or process innovations). The analysis does not deny that the short-term costs of compliance can be high and, indeed, rise proportionally with the degree of the environmental policy's stringency. Nonetheless, "the potential for innovation offsets may rise even faster. Thus, the net cost of compliance can fall with stringency and may even turn into a net benefit".

According to the hypothesis, there are several reasons why strict and flexible regulations are potentially capable of achieving this win-win situation. Porter and van der Linde provide six reasons:

1. "First, regulation signal companies about likely resource inefficiencies and potential technological improvements." The authors claim that companies do not have sufficient experience to properly understand the full costs of their toxic discharges and the partial exploitation of resources associated with them, resulting in an underestimation of the several positive aspects that new sustainable approaches can bring along.
2. "Second, regulation focused on information gathering can achieve major benefits by raising corporate awareness." Porter and van der Linde provide the example of Toxics Release Inventories, published annually as a part of the 1986 Superfund reauthorization, requiring more than 20,000 manufacturing plants to report their release of 320 toxic compounds. It can result in environmental improvements even in absence of compelling regulations.
3. "Third, regulation reduces the uncertainty that investments to address the environment will be valuable. Greater certainty encourages investment in any area."
4. "Fourth, regulation creates pressure that motivates innovation and progress." Porter and van der Linde's research stresses upon the fact that the outside pressure stemming not just from competition but also from the introduction of a strict environmental regulation can overcome organizational inertia, advance creative thinking and weaken agency problems.

[12] Michael E. Porter and Claas van der Linde. Source: The Journal of Economic Perspectives, Vol. 9, No. 4 (Autumn, 1995), page 110

5. “Fifth, regulation levels the transitional playing field”, so that one firm “cannot opportunistically gain position by avoiding environmental investments”. In this view, policies can ensure that companies are shielded from aggressive competition until the phase in which new technologies is validated and the learning effects are such that costs are eventually minimized.
6. “Sixth, regulation is needed in the case of incomplete offsets. We readily admit that innovation cannot always completely offset the cost of compliance, especially in the short term before learning can reduce the cost of innovation-based solutions. In such cases, regulation will be necessary to improve environmental quality”.[13]



There is still a lot of confusion about the real intentions of the Porter hypothesis, leading to sharp critiques. In 1997, Jaffe and Palmer partitioned the PH in order to test the theory step by step. The first part regards the link between well-designed strict and flexible innovation and the introduction of new sustainable technologies. This has been defined as the “weak” version of the Porter Hypothesis, since it does not specify whether the regulation-led innovation would be profitable or harmful for the firm. On the other hand, a “strong” version has been developed, concerning the link between the innovation spurring from strict regulation and the truthfulness of the thesis according to which innovation leads to more than offsetting any additional compliance cost, thus enhancing competitiveness. It is important to stress the fact that the original Porter hypothesis does not express that environmental regulation always result in increase in competitiveness/profits. Additionally, Jaffe and Palmer managed to develop the so-called “narrow” version of the hypothesis, expressing that flexible regulatory policies are preferred to prescriptive forms of environmental regulations because of the higher incentives they give to firms.

[13] Michael E. Porter and Claas van der Linde. Source: The Journal of Economic Perspectives, Vol. 9, No. 4 (Autumn, 1995), page 100.

The Porter hypothesis can be summarized with the following figure, in which the first two boxes concern the "weak" version while the upper-right hand concerns the "strong" version. Porter and van der Linde's work has been tested empirically by many economic researchers, using different methods: the first aims at analyzing the "weak" version of the hypothesis; the second examines empirically the "strong" version, by trying to assess the impact of environmental regulation on the business performance (although omitting the cause of the variation in performance, so no causality with the introduction of an innovation has been provided).

In order to assess the validity of the "weak" version, the expenses relative to R&D have been used and the PACE (that is, pollution control expenditures from the Census Bureau's Pollution Abatement Costs and Expenditure Survey) have been taken into account as a proxy for the stringency of the regulation. In their research, Jaffe and Palmer (1997) first estimate the relationship between the expenditures on R&D and pollution, finding a positive correlation between the changes in PACE and R&D expenditures over time. In particular, an increase of 0.15% in expenditures on research and development is associated with a pollution abatement cost increase of 1%. Then, they proceeded to analyse the relationship between PACE and the number of registered patents, which can be seen as the outcome of R&D effort. Nonetheless, no statistically significant link was found. Many other studies have been advanced (among the most recent ones, the works developed by Arimura et al. (2007), Johnstone et al. (2010) and Lanoie et al. (2011)) concerning the linkages among successful patents related with environmental innovations and the environmental policies. Summing up the various evidence, one can conclude that the "weak" version of the Porter hypothesis is fully supported. However, the "strong" version encounters empirical difficulties in being supported. As a matter of fact, Jaffe et al. (1995) have been reviewing several paper concerning this specific matter, finding negative links between the environmental regulation and business performances, notwithstanding some more recent positive evidence. In 2001 and 2002 respectively, in fact, Berman and But and Alpay et al. concluded that more stringent regulation is not always associated with a shrinkage in business productivity.

