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INTERNATIONAL DEVELOPMENT AND ENVIRONMENTAL DEGRADATION: THE POLICY IMPLICATIONS OF THE ENVIRONMENTAL KUZNETS CURVE

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ABSTRACT

This dissertation analyzes the existing relation between economic growth and environmental degradation. After having briefly discussed the concepts of limits to growth and of sustainable development, the focus will be drawn on the Environmental Kuznets Curve hypothesis —which describes the level of environmental pollution as a function of income— and its theoretical explanations. Following, I will provide a general overview of the policy measures to be taken in order to promote pollution control. In particular, I will stress the importance of the role played by governments and international organization in acting as benevolent social planners in the promotion of environmental wellbeing. Finally, I will illustrate the main sources of environmental degradation and concern in China and the policy strategies adopted to control pollution.

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INTRODUCTION

The relationship between environment and development has been widely discussed in economic development literature since the second half of the XX century. A first approach saw such a relationship as an inevitable tradeoff between environmental wellbeing and economic growth. The ecosystem, in fact, can be understood in a twofold way: as a *source* and as a *sink* for the economic system. The first understanding —whose analysis traces back to the XVIII century— relates to the fact that the economic system, in order to function and expand, has to rely on the exploitation of natural resources offered by the ecosystem; the second understanding —which has emerged in the 1980s— relates to the concept of the environment as a medium for assimilating wastes (Neumayer, 2003). The common denominator for both is the concept of the ecosystem's carrying capacity, which is inherently finite and implies the possible achievement of limits to economic growth.

In such a context, the threat that human activity would compromise the global ecosystem has progressively gained attention, becoming one of the main issues of today's worldwide policy debates. The statistics suggests that an economic growth that does not take into consideration the concept of carrying capacity is not sustainable over time. All the Developed world, in fact, is experiencing growth rates —thus resources' depletion rates— which do not allow for the regeneration of the environmental stock. According to an estimate by the Global Footprint Network (GFN), human activity and consumption has began to exceed the ecosystem's carrying capacity in terms of resources regeneration already in the early 1970s. In 2015, humans had exhausted in less than eight months a year's supply of natural resources. The impacts of such an ecological deficit are reflected in the progressive increase of deforestation, water resources' depletion and soil erosion. Similarly, also the ecosystem's ability to assimilate wastes is approaching its limits. According to the World Health Organization (WHO) data, air pollution has increased by 8% in the past five years, exposing a significant portion of the population to dangerous air. In many Underdeveloped countries those figures have lead to a public health emergency, with air pollution causing more than 3 million deaths a year.

The development of new technologies, however, has partially contested the idea that a tradeoff between environment and growth is necessarily true. From the late 1990s, a new hypothesis was advanced —namely the *Environmental Kuznets Curve hypothesis*, stating that although in early stages of development economic growth would translate in higher environmental depletion, once the country reaches more advanced stages of development it disposes of the necessary means to exploit more efficiently the resources offered by the environment and alleviate the damages caused by environmental degradation. For this to happen, however, it is fundamental the implementation of an international system of norms and regulations other than financial support aimed at environmental protection.

Object of this thesis is the analysis of the relationship existing between development and environmental degradation. After providing a general framework examining the concepts of *limits to growth* and *sustainable development* in an ecological reading, the focus will be shifted towards the Environmental Kuznets Curve hypothesis. I will analyze the five main theoretical factors that lie behind such a hypothesis and that explain the relationship between level of income and environmental degradation. Following, an overview of the main policies implications will be provided, discussing several examples of approaches to be adopted by governments in order to promote environmental protection. Finally, in order to give an empirical example, I will discuss a case study on the environmental concern in China and its policy implications.

CHAPTER ONE

ENVIRONMENT AND DEVELOPMENT

1.1 Economic growth and environmental deterioration

The economic system can be defined as an *open system* (Turner, Pearce, Bateman, 2003), meaning that in order to function it has to rely on the resources offered by the Planet. This relationship of dependence constitutes a serious burden for the economic activity, that might eventually prove very unstable. The Earth, in fact, has a limited *carrying capacity*, defined as the "maximum population size that an area can sustain under a given social system" (Daily and Ehrlich 1996, p. 992). Given today's social system, the Earth's capacity to support humans depends mainly on two factors: population growth and our technological choices, which determine the level of resources' consumption and the amount of waste we generate. While population growth is positively related to consumption of resources and production of waste, technological choices, if properly directed, will lead to a reduction of both. I will discuss such relationships in the first part of this chapter.

A distinction should be drawn between non-renewable and renewable resources; while in the case of non-renewable resources their exhaustible nature is inherent in their definition, in the case of renewable resources their exhaustibility is related to the rate of exploitation that may prevent them from regenerating. In both cases, a fundamental notion is the *Earth's Net Primary Productivity* (NPP), defined as the "total amount of solar energy converted into biochemical energy through plant photosynthesis, minus the energy those plants use for their own life processes" (Postel, 1994). In 1986, the biologists Vitousek, Ehrlich, Ehrlich and Matson estimated the impact the world population has had on the NPP, demonstrating the disproportionate control that humans hold on it if compared to other species. At its origins, the Earth's NPP had the potential to produce nearly 150 billion tons of organic matter per year; human activity, however, has destroyed the 12% of it and is currently using another 27%. Thus, one species has been appropriating of nearly 40% of the Earth's food supply. Although 40% might still seem as an acceptable percentage, it is important to consider that it could double in quite a short period of time as, while population grows at an ever-increasing pace, resources do not (Postel, 1994). The depletion of NPP has inherently lead to the slowingdown of the regeneration rate of renewable resources. According to the data gathered by FAO (2014), for example, the expansion of world's marine fisheries has exhibited a general declining trend since 1996: while by the end of the 1990s the recorded production was of 86.4 million tonnes, in 2011 and 2012 it declined to 82.6 million tonnes and 79.7 million tonnes respectively. Similarly, data gathered for forest expansion show a general trend of increasing deforestation: since 1990, 129 million hectares of forest had been lost (FAO, 2015).

The second factor influencing the Planet's capacity of sustaining our activity is the production of waste. Just like the offer of resources, also the environmental ability of absorbing waste is limited. On this behalf, Ayres and Kneese (1989) try to address the problem by assimilating the economy to a continuous process of transformation of materials which, at the end of the productive cycle, reemits into the surrounding environment an amount of waste equal to the quantity of materials initially extracted. This consideration —based on the First and the Second law of Thermodynamics, implies also the impossibility for *all* those waste products to be reintroduced in the system as usable resources through recycling processes. The proliferation of industries and the large-scale usage of chemical products, therefore, has lead to the dissipation of a significant number of substances that cannot be eliminated, constituting a further material burden to environmental exploitation.

The third factor, technological choices, will be discussed in more depth in section 1.3. For now, I will only mention the fact that, although in the First and Second Industrial Revolutions the technological improvement has had a negative impact on the exhaustion of the Earth's capacity by accelerating the exhaustion of resources and by emitting into the environment a high quantity of waste, today many scholars argue that if properly redirected, technological change could reduce the impact of economic activities and improve the future environmental situation. However, even if technologies might expand the Earth's carrying capacity, there still exists a *biophysical carrying capacity,* namely "the maximum population size that an area can sustain under given technological capabilities" (Daily and Ehrlich 1996, p. 992), which merely constitutes an upper bound on carrying capacity.

1.2 Limits to Growth

The interaction between all those factors lead the way to the formulation of several thesis regarding the possible existence of *limits to growth* —namely thresholds of resources' depletion and environmental exploitation which -once reached- cannot grant to the economic system the necessary elements that would allow it to further develop. The first hints regarding the possible existence of limits to growth was given already in the late XVIII century by the economists Malthus and Ricardo; they both argued in favor of this thesis and related it to the problem of the growing level of population and to the concept of *declining marginal returns on land.* In his several works, Malthus analyzed the role of land as the main resource of production of the economic system of that time. He argued that human survival on Earth depended on land and on the resources it provided (food, wool, wood, etc). However, he also pointed out that the supply of land is fixed, and as the level of population augmented, so did the demand for such land and for the resources it supplied; the economic system, therefore, would eventually collapse once the population would have reached a level such that the demand for land would be higher than its supply (Wrigley, 1988). As discussed later on by Mill, it seemed as if the process of economic development would eventually have to result into a *stationary state*, a situation characterized by a constant level of population, which would make the exploitation of the lands and of the resources sustainable over time (Turner, Pearce, Bateman, 2003). The only possible solution, thus, seemed to be preventing population from growing more.