The whole Porter hypothesis was tested for the first time by Lanoie et al. (2011). The research managed to comprise the entire causality chain by taking into account three dependent variables: innovation stemming from environmental regulation, environmental performance and business performance. It recorded a positive and significant link between the stringency of the regulation and the innovation, consistent with the "weak" version of the hypothesis. In addition to it, a positive correlation between the environmental innovation deployment and business performance was proven, also consistent with the "strong" version of the hypothesis. However, the direct effect of environmental regulation on business performance is negative and, on balance, the net effect on business performance is not positive, so that the negative effect of environmental regulation actually exceeds the positive effect associated with it. The issue, however, concerns accounting for the future effects of innovation on business performance, since the Porter hypothesis revolves around a dynamic view of the economy. As a matter of fact, Porter does not deny the initial costs of complying but states that in the medium/long-run costs will be reduced due to the reduction in inefficiencies. Supplementary (and more recent) analyses, in fact, show that the business performance experience a downturn in the initial phase of the environmental regulation appraisal, while reverting that tendency in the following years. In any case, it seems clear that further research is urgently needed in order to better interpret the cause and effect relationships among the different variables.

In this scenario, policymakers are requested to take into account the dynamic effects that any properly designed environmental policy can bring along and, most importantly, understand the focal importance of the regulations' stringency, stability and flexibility in order to achieve the best possible results.

Despite the brilliant intuition, the Porter hypothesis still appears to be a challenging matter.

Chapter 2

Introduction

This chapter focuses on the negotiations under the United Nations Framework Convention on Climate Change. The rising awareness of this phenomenon ultimately led to the coming into force of the most comprehensive climate agreement, built on the principle of common but differentiated responsibilities.

In section 2.1 an overview of the latest Conferences of the Parties (COPs) is proposed, aiming attention at the Kyoto Protocol. Section 2.2 discusses the Paris Agreement and the reasons why it is potentially capable of making a breakthrough in the climate issues, notwithstanding the recent US turnabout.

2.1 Prior to the Paris Agreement: the Kyoto Protocol

As already largely discussed, the global warming appears as a global challenge, requiring co-operation and commitment on a global scale. An effective mitigation implies coordination between countries and the acknowledgement that urgent action is deemed necessary to tackle the problem. Recalling the lecture held by Stern during the RES in Manchester (2007), being the global warming a serious negative externality problem, its responses require a compelling international collaboration.

Nowadays, the main international environmental treaty through which international negotiations are held is the United Nations Framework Convention on Climate Change (UNFCCC). Its aim is to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system"[14]. The Framework stresses the importance of international treaties and how they can be negotiated in order to reach its specific goals. However, it sets no binding limits on GHG emissions for single countries and it does not include any enforcement mechanism. It was adopted on May 9, 1992 and came into force on March 21, 1994. It was approved in occasion of the Earth Summit (1992) in Rio De Janeiro, during which we recall two more treaties strictly linked with it: the UN Convention on Biological Diversity and the Convention to Combat Desertification. From 1995, the member states' representatives have met annually in the Conference of the Parties (COP). The first concrete executions of climate change commitments took place during the COP3 in Kyoto, Japan (1997), which led to the adoption of the Kyoto Protocol. For the first time, there were legally established the binding obligations concerning developed countries' GHG emissions reductions for the period from 2008 to 2012. Emissions targets, however, differ

[14] United Nations Framework Convention on Climate Change (1992), Article 2, Objective, page 10. "The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."

from country to country in accordance with the principle of common but differentiated responsibilities. As a matter of fact, it demands binding obligations only for developed countries since they are deemed primary contributors to the global warming as their emissions shares are notably higher. For developed countries is hence required an overall reduction on average of 5% of their total emissions (CO_2, CH_4, N_2O, SF_6, HFCs, PFCs) with respect to 1990 levels. The European Union (EU[15]), Switzerland, most Central and East European states were required to meet the target with cuts of 8%; the United States were demanded a reduction of 7%; Canada, Hungary, Japan and Poland were required a reduction of 6% of emissions. Nonetheless, the US did not ratify the Protocol. Internally, the European Union has distributed the rates of emissions cuts among its member states. Furthermore, Norway, Australia and Iceland were allowed to increase their GHG emissions. It is worth noting the case of Iceland, for which emissions could increase by 10%. On the other hand, developing countries were not given any binding obligations regarding the limits on GHG emissions in order to avoid any deceleration in their economic growth.

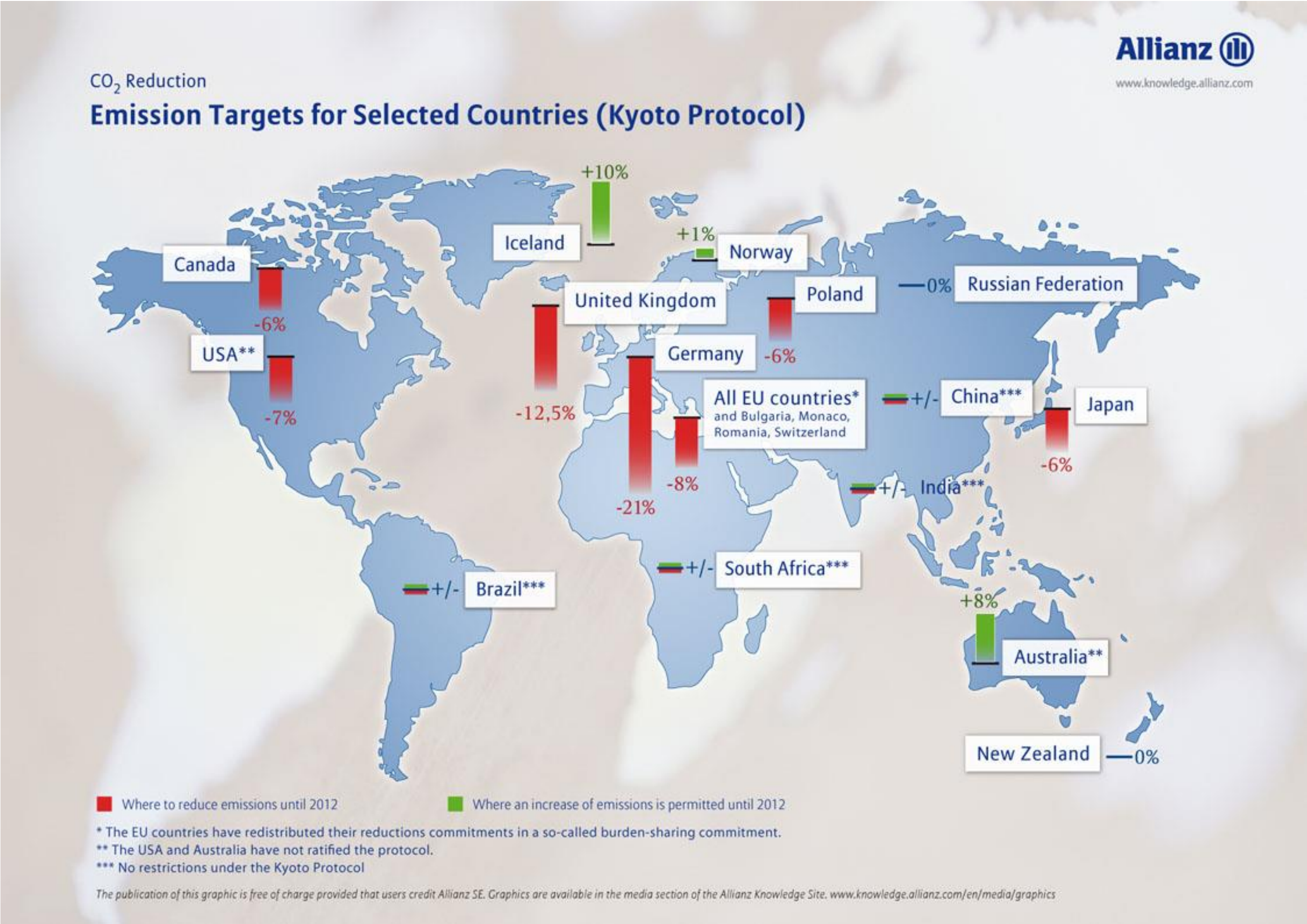


Figure 2.1 – Emission Targets for Selected Countries (Kyoto Protocol). Source: Allianz Knowledge, (2009). "Kyoto Protocol." Allianz Knowledge Partnersite. Retrieved 2010-09-18.

Anyhow, the agreement introduces some important instruments (the so-called flexible mechanisms) to favour international co-operation: International Emissions Trading (IET), allowing parties to trade the GHG emissions; Clean Development Mechanism (CDM), enabling firms operating in developed countries (with binding GHG reductions obligations) to provide for emissions reduction projects in developing countries; Joint

Implementation (JI), supporting developed countries to meet their environmental obligations. CDM and JI are often referred to as project-based mechanisms, since they support the GHG reductions through the implementation of projects. In particular, the Clean Development Mechanism allows Annex I parties to undertake projects related to the reductions of emissions in developing countries capable of generating Certified Emissions Reduction units (CERs), which can be traded in emission trading systems to achieve the desired objectives. This mechanism is useful to tackle the problem since it promotes the new low-carbon technologies transfers in order to pave the way for sustainable growth in developing countries. Meanwhile, it allows the emissions abatement where it is cheaper, enhancing efficiency while reaching the standards in countries included in Annex I. The Joint Implementation, on the other hand, gives the possibility to undertake environmental projects in Annex I countries to support their emissions reductions obligations as an alternative to reducing GHG domestically. Countries can undertake projects where the emissions reduction is cheaper and eventually exploit the resulting Emission Reduction Units (ERUs) to meet their own obligations. The aim is, again, to enhance efficiency by reducing compliance costs incurring in satisfying the Kyoto targets.