Those same concepts have been brought up again in 1972, when the Club of Rome —a global think thank— published *Limits to Growth,* a report that raised considerable attention on the matter of the economic growth and its relation with the environment. In their work, Meadows, Meadows, Randers and Behrens addressed the urgency of finding a solution to the growing level of population. According to the data they gathered, the limits to growth on Earth would be reached within the future one hundred years. This dramatic scenario is due to the fact that level of population, industrialization, pollution, production of food and exploitation of resources had been estimated to grow at an exponential rate, which means that they where expected to increase "by a constant percentage of the whole in a constant time period" (Pestel 1989, p. 1). Those factors, in fact, are interrelated between them: as population grows, so does the production of food; at the same time, in oder to sustain the increasing production of food, the consumption of resources necessary for the production also increases. As seen earlier, however, the resources will eventually finish, and their transformation will eventually be not sustainable in terms of waste production. Again, the implication here is that the only way to prevent the collapse of such a system and to grant it's capability of satisfying the basic needs for all its people in the future, is to set a limit to the population growth. In a world characterized by its finiteness, the only viable way seemed to be that of accepting restriction to further development.

The report *Limits to Growth* has been strongly criticized in the subsequent years. In particular, a group of students from Sussex University —the Sussex group— in their work *Thinking About the World: a Critique to the Limits to Growth* published in 1973, developed their critique around two important factors that the report has omitted, compromising the veracity of its findings: price mechanism and technological and human development. They argue that price mechanism plays a fundamental role in the efficient allocation of resources: as their scarcity augments so does their price, forcing the economic system to look for adequate substitutes (*substitution effect)* and to improve processing techniques. An increase in the price of carbon energy, for example, will induce users to buy more energy-efficient equipment (Nordhouse, 2002). However, although the price system may prove effective in several areas, it holds several limits as it comes to the allocation of natural resources offered for free by the environment. Concerning the second factor, technological and human development, much literature sustains its importance. Beckerman, for example, argues that resources limitation proves false if seen in the context of technological and scientific development; in fact, 'the known reserves at any point of time are only the reserves that have been worth finding' (Beckerman 1992, p. 483), meaning that new explorations and findings would eventually compensate for the depletion of non-renewable resources; with the advance of technological discoveries, several solutions could be found also regarding the improvement of the recycling process, significantly reducing the production of waste.

1.3 The role of technology

In the context of the technological development critique, in the 1960s Lucas and Romer developed a new thesis denominated *New Growth Theory,* which states the importance of taking into consideration the concept of *induced innovation,* defined as the 'impact of economic activity and policy on research, development and the diffusion of new technologies' (Nordhouse, 2002, p. 260). Basic and applied research can be used to improve the level of knowledge of a society, that will result into an improvement of the efficiency in the use of environmental resources. Investing in research will prove very profitable for a society especially in the long run: while it is necessary to face a high cost at the beginning, as the inventive activity develops, improvements will reduce the costs of environmental control. In this way new knowledge is created, and also knowledge which already exists is spread across firms (Weizsäcker, 1966). Many scientists believe that the new technologies may play a fundamental role in trying to solve todays environmental problems. As Nordhouse (2002) points out, in the long run the induced innovation approach will prove more efficient than the substitution approach caused by the price mechanism. In his study related to greenhouse gasses emissions, he found evidence that, although in the short run the substitution effect or the implementation of restrictions on emissions might lead to a higher decrease of greenhouse gasses, in the long run the benefits of induced innovation approach are doubled.

Although improvements in technologies and knowledge prove to have a very high *social* rate of return (in the USA it has been estimated as the 30-70% on initial investment), they have a smaller *private* rate of return (6-15%) (Nordhouse, 2002). Normally, investment on applied research is carried out by private laboratories for commercial purposes and in order to increase their profits. As long as the final value of the research exceeded the cost, firms will be willing to invest their money. However, problems might arise when there is the need of investing in basic research. Unlike applied research, basic research is not immediately patentable, and therefore is not an immediate source of profits. This might prove as a deterrent for private industries in investing in basic scientific knowledge that is fundamental in order to make significant technological advances (Nelson, 1959). Only big firms operating in a wide range of different technology will find it profitable to invest in basic research, that might be useful in different sectors. In this perspective, the induced innovation function is related to the idea of a *depletable pool*, which implies that heavy research today will reduce the number of 'available research' in the next period, leading to *diminishing returns on technology* (Nordhouse, 2002). Furthermore, private investments in research might prove inefficient also taken the fact that industries are keen to keep their findings secret so to hold an advantage on the competition. For those reasons it is fundamental the role played by the government in making public investments on basic and technological research aimed first and foremost at social returns. In the absence of public funding, in fact, research investments might not be enough or inventive activity might prove non so efficient on a social and temporal basis. Furthermore, in the case of developing countries, it is important to remember that often their economic structure is characterized by insufficient investment, innovation and human capital (Stiglitz, Sen and Fitoussi, 2009), leading to a non-homogeneous spread of technological achievements. According to the data gathered by the World Bank, in the timeframe that goes from 2006 to 2012, OECD countries have spent on average 2,36% of their GDP on R&D, as opposed to the 1,09% average spent by Low Income countries. Considering the different magnitudes of GDPs of the two group of countries, it is clear that the under-developed countries cannot solely count on on technological development in order to improve their environmental condition.

Although some estimations can be made regarding the beneficial impact that new technologies will have on the environment, the actual path that their development will take is still uncertain. An opposing thought to the *technological optimism* —which believes that technologies will eliminate resources and energy limits to growth— is that of *technological pessimism*. This line of thought assumes that there are some fundamental natural constraints related to resources and energy's scarcity that technology won't be able to circumvent. The supporting argument of this hypothesis is that by studying natural systems, it emerges that they *inevitably* stop growing when they reach resource constraints and neither intelligence nor innovation can defeat those constraints. To further support the notion of technological pessimism lies the belief that as long as a market for natural resources will be absent, firms will be unwilling to invest in R&D aimed at improving environmental quality; this particular issue will be analyzed in more depth in chapter three. Those two approaches imply the adoption of very different measures and precautions, but, because of the uncertainties over the future actual development of technologies, it is hard to choose that correct approach to follow.

Costanza (1989), in his work, has proposed a solution to this dilemma by adopting the *maxmin approach,* which consists in opting for the alternative that maximizes the minimum payoff available. He constructed a payoff matrix for technological optimism and technological pessimism, where on the left he lists the possible policies to implement —either that sustained by technological pessimists or that sustained by technological optimists— and on the top he lists the two possible future scenarios: the one in which technological pessimists are right and the one where technological optimists are right. At the intersections, there are the results of the combinations of policies and future scenarios. The highest possible payoff is the one that would occur if we would follow the technological optimism policy and if thereafter their theory would prove right. If, however, after adopting the technological optimism policy, their theory would prove to be wrong, the outcome would be *disaster*, meaning that the ecosystem would have incurred in irreversible damages. The risk taken in deciding to follow the technological optimism policy, therefore, is very high. On the other hand, if we would adopt the technological pessimist policy, the payoff in the case pessimist would be right will be *tolerable.* However, if the pessimist would prove wrong, still the payoff would be *moderate.* According to Costanza, in a context were the future developments and the future scenarios are very uncertain, the most prudent alternative we have is that of adopting the technological pessimists policies, or at least taking them in consideration in the political and economic debate.

Costanza's payoff matrix		
	Optimists Right	Pessimists Right
Technological Optimism Policy	High	Disaster
Technological Pessimist Policy	Moderate	Tolerable

1.4 Towards Sustainable Development

Taking into consideration all the factors discussed so far, and given the uncertainties prospected for the future, many policymakers and global think thanks have understood the importance of deepening the political and economic debate over environmental exploitation and the ever increasing resources' shortages. On this behalf, in the second half of the XX century the concept of *Sustainable Development* has emerged. Its most known definition is that given in 1987 by the World Commission on Environment and Development, also known as the Brundtland Commission:

> "Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs. The concept of sustainable development does imply limits - not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities[1]".