Nevertheless, the Kyoto Protocol has been subject to much criticism, mainly because of the limited time horizon objectives. In fact, Stern (2007) noticed that the short-time goals set by the Kyoto Protocol may result in low incentives in complying with the obligations. The underlying reason stems from the fact that countries and firms have low incentives in undertaking long-term investments. As a matter of fact, he states that "the Kyoto framework is not currently providing a sufficiently credible, long signal for countries or businesses to make long-term investments". However, he assesses that "The Kyoto Protocol can be seen as a first stepping-stone on the path to international co-operation on climate change, given political, economic and scientific realities"[15]. The sharpest criticism concerns the issue of only addressing obligations to rich countries, although some developing countries (such as India and China) are responsible for a high share of GHG emissions in the atmosphere. As a consequence, the US and Australia have not ratified the Protocol, while several countries did not take on decisive actions to implement it, leading to the ultimate impossibility of achieving the UNFCCC goals. Nevertheless, the Kyoto Protocol contributed to the development of the collective awareness of the climate change, motivating authorities to take urgent action and to cooperate in order to combat the problem. Furthermore, it provided useful elements to build on future agreements.

Anyway, later negotiations, did not bring significant results. COP13 (2007) and COP15 (2009), for instance, did not result in any emissions reduction commitment but only in a non-binding agreement built on generic targets to limit future global warming below 2 °C (Cancún agreement). An important step was made with the COP16 (2010), during which the Green Climate Fund was established, aimed at supporting developing countries in the mitigation and adaptation. The commitments, however, still remained on a voluntary-basis. A great development was accomplished during COP18 (2012), in Doha. The Protocol was finally amended to encompass the period from 2013 to 2020, establishing a second commitment period, but

[15] Stern Review on the Economics of Climate Change, 2007, page 478-479.

few countries have adhered so far. The EU, instead, ratified the agreement with a commitment to reduce overall emissions to 20% with respect to 1990. Concerning the post-2020 period, during the COP18, the urgency of a new climate agreement was pointed out that should enter into force when the Kyoto Protocol extension is set to expire.

2.2 The Paris Agreement

The 21st yearly session of the Conference of the Parties (COP) represented a radical step forward towards the ultimate achievement of the environmental standards. It was finally deemed necessary to reach an agreement that could ensure global warming would not exceed 2 °C and to define an action plan from 2020 onwards. As formerly agreed in the previous negotiations, prior to the conference, almost all participating countries (146) publicly presented draft national climate contributions (Intended Nationally Determined Contributions, INDCs). The European Union planned to reduce its emissions by 40% within 2030 with respect to 1990; the United States suggested Intended Nationally Determined Contribution was a commitment to reduce emissions of 26-28% within 2025 compared to 2005 emissions; China committed to reach its emissions peak within 2030. However, although the contributions represent a significant evolution, estimations resulting from the INDCs resulted in a 2.7 °C increase in temperatures within 2100, hence they were not sufficient to cope with the 2 °C targets. As a matter of fact, the Executive Secretary of the United Nations Framework Convention on Climate Change said: "The INDCs have the capability of limiting the forecast temperature rise to around 2.7C by 2100, by no means enough but a lot lower than the estimated four, five, or more degrees of warming projected by many prior to the INDCs."[16]

COP21 negotiated the Paris Agreement, a big turning point in international climate negotiations, adopted by 195 countries in December 2015. It is, in fact, "the first-ever universal, legally binding global climate deal"[17] and, hence, the first real progress towards concrete international actions to properly contain global warming. The greatest goal achieved was managing to include all the major contributors to the GHG emissions in the world (US, EU, China, India, Russian Federation, Japan). Finally, it was crystal clear that any concrete action decision could not be undertaken without the international cooperation of the bigger emitters. It is noteworthy to remember the key importance of the Sino-American agreement concerning environmental issues, signed on November 12, 2014, in Beijing. Basing the bilateral agreement upon the fact that US and China play a critical role in fighting climate change, after year of frictions, the two countries eventually managed to find a common ground to jointly work and mutually settle environmental problems. As a matter of fact, an agreement was reached about the deployment of more sustainable technologies and the support of clean energy. Furthermore, they agreed on a collaboration aimed at reaching an agreement during COP21, on common but differentiated responsibilities. To come into force, the Paris Agreement required the ratification

[16] Christiana Figueres, Executive Secretary of the United Nations Framework Convention on Climate Change, 2015 press release.
[17] From the EU Commission's webpage, Paris Agreement.

of at least 55 countries that produce at least 55% of global GHG emissions. The Sino-American relationship resulted in the ultimate ratification of the Agreement, which was a success since the two countries together contribute to almost 40% of global emissions. 174 states and the EU ratified the agreement and eventually it obtained enough countries to come into force on November 4, 2016. The amount of emissions covered accounted for 58,82%.

In the Adoption of the Paris Agreement's document, "Parties aim to reach global peaking of greenhouse gas emissions as soon as possible"[18] and to engage in mitigation actions to keep temperatures "to well below 2 °C"[19], although the difficulties for developing countries to reach the goal have been recognized (article 4). Nonetheless, no specific target has been set, although a central role has been attributed to INDC, since "Each Party shall prepare, communicate and maintain successive nationally determined contributions that it intends to achieve. Parties shall pursue domestic mitigation measures with the aim of achieving the objectives of such contributions."[20]. The aforesaid contributions should be as ambitious as possible and should reflect the "common but differentiated responsibilities and respective capabilities, in the light of different national circumstances"[21]. It points out the importance that the equity principle plays in this context: developed and richer countries bear higher responsibilities while developing and less industrialized countries are encouraged to improve their mitigation efforts in the future.