This concept is linked to a more general definition of sustainable development, that implies that a development path in order to be sustainable has to grant the maintenance or the increase of the capital assets over time and throughout generations (Wheeler and Beatley, 2014). The innovative element introduced by the Commission is the consideration given to the environmental factor. The recognition of the existence of relative limits implies that the current generation does not have to care only about the preservation of the *manufactured capital,* but also of the *environmental* —or *natural capital*, without which even the manufactured capital could not be preserved or developed. This observation does not imply that today's society has to choose either the imposition of limits to growth or the unrestricted economic growth, but suggests the need of adopting a more comprehensive view of the performance of today's economic systems. In order to do so, it is fundamental to grant equal distribution of resources in present and future generations. As we will see in more depth in chapter two, natural resources and environmental costs are not equally distributed among countries. In particular, the Environmental Kuznets Curve describes the relation that exists between income and environmental deterioration, claiming that at low levels of income the latter tends to increase. According to World Bank's data, in 2014 the rate of depletion of natural resources (forest, energy and minerals) was nearly 6 times higher[2] in low and middle income countries if compared to the rate of OECD countries. Similarly, the population-weighted exposure to air pollution was 2.5 times higher[3] in low and middle income countries than in OECD countries. Moreover, environmental degradation is more regressive in poor and emerging countries. Policies of redistribution of wealth and technologies together with the implementation of environmental

[1] World Commission on Environment and Development (1987), p. 4

[2] The World Bank, World Development Indicators (2016). *Adjusted savings: natural resources depletion (% of GNI)*. Retrieved from http://data.worldbank.org/indicator/NY.ADJ.DRES.GN.ZS/

[3] The World Bank, World Development Indicators (2016). *PM2.5 air pollution, mean annual exposure (micrograms per cubic meter)*. Retrieved from http://data.worldbank.org/indicator/EN.ATM.PM25.MC.M3/countries/1W-XS-XO

regulations, can help the underdeveloped world to escape the trap of non-sustainability. Because of the transversal and global nature of environmental degradation, assuring a universal and homogeneous adoption of high environmental standards and sustainable resource depletion is necessary in order to assure the preservation of environmental capital throughout time.

In order for institutions and governments to efficiently allocate investments and redistribute wealth that would compensate for the loss of value of the physical capital and for the consequent environmental damage, it is important to internalize environmental accounting in policymaking. On this behalf, the Commission on the Measurement of Economic Performance and Social Progress in its report published in 2011, questions the validity of GDP as an indicator of the economic performance of a country. The CMPEPS argues that the measurement of many economic variables used to quantify development and growth does not necessarily reflect their actual impact on society and economy. Especially as it comes to the environment, the variables that measure the economic performance in relation to environmental deterioration might be not very consistent (Stiglitz, Sen, and Fitoussi, 2009). The reason for this failure of measurement is probably related to the difficulty of giving a consistent value to the natural capital. As we will see in chapter three, the role of government in internalizing environmental externalities through market and non-market measures, together with a targeted investment on green technological innovation is fundamental in order to grant a sustainable development of the economy.

CHAPTER TWO

THE ENVIRONMENTAL KUZNETS CURVE

2. 1 The analytical model

The first studies that addressed the problem of an unequal distribution of environmental depletion and costs among countries emerged in the 1990s. The relationship associated with this phenomenon is that of the *Environmental Kuznets Curve* (EKC), which describes the change in environmental degradation as a function of income. The EKC derives its name from the Kuznets Curve (Kuznets, 1955), which graphs the hypothesis that as a country develops and as its per capita income increases, economic inequality within that country will first increase and then decrease, generating an inverted-U shaped curve. In the early 90s, Panayotou (1993), Shafik and Bandyopadhyay (1992) and Grossman and Krueger (1993) reconsidered the idea of the Kuznets Curve in the context of environmental degradation and found the same inverted-U shape in the EKC.

According to the EKC, the pressure put on the environment grows at a higher rate than income in the first stages of the economic development of a country, and slows down at higher levels of income, after having reached a turning point (TP). The relationship describes a dynamic process that develops in the long run that, in other words, represents a development trajectory of an economy that evolves throughout different steps over time (Dinda, 2004). Although there are several models explaining the relationship, the equation[4] typically used in the estimations of the EKC is that of an environmental indicator of environment degradation regressed upon income, squared income, and other variables which have an influence on environmental degradation:

$$y_{it} = \alpha_i + \beta_1 x_{it} + \beta_2 x^2_{it} + \beta_4 z_{it} + \varepsilon_{it}$$

Where y stands for the environmental indicator used, x stands for per capita income, z relates to the variables that influence on environmental degradation, α is a constant, i represents the country object of study, t stands for time, and β_k represents the coefficient of the explanatory

[4] Dinda S. (2004), pp. 440

variable k. In order for the equation to graph an inverted-U shaped curve —such as the EKC—, β_1 has to be positive, β_2 has to be negative and β_3 has to be equal to zero, so to allow for a directional change. The TP derived from such formulation is identified at $x^* = — (\beta_1 / 2\beta_2)$. For values of β_k different from those stated, the model will give an outcome different from the EKC.

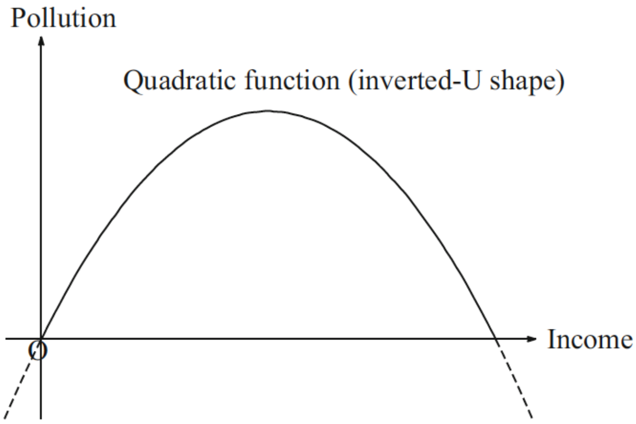


Fig. 1 - The Environmental Kuznets Curve

One of the main problems related to the empirical testing of the EKC model is that of the *multidimensionality* of environmental degradation. The difficulty in defining an indicator able to capture environmental depletion —or conversely environmental quality— is due to the fact that its concept does not have an universal definition (Antle and Heidebrink, 1995). The dimensions of a possible environmental indicator, range from those related to human health and human standards of living to those related to ecological conditions. The relationship between income and environmental degradation, thus, will vary accordingly to the indicator used, and only some of them will prove consistent with the EKC hypothesis. For some indicators, such as emissions of CO2 and municipal solid wastes, β_k assumes different values so to describe a monotonically increasing function with respect to income. Other indicators, such as lack of clean water, will describe a curve that falls monotonically as income increases (Kijima, Nishide, Ohyama, 2010). Because the equation provided for testing the EKC is a reduced-form model[5], it reflects a correlation between environmental degradation and income rather than a casual mechanism (Cole et al., 2001; Kijima et al. 2010). This implies that the effect that income has on environmental degradation is not a direct one, but it is influenced by many other variables that we will discuss in the next sections.

[5] The endogenous variables are expressed as functions of exogenous variables

2.2 Empirical Evidence

The first main empirical evidence that supports the hypothesis of an inverted-U correlation between income and environmental degradation is that provided by Panayotou (1993), Shafik and Bandyopadhyay (1992) and Grossman and Krueger (1993).

2.2.1 *Shafik and Bandyopadhyay (1992)*

Shafik and Bandyopadhyay have tested the EKC hypothesis on 149 countries using data gathered in 1960-90 and measuring GDP per capita in terms of purchasing power parity dollars ($PPP). They took into consideration also other regressions that comprehended policy variables. They have tested ten different environmental indicators: (a) absence of clean water, (b) absence of urban sanitation, (c) levels of suspended particulate matter (SPM) in the air, (d) presence of sulfur dioxides in the environment (SO_2), (e) change in the forest area in 1961-86, (f) annual rate of deforestation in 1961-86, (g) pollution of rivers (in terms of presence of dissolved oxygen and faecal coliform), (h) quantity of municipal waste per capita and (i) carbon emissions per capita. According to their findings, the quality of water and of urban sanitation monotonically declines as income per capita increases. Pollution of rivers, on the other hand, deteriorates as income per capita increases, probably because as the economy of a country develops so does the water supply, leading to a decline of the perceived environmental cost of river pollution. Carbon emissions per capita and quantity of municipal waste per capita also increase with income. For the indicators related to deforestation and change in forest area no significant change related to the increase of income was found, probably because of the absence of accurate data. Evidence for the EKC, however, was found for all the indicators of air pollution, namely presence of SO_2, and the level of SPM. The TP found for both the indicators floated between $3000 and $4000. Shafik and Bandyopadhyay argued that with increasing income the levels of both pollutants could decrease to zero (Shafik and Bandyopadhyay, 1992; Stern and Common, 1996).

2.2.2 *Panayotou (1993)*

Panayotou tested the EKC for four environmental indicators: levels of SO_2, NO_x and SPM —measured in terms of emissions per capita— and deforestation. In the regression, he postulated deforestation as a function of income per capita and density of the population. For the air polluters he used a sample of 54 countries, while for deforestation he used a sample of 68 countries. Unlike

Shafik and Bandyopadhyay, Panayotou used cross-sectional data and measured income as GDP in terms of 1985 US dollars, utilizing the official exchange rate instead of $PPP. This method tends to lower the level of GPD of underdeveloped countries if compared to that of developed countries. All four the indicators were consistent with the EKC hypothesis. In particular, for deforestation, beginning at US$100, he found a rate of forest loss of 1.3% per annum. The TP was identified at UD$823, where deforestation reaches a pick of 3.5% per annum. As income rises above US$2000, the rate of deforestation drops below 3%. At income levels above $4000 it falls to 2%, and it reaches zero when income exceeds US$12000. Thereafter, deforestation rate becomes negative. For SO_2, NO_x and SPM, he noted that their levels vary over time and across countries, according to variables such as the type of industrial activity, quality and quantity of vehicles, consumption of electricity and pollution control. All those variables are directly related to the stage of the economic development of the country. For SO_2, he found that at the lowest level of per capita income present in the sample ($300 in India), an increase of 1% in income reflected a 2.3% increase in emissions. The emissions elasticity reaches a unitary value at income levels above $1000. The turning point, where emissions elasticity equals zero, is identified at income $3000. Thereafter, further increases in income leads to a decrease in emissions, with an elasticity of -0.55 at income level of $5000. At income levels above $20000, emissions elasticity drops to -2.00. Similar results were obtained for NO_x and SPM, where the turning point were identified respectively at $5500 and $4500. The fact that the TP for deforestation occurs at a much lower level of income is related to the fact that deforestation takes place at earlier stages of the economic development; between $1000 and $3000 the economies undergo a structural change shifting from agriculture-based to industrialized. A second important threshold is reached at income levels above $10000 where the industries shift from energy-intensive to the services and information-intensive.

2.2.3 *Grossman and Krueger (1993)*

Grossman and Krueger tested the EKC for SO_2 and SPM in the context of a study of the impact of the North American Free Trade Agreement (NAFTA) on the Mexican environment. They used cross-country sample of 52 different cities in 32 countries using data gathered in 1982 which measured the air quality in several locations of each city. Income is measured as GDP per capita in terms of $PPP. In the regression they included also the city population and variables measuring trade intensity, which can influence the environmental degradation of a location. The EKC hypothesis was consistent for the indicator of SO_2, for which they found a TP between $4000 and $5000. For SPM, they found evidence that their level monotonically decreases as income increases, failing to support the EKC hypothesis (Grossman and Krueger, 1993; Stern and Common, 1996).

2.3 Theoretical Explanations

Behind the relationship described by the EKC, lie several factors that are responsible for the inverted-U shape of the curve. Any of those factors is related to the growing level of income and therefore to the stage of the economic development of a country. A growing economy, in general, has positive socio-economic effects, that both directly and indirectly affect the level of environmental deterioration experienced by the country. Several studies (Panayotou, 1993; Dinda, 2004; Stern and Common, 1996; Lopez and Mitra, 2000) have identified five main factors that explain the EKC relationship:

- **a.** Change in preferences and in the demand for environmental quality as a function of income
- **b.** Scale and Composition of the economy
- **c.** Availability and adaptability of the technologies
- **d.** International trade
- **e.** Governmental integrity

In the next sections I will analyze them and, other things being constant, I will discuss their effects. As we will see, for any factor, the role played by policies and institutions has some degree of influence. By now, however, I will not take it into consideration, as it will be discussed in more depth in Chapter Three.

2.3.1 *Change in preferences and in the demand for environmental quality*

The level of environmental degradation in a specific country is strongly related to the demand for environmental quality. This demand is deemed to be *income elastic* after a modest threshold, meaning that it rises alongside with income (Radetzki, 1992). At a higher income, in fact, people's priorities will change and, as the awareness of the negative effects of pollution will increase, more value will be given to a healthy and clean environment. This change in people's perception will have both a *direct* and *indirect* effect on the improvement of the environmental quality. The direct effect is reflected in the increasing pressure that people will exert on policymakers and institution, asking for the implementation of higher environmental standards. The indirect effect is reflected in a change of the choices made by consumers, who tend to value goods and services that are affected by pollutants, not the pollutants themselves (McConnel, 1997). Households cannot directly buy environmental quality, but can reduce pollution and environmental depletion by choosing to purchase private goods that hold environmental characteristics. However, this *substitution mechanism* —from 'dirty' goods to 'green' goods— is enacted only starting from middle-income countries. Pfaff *et al.* (2004) demonstrate that low income households tend to spend all their income on cheaper and dirty goods; substitution towards cleaner goods is discouraged. Thus, as their consumption increases so does the pollution. After an income threshold is reached, households will be more willing to substitute their consumption habits for more clean products. In other words, the path of the equilibrium income-pollution starts to decrease when "the marginal rate of substitution between consumption and pollution declines faster than the marginal rate of transformation between consumption and pollution as income increases" (Khanna and Plassmann 2004, p. 227; Lieb, 2002). This behavioral pattern reflects the inverted-U shape of the EKC.

McConnel (1997) tries to capture the mechanism hiding behind the relationship between environmental degradation and income, claiming that at low level of income the priority is generally given to the increase of material output, thus of consumption and level on employment. On this behalf, he formulates a utility function that describes the condition for utility maximization:

$$U_C + U_P P_C = U_P P_A$$

Where C stands for consumption, P for pollution, and A for pollution abatement costs. The marginal utility of increasing consumption by one cost unit, plus the negative utility of pollution in terms of an additional cost unit has to be equal to the marginal utility of reduction in pollution, expressed in terms of an additional cost unit to be dedicated to abatement spending. If at a certain level of income more value is given to the amelioration of the environmental condition, then more environmental quality is going to be bought, even though this might result in a lowering the level of consumption that would otherwise be met (McConnel, 1997; Roca 2003).

Similarly, Munasinghe (1999) has tried to explain the relationship between growing income and demand for environmental amenities as a function of the interaction of the marginal costs (MC) and marginal benefits (MB) of abatement curves. He argues that the maximum net benefits (NB) from achieving an improved environment are both dependent on the level of environmental degradation (E) and on the level of income (Y):

$$\max NB = B(E, Y) - C(E, Y)$$

At any given income, in order to maximize NB, the MC should equal MB, determining a point of equilibrium at (E*, $\underline{Y}$). We could thereafter analyze small shifts around this equilibrium point through the formula:

$$\Delta E/\Delta Y = (MB_Y - MC_Y) / (MC_E - MB_E)$$

If the ratio is positive, environmental degradation will increase with rising income. Munasinghe notes how in the early stages of economic development the denominator of the equation tends to be negative, thus $MB_E > MC_E$. Given the considerations done so far, the explanation lies again in the fact that at low levels of income people do not attribute the correct value to the costs of environmental degradation, leading to increase in pollution. The relation between MC and MB curves and the EKC has been graphed in *Fig. 2*. The graph shows how MC and MB curves may vary at different levels of income. At very low levels of income (Y_0), MB is positive, meaning that with rising income the willingness to pay for environmental quality rises as well, shifting the MB curve upwards. On the other hand, at low levels of income the MC curve is very low as well, because at low levels of development the pressure on environmental is generally minimal. As income increases, MC of environmental protection will increase at a higher pace than MB, because of the progressively higher pressure put on the environment and the scarce knowledge to the population relative the environmental degradation effects. Once a turning point is reached, MC will begin to increase at a lower pace than MB, as the economy will be facing improvements in technologies that will lower the abatement costs people will be more informed about the benefits of a high environmental quality.

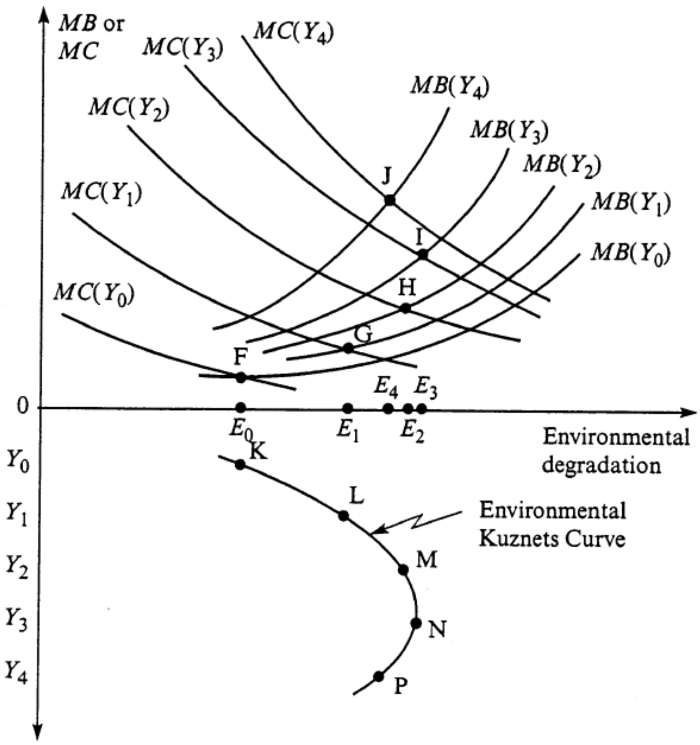


Fig. 2 - Deriving the EKC from MC and MB curves

With this first factor analyzed, it emerges that a low income affects the level of environmental degradation of a country. Active international policy aimed at correctly evaluating environmental costs and at informing the society about the consequences of environmental degradation could help to overcome the problem.