Furthermore, provisions on the objectives' revision and on transparency are noteworthy. Every five years Parties are required to track progress and to communicate their own commitments to the extent that they will constitute a development from the former ones, in order to achieve the purpose of the long-term goals (called "global stocktake"). It is intended to enhance the ambitiousness of countries commitments and favour the cooperation among Parties. National contributions are then subject to international evaluation. The first global stocktake will be in 2023 "and every five years thereafter unless otherwise decided by the Conference of the Parties"[22]. The Paris Agreement assumes a clear and solid transparency system concerning countries' mitigation and support decisions. As a matter of fact, countries are required to disclose certain information "in order to build mutual trust and confidence and to promote effective implementation"[23]. Parties should regularly provide: "a national inventory report of anthropogenic emissions by sources and removals by sinks of greenhouse gases" consistent with the IPCC principles; "information necessary to track progress made in implementing and achieving its nationally determined contribution"; "information on financial, technology transfer and capacity-building support"[24].

[18] UNFCC, COP21, Adoption of the Paris Agreement, 12 December 2015, Article 4, page 21.
[19] UNFCC, COP21, Adoption of the Paris Agreement, 12 December 2015, Article 2, page 21.
[20] UNFCC, COP21, Adoption of the Paris Agreement, 12 December 2015, Article 4, page 21.
[21] UNFCC, COP21, Adoption of the Paris Agreement, 12 December 2015, Article 4, page 21.
[22] UNFCC, COP21, Adoption of the Paris Agreement, 12 December 2015, Article 14, page 28.
[23] UNFCC, COP21, Adoption of the Paris Agreement, 12 December 2015, Article 13, page 27.
[24] UNFCC, COP21, Adoption of the Paris Agreement, 12 December 2015, Article 13, page 27-28.

Adaptation has been largely discussed in article 7, recognizing that it "is a global challenge faced by all with local, subnational, national, regional and international dimensions"[25]. Parties agree upon the importance of periodically providing "an adaptation communication", including "priorities, implementation and support needs, plans and actions"[26].

In order to find a common work to cooperate and mutually benefit from the Agreement, one important requisite was the support and financial aid for developing countries, which are often unable to properly cope with further economic and social issues. Therefore, developed countries are required to provide "financial resources to assist developing country Parties with respect to both mitigation and adaptation"[27]. In regard to this matter, it is noteworthy that, in accordance with article 9, richer countries are supposed to send US$100 billion a year by 2020 to poorer countries (the amount of money needs to be higher in the times to come) "for mitigation and adaptation while significantly increasing adaptation finance" and "to provide technology and capacity-building support"[28]. A first meeting to check the results and to define a new goal will take place in 2025. Moreover, the Green Climate Fund will be used to support poor countries in their emissions reduction and to build on a sustainable energy system. For the first time, however, developing country Parties are also invited to contribute financially on a voluntary basis (article 11), although a greater burden is given to developed countries.

On June 1, 2017, the president Donald Trump announced that the US will no longer respect the Paris Agreement, thus pulling his nation out of the Paris climate accord. It means that the US will stand alongside Syria and Nicaragua as the only countries which are not part of it. His decision was made according to the belief that the aforesaid Agreement was disadvantageous in economic terms and would only benefit other nations. This announcement resulted in several criticisms. As a matter of fact, it will be harder – or even impossible – to achieve the desired environmental goals without the aid of the second largest contributors to GHG emissions since, furthermore, the US promised $3 billion to support other countries. According to Trump, then, the United States will stop their contribution to the Green Climate Fund. However, the Paris Agreement was entered into by executive order and it was established that no country can withdraw from it for three years after its ratification; moreover, one year notice was required, meaning that pulling US out of the Paris Agreement could not be finalized until 2020. During the US Conference of Mayors, the President's decision was strongly condemned. Consequently, its members promised to continue the efforts to reduce the GHG emissions at the city and state level. As a matter of fact, the states of Connecticut, Delaware, Hawaii, Massachusetts, Minnesota, Oregon, Puerto Rico, Rhode Island, Vermont and Virginia joined the US Climate Alliance (founded by the governors of California, New York and Washington as a response to Trump's announcement to withdraw), promising to continue the efforts to reduce the emissions by 26-28% from 2005

[25] UNFCC, COP21, Adoption of the Paris Agreement, 12 December 2015, Article 7, page 24.
[26] UNFCC, COP21, Adoption of the Paris Agreement, 12 December 2015, Article 7, page 25.
[27] UNFCC, COP21, Adoption of the Paris Agreement, 12 December 2015, Article 9, page 26.
[28] UNFCC, COP21, Adoption of the Paris Agreement, 12 December 2015, Enhanced Action Prior to 2020, page 16.