2.3.2 *Scale and Composition of the Economy*

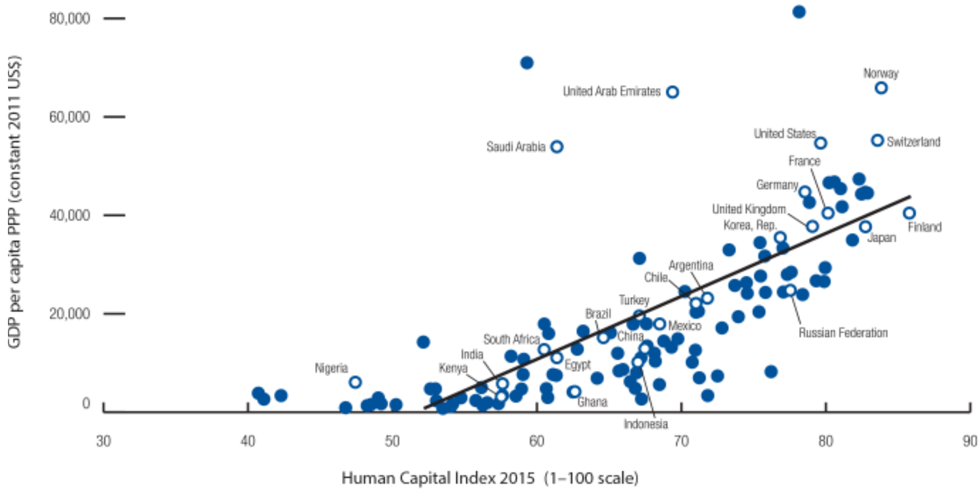
Growing income affects the degree of environmental degradation also from a structural point of view. Firstly, increasing income is reflected in an increase in the size of the county's economy. Not considering the technology effect, we have already seen in chapter one that economic growth results in a higher degree of resources' exploitation, that translates into a general deterioration of environmental quality. This direct relation between environmental degradation and growing size of the economy is called the *scale effect.* The scale effect is in turn correlated also to the *composition effect,* which describes the degree of environmental degradation as a function of the changing composition of the economic structure. At early stages of development, the society depends primarily on agriculture[6] and on industries that are based on high rates of resource depletion, such as deforestation and soil erosion, but with lower levels of industrial pollution (Panayotou, 1993). As the economy further develops towards a middle-income level, the economy shifts away from agriculture-intensive composition towards a more intensive-industrial structure, that generates a higher quantity of industrial pollutions. Middle-income countries, thus, are usually situated at the peak of the EKC (Panayotou, 1993). Finally, as the country further develops, the economy shifts towards the service sector[7] and lighter manufacturing, which should have lower emissions per each unit of output (Stern, 2004), thus progressively lowering the local level of environmental degradation.

2.3.3 *Technology Effect*

Change in people's perception of environmental degradation, increasing pressures for improved regulations and economic development, stimulate the demand for green technological innovation. New technologies can have a positive effect on the improvement of environmental quality, replacing old dirty industries with newer and more clean ones (Dinda, 2004). Increasing income is not only beneficial for green technological development in terms of a higher *physical* capital to be devolved to R&D (see Ch. 1.3), but also in terms of a higher level of *human* capital, necessary for an effective implementation of new technologies in the county's economic and industrial system. The functionality of new technologies with respect to human capital has been related by Schumacher (1973) to the concept of *appropriate technologies.* He argued against strong financial investments in developing countries aimed at a mere technological transfer. Poor countries, in fact, lack of the appropriate financial and marketing infrastructure to properly implement new technologies. Furthermore, they are characterized by unskilled workers and inappropriate inputs that would fail to mach the technologies adopted in more developed countries.

[6] In Low and Middle income countries the rate of employed in the agriculture sector is 38.4% of the population, against the 3.4% of OECD countries. The World Bank, World Development Indicators (2016), Retrieved from http://databank.worldbank.org/data/reports.aspx?source=jobs

[7] The rate of employment in the Service sector in OECD countries is 74.1%, against the 36.6% in Low and Middle Income countries. The World Bank, World Development Indicators (2016), Retrieved from http://databank.worldbank.org/data/reports.aspx?source=jobs



Source: Human Capital Index 2015 and the World Bank's World Development Indicators online database, accessed April 2015.

Fig. 3 - Relationship between GDP per capita PPP (constant 2011 US$) and the Human Capital Index, 2015

At early stages of development the level of human capital is generally very low. *Fig. 3* represents the positive correlation that exists between income and the Human Capital Index[8]. Human capital, in fact, is deemed to be both a consequence and a condition for economic growth and development. A condition in the sense that it can be seen as a factor of production, and a consequence given its conditionality to physical capital (Mincer, 1981). In general, this correlation is due to the different degrees of importance that is given to investment in education and research at different levels of income[9]. According to the data gathered by the World Bank, for example, public spending on human capital —thus on education— is much inferior in developing countries that in OECS countries. Countries such as India, Indonesia, Thailand, Venezuela, Egypt and Angola spend on average 3.5% of their GDP in education, against the 5.84% average spent by countries such as United States, France, Sweden, UK and Germany.

Thus, for a developing country waiting for technological improvements to costlessly flow in, is not sufficient; differences in endowments between developed and underdeveloped world may

[8] "The Human Capital Index measures countries' ability to maximize and leverage their human capital endowment. The index assesses Learning and Employment outcomes across 5 distinct age groups, on a scale from 0 (worst) to 100 (best), and assesses 124 economies". World Economic Forum (2015), *Human Capital Report 2015*, retrieved from http://reports.weforum.org/human-capital-report-2015

[9] An exception is given for example by Saudi Arabia, whose GDP is almost tied to that of the United States and Switzerland, indicating that policies and planning have a fundamental role in the development of human capital.

lead to a failure in efficiently exploiting and adapting technological innovation (Basu and Weil, 1996). Technology, in order to be appropriate, has to be "comprehensible, controllable and maintainable within a community" (Tharakan, 2015). Looking at the different levels of technological development among countries, the latter can be divided into two separate categories: technological leaders and technological followers. Several studies have analyzed the relationship between leaders and followers, examining the role of spillovers. In literature, it has been developed the theory that countries may be converging into two *converging club:* one where the development and growth rate gets lower, and one where it gets faster (Quah, 1993; Basu and Weil, 1996). Benhabib and Spiegel (1994), in particular, analyze 27 different countries over a timeframe of 35 years, comparing their improvement in productivity growth to that of the United States. Their findings show that 22 of those 27 countries have fell far behind the improvements in productivity growth experienced by the US. The cause is to be found in the differences in the levels of human capital. They have estimated that an average of 1.95 years of additional schooling for the over-25 is necessary in order to catch up with the leading nation.

Technology, income, scale and composition effect all interact with each other and are in some sense dependent from each other. Vukina et al. (1999) suggest that at the initial stages of economic development of a country, the scale effect dominates. After a turning point is reached, the composition effect and the technology effect, which positively affect the level of environmental quality, together with the income effect, take over, leading to a general improvement of environmental quality.

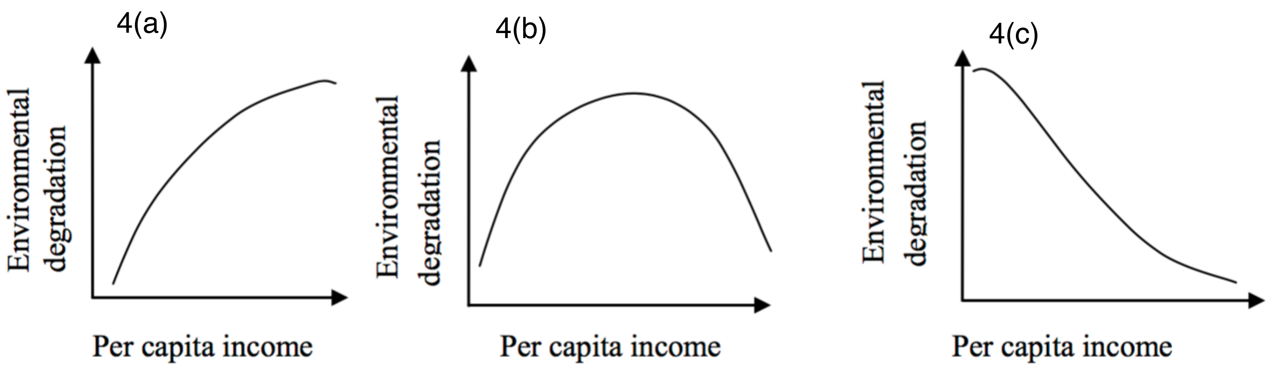


Fig. 4(a) - The Scale Effect; *Fig. 4(b)* - The Composition and Technology Effect; *Fig. 4(c)* - The Income Effect

2.3.4 *International Trade*

Several studies demonstrate a correlation between international trade and the deterioration of the environment in low-income countries. In the last decades it has been observed a gradual displacement of dirty industries from developed countries to the underdeveloped economies[10]. This phenomenon —called *Pollution Heaven Hypothesis* (PHH)— occurs because of less stringent environmental regulation in low and middle income economies, which allows them to have a competitive advantage by being able to set lower prices for the goods produces, since no environmental cost is taken into consideration. The displacement of industries towards emerging countries is directly related to the composition effect: developed countries are able to shift their economies towards the assembling industry and services sectors also because they displace the manufacturing industries in countries where production costs less (Porter, 1999).

Levinson and Taylor (2008) identified a negative correlation between standards stringency and economic activity; they argue that stricter environmental regulations will lead to an increase in the prices of inputs, pushing firms to dislocate their industries in countries where those regulations are lower. Wilson, Tsunehiro and Sewadeh (2002) empirically tested the PHH through cross-sectional and cross-country studies where they analyzed the effect that environmental regulations has on export competition of pollution-intensive industries. In order to construct an indicator for environmental regulations they took into consideration factors such as the estimation of the quantity of money spent within a country by different agencies to control air and water pollution and the level of local pollution-abatement efforts. They found evidence that "more stringent environmental standards imply less net export of pollution-intensive industries" (Wilson *et al.* 2002, p. 21). Furthermore, the implementation of higher standards has a larger effect on the reduction of net exports of non-OECD countries (-11%) that of those of OECD countries (-2.5%), implying a higher level of production of pollution-intensive output in the former. A second useful method used to assess the level of polluting industries in developing countries relates to the level of industrial consumption of energy. Suri and Chapman (1998) demonstrated that the ratio of manufactured export to the domestic production of manufacturing is positively related to the consumption of energy. Where the levels of energy consumption are low, the economy is mainly specialized in the services sectors or in 'assembling industries'. On the other hand, countries with high industrial

[10] Heerings (1993); Suri and Chapman (1998)

energy consumption generally produce manufactured goods —with high pollution inputs— that are thereafter exported. Analyzing the 2014 data[11] on the World's energy consumption, it emerges that Asia alone has consumed 34% more energy than North America and Europe together.

The uncontrolled trade competition that occurs among countries with different environmental standards, will progressively apply a downward pressure on regulations leading to the *race to the bottom* problem (Etsy, 1994). According to the race to the bottom, each jurisdiction will operate on its own, setting its own standards. In this way, low-income economies seeking for foreign investment to expand their economies, will be inclined to keep their environmental standards low so to maintain their competitive advantage (Porter, 1999). Several studies, in fact, prove that the competitiveness of emerging economies on the international market lies in their ability of producing goods at low prices. This is possible both because of the low environmental standards and also because of the low cost of labor (Hokisson *et al.,* 2000). For those reason, industries and the government of those countries are not incentivized in investing in cleaner productive processes and in higher environmental regulation, as this would mean an economic loss. This situation leads therefore to a second major threat: the *stuck at the bottom* problem, where no country will ever rise their environmental standards unless it has an economic incentive to do so.

2.3.5 *Governmental integrity: corruption and political rights*

A final factor to be analyzed concerns the integrity of the government, which can be analyzed through its levels of corruption and of political rights. Integrity of the government is generally deemed to be positively related to growing income, thus supporting EKC evidence. In this section I will briefly analyze both the role of corruption and political rights on environmental performance.

Several studies have identified a negative relationship between the degree of corruption of a country and its ability to make optimal decisions regarding environmental concerns, as the less corrupted a country is, the more it will be able to efficiently implement environmental norms and regulations. In general, the level of corruption of a country is positively related to increasing income. On this behalf, Transparency International has developed the Corruption Perception Index

[11] EnerData (2015), *Global Energy Statistics Yearbook*, retrieved from https://yearbook.enerdata.net

(CPI), which measures the perceived levels of corruption in the public sectors. According to their findings (*Fig. 5*), developing regions such as Asia (with the exception of Japan), Africa and South America have a significantly higher CPI than developed regions.

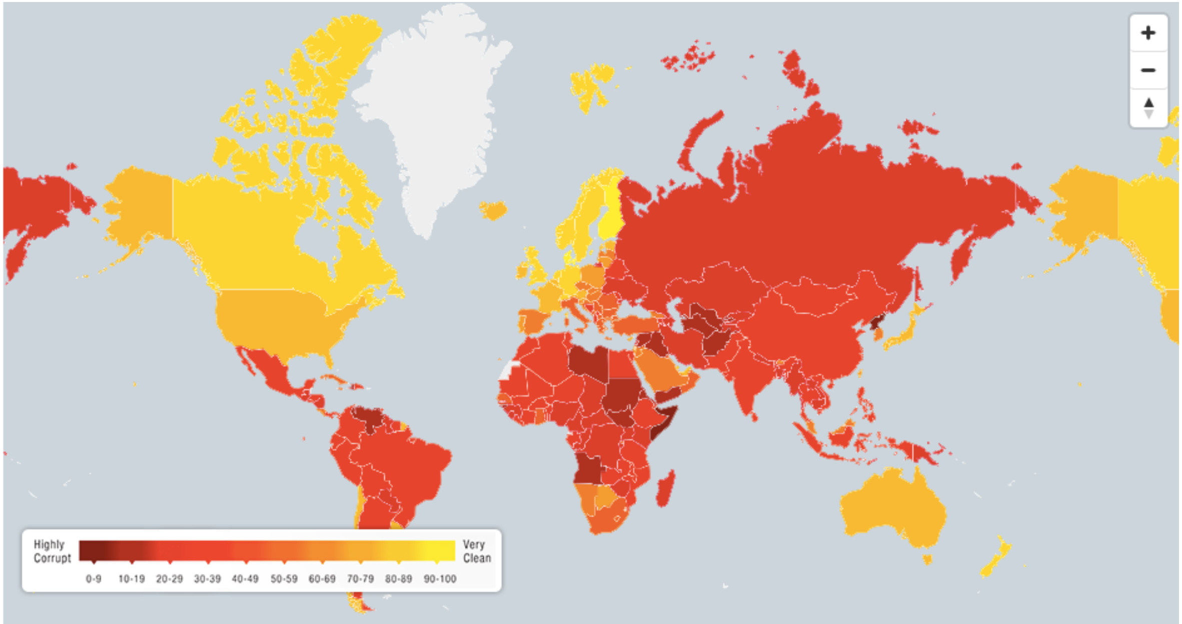


Fig. 5 - CPI worldwide

Leitao (2010) has empirically analyzed the positive relationship between pollution and corruption —identified in 2000 by Mitra and Lopez— for the environmental indicator of sulfur emissions. She found that "a country's degree of corruption is positively correlated to the critical threshold level of income beyond which sulfur emissions decline". The reason behind this is that higher corruption will induce the government to postpone stricter environmental norms. In relation to the EKC, Leitao has found that increasing corruption will also influence the income level at which the TP is reached, delaying the country ability to undergo the second half of the curve.

Concerning political rights, according to the literature their effect on environmental performance of a country is ambiguous. In general, though, democracies —which have a higher degree of political rights, have higher degree of accountability and thus are more keen to cooperate with international treaties to implement environmental protection (Gallagher and Thacker, 2008). The intuition behind this is that a higher degree of political rights will allow for a better representation for environmental groups and parties, which will increase public awareness on environmental concerns (this influencing the demand for environmental amenities on behalf of the population) and will influence policy decisions.

This last factor analyzed, in particular, refers to a strong correlation between the shape of the EKC and the government's ability and willingness to adopt and design norms and policies keen to improve and protect environmental quality. Different approaches can be adopted in order to do so. Its efficacy is once again related to the country's level of per capita income and to its characteristics. I will analyze the policy implications in the following chapter.