levels by 2025 (a target enshrined in the US NDC) and to meet the CPP objectives. Moreover, on June 6, 2017, the state of Hawaii became the first US state to translate the Paris Agreement climate goals into official policy, by enacting laws aimed at reducing GHG emissions. Other states (and cities), such as Colorado, Maryland, Montana, North Carolina, Ohio and the District of Columbia, have expressed their support. It is noteworthy that California is now seeking its own international agreement with China concerning the climate change issue. The state's governor Jerry Brown stated that he would discuss a merge of California carbon trading market (already connected to the Canadian one) with the China's market. Furthermore, after the Obama administration (which provided companies with funds and subsidies to develop and reduce the emissions) changing the course of action appears to be tough. Many CEOs, in fact, have understood the profitability of "green" investments and are determined to keep the environmental commitments and to continue the production processes according to their sustainable plans.

However, the US scenario remains critical. From the very beginning, the new administration managed to alarm environmentalists worldwide. It is worth noticing the controversial appointment of Scott Pruitt (the attorney general of oil-producing Oklahoma, well-known for his skepticism about climate change) as the new administrator of United States Environmental Protection Agency (EPA). On March 28, 2017, furthermore, Trump officially declared an end to the "war on coal"[29] before signing the executive order aimed at ending the Obama-era environmental regulations, involving the experiment of putting a price on GHG emissions. Although from a political point of view it is a mere demonstration of the truthfulness of his campaign promises, it reveals his carelessness in environmental decisions. By doing so, he put an end to the federal government's use of the social cost of carbon calculation and began unravelling the Clean Power Plan (CPP), implemented to fund with billions of dollars the shift toward a cleaner energy system, aiming at reducing emissions by 32% within 2030 compared with 2005 by shutting down coal-fired power plants, stopping the construction of new ones and replacing them with renewable energy plants. According to Donald Trump, the re-evaluation of the CPP can be regarded as a step towards US energy independence, although the US has been exporting more coal than it has been importing for the past decade and, by 2018, it is expected to become a net exporter of natural gas (AEO2017). Trump also stated that the CPP will threaten American miners, energy workers and companies. Nevertheless, the CPP never really came into force since, in February 2016, it was frozen by the Supreme Court. From the day it was announced (in August) to the day its enforcement was halted, the US registered a drop of 9,300 coal mining jobs which is, however, in line with the historical trends. As a matter of fact, since the 1980s, coal mining jobs have been steadily decreasing because of the boost in production of natural gas and the increase in automation. Natural gas is, in fact, cheaper and cleaner and the increase in

[29] Remarks by President Trump at Signing of Executive Order to Create Energy Independence. "We've already eliminated a devastating anti-coal regulation -- but that was just the beginning. Today, I'm taking bold action to follow through on that promise. My administration is putting an end to the war on coal. We're going to have clean coal -- really clean coal. With today's executive action, I am taking historic steps to lift the restrictions on American energy, to reverse government intrusion, and to cancel job-killing regulations."

automation will certainly not lead to an increase in recruitment. Without the CPP, it would be impossible in any case to respect the commitments made in Paris. This aggressive protectionism mix will probably result in the progressive isolation of the US, which will plausibly give up every opportunity to economically thrive and develop. The new OECD report, in fact, by measuring the positive economic effects that environmental policies can lead to, explains that "Investing in Climate, Investing in Growth"[30] is possible. According to the aforesaid report, these aspects go hand in hand, as it explained that "bringing together the growth and climate agendas, rather than treating climate as a separate issue, could add 1% to average economic output in G20 countries by 2021 and lift 2050 output by up to 2.8%"[31]. By taking into account the several benefits that avoiding the consequences of global warming can bring, "the net increase to 2050 GDP would be nearly 5%"[32]. If, on one hand, past international negotiations aimed at containing global warming have been postponed, nowadays there is no room for delay. As stated by the OECD Secretary-General "There is no economic excuse for not acting on climate change, and the urgency to act is high"[33]. Delaying climate actions - for instance, taking concrete action only from 2025 - would mean an average GDP loss for G20 economies of 2% with respect to the immediate realization of economic policies to tackle climate change. The report explains that stopping global warming at 2 °C above pre-industrial levels will require $6.9 trillion per year in infrastructure investment from now to 2030, which is only 10% more expensive relative to the carbon-intensive alternative and will result in a higher degree of energy efficiency. Moreover, it will lead to fossil fuel savings accounting for $ 1.7 trillion annually, hence, more than offsetting the costs incurred to achieve the goal. The OECD analysis emphasizes that the benefits will exceed the costs even for those economies currently focused on fossil-fuels exports and provides some recommendations for G20 countries, based on international coordination and cooperation. Developed economies should engage in strict climate mitigation policies aimed at discouraging CO_2 emissions (through carbon pricing instruments) while supporting private investment in low-emission and climate resilient infrastructure. There is, in fact, ample empirical evidence supporting the argument that "decoupling" economic activity from carbon dioxide emissions is possible and is actually happening right now. In 2016, the International Energy Agency (IEA) reported that, while global emissions of CO_2 remained flat from 2013 to 2015 at 32.1 billion tonnes, global GDP grew by 3.4% in 2014 and by 3.1% in 2015. This trend is clearly supported by the increase in renewables deployment and by those countries that accurately managed to comply with environmental standards trough emissions reductions. Figure 2.2 provides with comprehensive evidences of countries that managed to "decouple" CO_2 emissions from economic growth. It is surprising that, indeed, the US is the largest country experiencing multiple consecutive years in which a

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[30] OECD, "Investing in Climate, Investing in Growth", published on May 23, 2017

[31] Assertion from the OECD website, "Taking action on climate change will boost economic growth", 2017. Available at: http://www.oecd.org/economy/taking-action-on-climate-change-will-boost-economic-growth.htm. Accessed June 2017.