CHAPTER THREE

POLICY IMPLICATIONS

3.1 Environmental regulation

Although several economists may argue that increasing wealth of a country will necessarily lead to a more stable government and to a more efficient implementation of environmental standards —thus implying that economic growth may be the only key to environmental protection (Beckerman, 1992), other literature analyzes the importance of adequately guiding developing countries towards the implementation of a environmental depletion control system. The lack of stable governmental structures, unable to efficiently implement environmental norms and unable to internalize environmental externalities, foresees the importance played by supranational organizations in stimulating a system of compliance and enforcement of environmental standards. Although the imposition of environmental regulations may compromise the economic growth of developing countries —as it may force countries to substantially limit their productivity— (Porter, 1999), in the long run it will prove more profitable, as it will lead to a significantly more sustainable economic development.

On this behalf, Panayotou (1993) suggests at least three reasons to implement environmental policies in developing countries, aiming at reducing their pollution levels independently from their position on the EKC:

a. Developing countries placed on the positive sloping section of the curve may take several decades before reaching the turning point. The crossing time may be further stretched if we take into account the tendency of many pollution factors to cumulate through time. The environmental impact is in fact defined as a *stock problem* (Arrow *et al.,* 1995), implying that in the future, efforts of cleaning the environment may by more costly as the pollution levels to be eliminated will be higher.

b. Several types of environmental degradation may become irreversible in a few years. Just to cite an example, the 2014 Report drafted by the UN Intergovernmental Panel on Climate

Change (IPCC) addressed the importance of a compelling reduction in the emissions of greenhouse gasses. Failure to stop average temperature from increasing will lead to permanent changes such as the melting of the polar cap and the rise of the sea level, which will threaten the existence of many coastal cities. Furthermore, we have already been assisting to a gradual loss of biodiversity due to the intensive tropical deforestation and to the destruction of unique natural landscapers whose costs of reversion are prohibitive.

c. Increasing environmental depletion will eventually constrain growth. This problem, already analyzed in chapter one in terms of depletion of resources, has to be complemented also with the problems related to human health and human productivity that environmental depletion will cause.

Taking into consideration all these factors, it would be desirable for the international community to take effective measures with regards to the highly-polluting economies. In order to limit environmental degradation, economic agents will have to internalize several environmental externalities that are generally not taken into consideration in economic calculus. For this reason, the intervention of external actors —such as governments or international organizations— is fundamental in promoting the development of environmental regulations and policies aimed at balancing the costs and benefits of environmental protection in order to maximize the total benefits of such protection. *Figure 6* describes this scenario. TB is the demand for environmental amenities, and —as we have seen— its position depends on income and preferences. Its shape depends on the damages associated with environmental degradation in terms of peoples' welfare. In general it is deemed to be slightly concave because, as the level of environmental protection increases, the society will experience diminishing marginal benefits to pollution control. On the other hand, the TC curve depends on the efforts made for cleaning the environment/controlling pollution (*e.g.* investments in pollution control technologies or *clean technologies*, etc.). Costs tend to increase at an increasing rate, because higher levels of pollution control necessitate more sophisticated techniques in order to be implemented. Of course, an efficient level of environmental protection will be the one that maximizes the difference between total benefits and total costs (Bluffstone *et al.*, 1997).

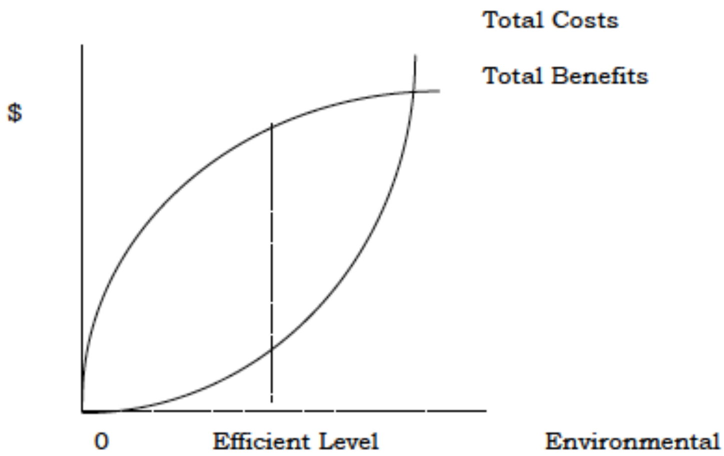


Fig. 6- Total costs and total benefits of environmental protection

In order to reach such a efficient level of environmental protection, policymakers can adopt two different kinds of measures: non-market and market ones. I will briefly analyze them in the following sections.

3.2 Non-market Measures

The first environmental control measures to be analyzed are the non-market ones, namely those that do not operate through markets and which include social, institutional and legal actions. In this section I will analyze only two of the possible non-market instruments to be adopted: the *command and control approach* (CAC, which includes institutional and legal actions) and *public disclosure* (which includes social and institutional actions).

3.2.1 *Command and Control*

The Command and Control approach refers to any type of environmental regulation that dictates abatement decisions. It operates through the fixing of environmental standards, namely a mandatory level of pollution which is enforced by law. In order to set an environmental standard, the first problem to be addressed is how to determine the desirable level of environmental protection/pollution control. Several criteria can be used for different standards: *efficiency standards*, which maximize economic welfare; *health-based standards*, whose primary goal is that of protection human health; *ethical standards*, which operate through ethical considerations. Given the uncertainty of future damages caused by pollution and given the impossibility of reaching zero pollution, policymakers set their environmental goals through the minimum safety standard approach, which aims at determining how much pollution is acceptable.

As it comes to the types of environmental standards utilized by policymakers, they can be divided into three categories: ambient standards, emission standards and technology standards. *Ambient standards* regulate the level of polluting elements (*e.g.* levels of SO2 and SPM in an air shed) present in the surrounding environment. *Emission standards* regulate the levels of emissions permitted (*e.g.* residuals per unit of output). *Technology standards* require pollutants to adopt specific technological equipment. An example of an efficient adoption of a mixture of those standards is provided by the US Clean Air Act, through which the government sets ambient standards for six different pollutants in each region, imposes the use of the Best Available Control Technology on behalf of plants and regularly monitors the levels of emissions through several Air Quality Control Regions set up in every state.

The CAC approach has largely been preferred by policymakers if compered to economic measures (Turner, Pearce, Bateman, 2003). Young (1992) has identified three different reasons explaining why administrators prefer the normative approach:

a. In order to implement and introduce a norm, much less information regarding the costs of environmental damages is required.

b. It is largely accepted since the program does not constitute too of a large departure from ordinary practices.

c. It promotes a certain degree of cooperation between polluters and administrators, who seek to build a common understanding.

Critiques to the approach claim its inefficiency, both in terms of environmental benefits obtainable and in terms of applicability. When setting environmental norms, in fact, legislators are asked to consume resources in order to acquire information regarding environmental damages and abatement costs that polluters already hold. Environmental standards, furthermore, do not take into consideration the differences between diverse production processes and inputs utilized; some industries, in fact, can attain to the norms more easily than others. Implementing regulations is also very costly as it holds several fixability costs and efforts (Turner, Pearce, Bateman, 2003). Concerning this latter point, their weakness is easily demonstrable in developing countries, where governments are characterized by weak institutional structures that are hardly able to implement and enforce the norms. In developing countries, where rent-seeking and corruption is an integral component of government's behavior, the implementation of pollution control regulation may be seriously compromised (Lopez and Mitra, 2000). Sapru (2013), in analyzing the relationship between government and polluting industries in Indonesia, argues that the administrative elite is often unwilling to implement normative policies that would slow down the rate of economic growth. Similarly, he found evidence that in India many industrialists hold links with the governing parties, which tolerate the infringement of standards.

3.2.2 *Public disclosure*

The second non-market instrument to be analyzed and that proliferates in developing economies is that of *public disclosure*. Unlike CAC, this policy tool does not require strict enforcement (Dasgupta, Wheeler and Wang, 2007); rather, it encourages a reduction in emissions through its pressure on external factors that influence the demand for environmental quality (*e.g.* education), or through improvements in industries' information about pollution and pollution control technologies. One type of government's public disclosure strategy is that of *performance evaluation and ratings programs* (PERP), which consists in the collection of data used to rate the environmental performance of industries. In order to strengthen its deterrent effect, non governmental agencies may impose penalties on the industries with the worst performances. Empirical studies carried out by Dasgupta, Wheeler and Wang (2007) in Indonesia, Philippines and Vietnam show that industries whose environmental performance appeared to be in 'flagrant violation' category, were the ones who improved[12] most rapidly their pollution standards. Garcia *et al.* (2009) have analyzed the causes that influence industries' performance though PERP. Their study shows that public disclosure leads to a decrease of industries' marginal abatement costs. Furthermore, they proceed with the ranking of the importance of the different channels through

[12] Specifically, compliance rates increased by 24% in Indonesia, by 50% in the Philippines and by 14% in Vietnam.

which PERP encourages emissions reduction; the results suggest that the most important channel is that of informing industries of their abatement opportunities.