[32] Ibid.

[33] OECD Secretary-General Angel Gurría, presenting the report at the Petersberg Climate Dialogue in Berlin, 2017.

growth in GDP has been accompanied by a reduction in emissions. However, this positive trend could only be supported with the implementation of the Clean Power Plan and with the compliance with the Paris Agreement's commitments. Most countries that have "decoupled" their emissions from GDP have also reduced the industrial share of their economies, hence, advanced countries could have limited their emissions by offshoring heavy industry to developing countries. However, although these countries managed to reduce emissions by 15% on average, cuts in the industrial sector share of output are only 3%. The remarkable cases of Bulgaria and Uzbekistan show that it is possible to reduce the environmental pressure while increasing GDP also with an expansion of the industrial sector. Moreover, Switzerland and the Czech Republic's industrial sector share of GDP remained constant while "decoupling". These positive trends, mainly driven by the dramatic growth of renewable energy, demonstrate that it is feasible to encourage environmental protection while increasing GDP at the same time. However, this is just the beginning. It is necessary, in fact, to quickly scale up this tendency to support the Paris Agreement's goal of limiting the global warming to 2 °C. Nevertheless, it demonstrates that countries are indeed shifting towards cleaner approaches to foster economic activity. Anyhow, the road towards a new energy system will require deep changes in the energy production mechanisms, in the industrial processes and in transportation. In order to stay competitive, countries and firms are required to improve their energy efficiency and to focus on research and innovation, relying on clean energy forms to cover their needs. The introduction of the Task Force on Climate-related Financial Disclosure could promote this shift by supporting companies in evaluating

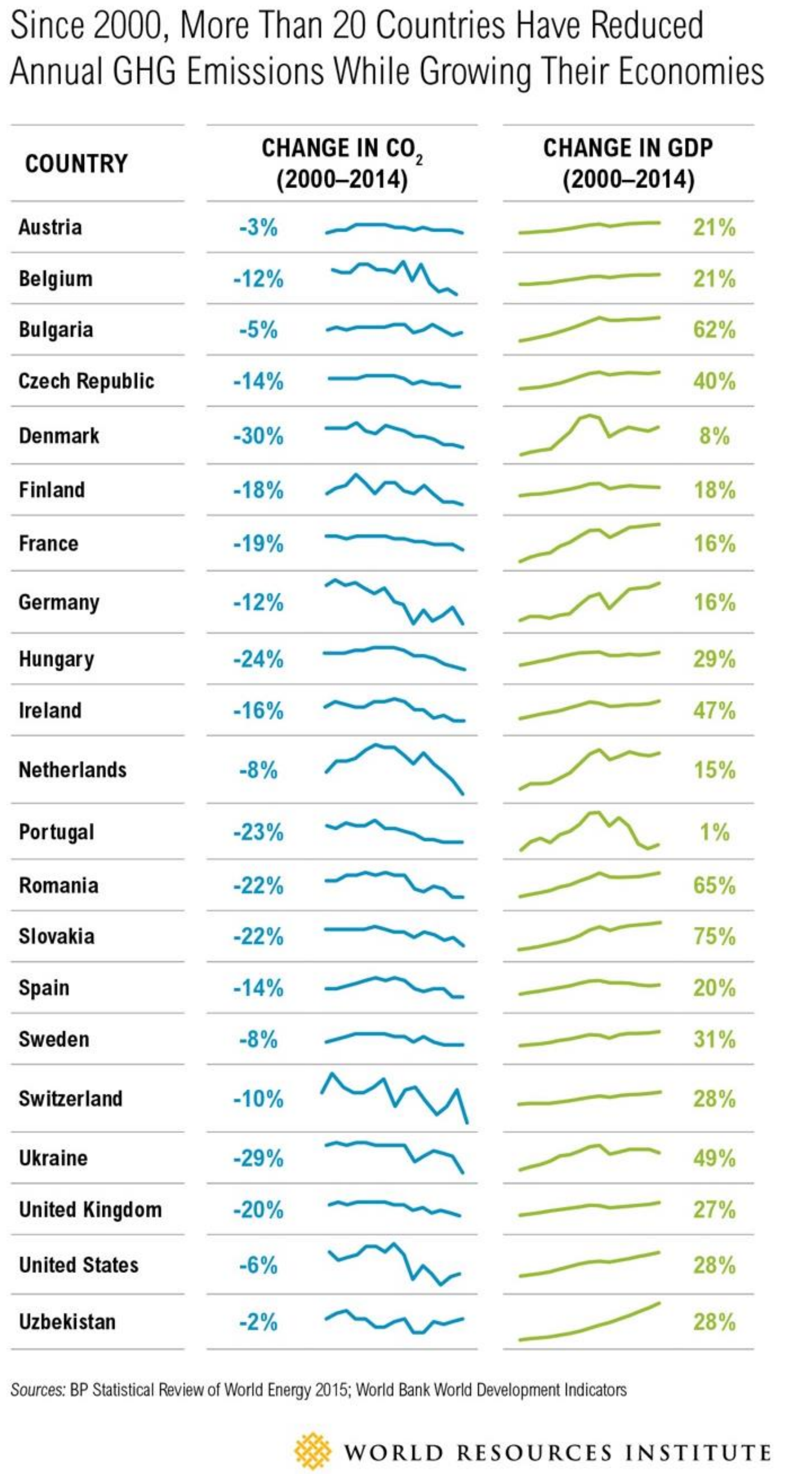

Figure 2.2 – 21 countries – all in Europe except for US and Uzbekistan – which managed to reduce CO_2 emissions while increasing their GDP. Source: BP Statistical Review of World Energy 2015; World Bank World Development Indicators.

the climate change-related risks and encouraging investors in making conscious choices in the prospect of a low-emission world economy.

The Paris Agreement, by building resilience and awareness and in its attempt to decrease vulnerability to the adverse effects of global warming, represents a revolution in tackling climate change. Nevertheless, it demands strong cooperation among Parties. Without it, any effort would be vain and the whole of humanity would eventually lose the challenge of a sustainable future and the possibility of leaving the generations to come with a habitable planet in which they can live. By respecting commitments, the positive implications on the world economy will be considerable, from an equity point of view as well. In a speech held after the US withdrawal, Emmanuel Macron firmly said: “The Paris Agreement remain irreversible and will be implemented not just by France but by all the other nations. We will succeed because we are fully committed, because wherever we live, whoever we are, we all share the same responsibility: make our planet great again.”[34]

[34] Statement from Emmanuel Macron, president of France, June 1 2017.

Conclusion

According to what has been forecasted by the IPCC, unless immediate and proper action, global warming repercussions will become irreversible and will affect the entire world population, with a tremendous impact on the environment and living beings, of which the minor contributors are expected to be the ones that will bear the heaviest consequences. Keeping doing business-as-usual will result in temperatures rising well above 3° C. In this scenario, a considerable percentage of rainforests will be destroyed as well as vegetation; many regions in the world will not be habitable any longer because of the rise in sea level and unbearable heatwaves, leading to intense migration flows towards northern countries; agriculture in several areas will collapse and global economy would be adversely affected. Nevertheless, after several climate summits resulting in little or no action taken, the 2015 United Nations Climate Change Conference represented a first real step towards environmental protection and climate change awareness. COP21 negotiated the Paris Agreement, built on the principle of common but differentiated responsibilities, with the ultimate goal of limiting global warming to well below 2 °C through the vital and urgent cooperation among countries, in order to favour the transition towards low-carbon economies. The final draft of this historic accord has been ratified by almost 200 nations (including the world's largest emitters), all of which providing resolute national emissions reduction targets aimed to be made more and more ambitious in the time to come, since, despite the efforts, they cannot be considered sufficient yet in order to arrest climate change. The Paris Agreement has no penalties associated to the non-compliance nor any enforcement provisions included. Therefore, countries are required to scale up their efforts, constantly build resilience, encourage cooperation, support developing countries in the achievement of environmental targets and strengthen climate mitigation policies. The latter should be coordinated through the proper degree of international synergy in order to achieve the best possible results in terms of market efficiency and environmental results.

This dissertation embraced the OECD and the COP21 argument about the effectiveness of carbon pricing instruments, perfectly complying with the polluter pays principle. Policies' effectiveness depends upon the flexibility of the policy instrument and the right choice of policy mix. Market-based solutions are, in fact, flexible (since firms would be in the position of reducing the cost of compliance because of the combination of different instruments) and cost-effective (allowing for the achievement of the environmental objectives in the cheapest way). Following the recommendations and, hence, implementing flexible and strict environmental policies, results in the use of brand new technological innovations that could potentially lead to an improvement in economic performances. Therefore, policymakers are required to consider the several dynamic effects deriving from the implementation of any properly designed environmental policy when accounting for costs and benefits. Furthermore, it has been proven that "decoupling" carbon dioxide emissions from economic growth is possible and is happening right now.

Nowadays, the great majority of scientists have provided clear evidence on the existence of the climate change, highlighting the causes and the dramatic consequences associated with it. Our social challenge is to raise awareness and change people's behaviour in order to support the full transition towards a sustainable economy. Our economic challenge is to provide the right incentives by adopting the available tools in the most efficient manner. The analysis showed that, where implemented, market-based instruments' net results are positive. The question, however, is whether countries are motivated to take concrete actions, to fulfil their goals and to eventually develop a livable, sustainable future.

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