3.3 Market instruments

A second approach to be analyzed is that of the implementation of policies that act directly on economic incentives. The instruments of economic incentives operate through three different forms: a direct intervention on prices and costs, an indirect intervention on prices and costs through financial and fiscal instruments, and the creation and support of a market for the environment.

3.3.1 *Direct intervention: Microeconomic policies*

Direct intervention on prices and costs concerning environmental degradation occurs, for example, when taxes are applied on emissions, products or processes that generates such bads. The first idea of an ecological tax was advanced by the economist Pigou (1920). He proposed a system of environmental taxation to be fixed according to the estimated damage caused by an additional unit of polluting emissions; optimal pollution is reached when marginal damage is equal to the marginal abatement cost, assuming that monitoring is free and that policymakers hold perfect information[13]. Those kind of taxes take the name of *pigouvian taxes.* The implementation of taxes on emissions is desirable mainly for two reasons: first, it allows the government to raise revenues that can be invested in the alleviation of environmental damages; second, it alters the economic behavior of polluters, who will have to revise their marginal costs of production by taking into consideration environmental externalities, leading to a efficient allocation of resources (Bluffstone and Larson, 1997).

The implementation of pigouvian taxes alters the price setting of industries, modifying the allocation process through the price mechanism, i.e. the market, as shown in *Fig. 7*. Without a tax, a firm would maximize its profits by producing an amount of goods for which the marginal net benefit (MB) is positive, thus expanding its production up to Q_e. Supposing that for each additional unit of good produced an additional quantity of pollution (W) is emitted, at Q_e the level of

[13] One of the main issues regarding the implementation of Pigouvian taxes relates to the difficulty of properly setting ad adequate level taxation. Estimating environmental costs of pollution necessitates a high level of information, given the uncertain effects of environmental depletion.

emissions is equal to W_e. The optimal level of pollution W*, however, is identified at Q*. In order to decrease production to its optimal level, thus, a tax *t* has to be introduced, which should be equal to the cost of the environmental harm produced in Q*. With the introduction of the tax, for the firm to produce above Q* would result into an economic loss, thus it is incentivized to limit its production.

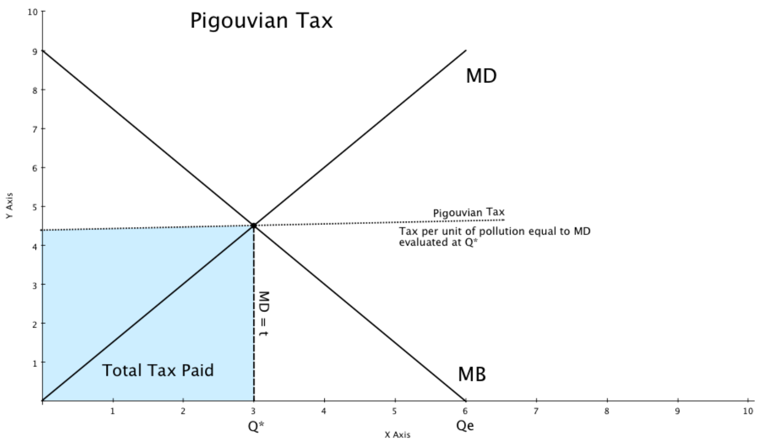


Fig. 7 - The Pigouvian Tax

Proposing a more practical example, I will analyze the scenario of a underdeveloped economy with free or unregulated access to a resource use (*Fig. 8)*. Initially, the demand for such a resource is given by D_0. Following an external factor that leads to a sudden increase in the demand (*e. g.* a trade liberalization reform package), the curve shifts from D_0 to D_1. At this point, the quantity demanded for a price P —given by Q_s— is much higher that the safe limit for environmental degradation. The government should intervene by imposing an externality cost that would reflect the environmental costs of pollution, increasing the price level to P_{EN} which would limit the quantity produced to Q_{EN}, granting a more efficient allocation of the resource

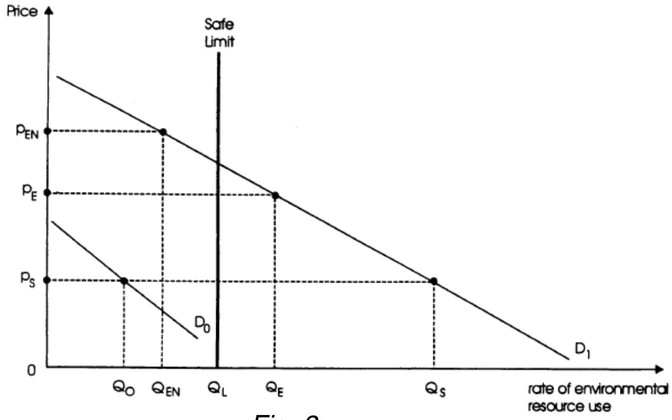


Fig. 8

Environmental taxes will lead to both short-term and structural responses. In the short-term, in fact, firms will increase prices, reducing output and affecting consumers' choices, who will substitute for less polluting products. In the long-term, firms will change their decisions regarding capital and innovation programs. On this behalf, in fact, environmental taxes are deemed to constitute a strong incentive for innovation. Improving technological equipment will lead to an improvement in the firms' productivity and to a decrease in pollution levels (Turner, Pearce, Bateman, 2003). Furthermore, unlike CAC approach, environmental taxes are more easy to administer for several reasons. First of all, they operate through government tax collection institutions rather than environmental regulatory institutions. In general, in developing countries the former are more effective and established (Blackman and Harrington, 2000). Secondly, in setting a requisite tax, policymakers need much less information about firms' abatement costs.

On the other hand, despite the apparent efficiency, several critiques have emerged. First of all, environmental taxes have a regressive distributional impact (Pezzey, 1988). Firms will try to transfer taxes on prices and, therefore, on consumers. If the product demanded is highly elastic, consumers will easily switch to more ecological products as the price of the polluting one increases; this scenario constitutes a further incentive for the polluting-product firm to improve its polluting standards. On the other hand, if the demand for the product is highly inelastic —gasoline for example—, consumers will be less willing to stop purchasing it. The consequence will be that consumers with a lower budget will be more disadvantaged then wealthy consumers for whom the increase in price won't constitute much of a burden. Eskeland's and King's (1998) findings show that the implementation of taxes has a more severe impact on poor households, and argue that this aspect has to be seriously taken into consideration in the context of Developing countries, where there are high income disparities within the population and where consumers tend to purchase essential goods for which the market does not provide a wide choice of substitutes. Distributional issues may be readdressed by devolving tax revenues to policies aimed at relieving the regressive impact.

A second critical aspect concerns targeting. Environmental taxes could affect non targeted activities. An example may be that of a coal tax aimed at reducing sulfur emissions; the tax will also affect chemical manufacturers who utilize coal as a raw material and not as a fuel. A solution to this issue may be that of discharging some consumers from the tax (Blackman and Harrington, 1999). A third critical point, finally, concerns the international willingness to cooperate on the implementation of environmental taxes. If all other states fail to implement a similar system, the country who does adopt will have to face a loss in terms of competitiveness. The imposition of environmental taxes on only one country will lead to an increase in domestic prices, inducing consumers to switch to foreign substitutes. For those reasons it is fundamental the role played by international agreements and treaties (Turner, Pearce, Bateman, 2003).

3.3.2 *Macroeconomic policies and pollution control*

Macroeconomic policies can affect pollution control in different ways[14]. Munasinghe (1998) has demonstrated that achieving a Pareto optimum through first-best macroeconomic policies will not reach an efficient allocation of resources if some environmental externalities are present. Macroeconomic reforms should take account of such externalities; a correct timing and sequencing of macroeconomic policies may lead to an efficient dealing with environmental problems. Second-best macroeconomic policies should thus be considered in the context of a trade-off between macroeconomic goals and environmental degradation. An example is provided by contextualizing the example provided in the previous section into a macroeconomic perspective: in a stagnant economy the government often pursues policies of trade liberalization and currency devaluation in order to attract greater foreign investment, which will subsequently translate into an expansion of energy-intensive industries, leading to more pollution. Supporting macroeconomic reforms with complementary policies will correct environmental externalities.

3.3.3 *Creation of a market for the environment*

Finally, environmental protection can be obtained through the creation of a market for the environment — for example— by implementing emissions rights (*emission trading)* and auctioning the emission quotas fixed on the grounds of emission limits (Turner, Pearce, Bateman, 2003). A certain number of *tradable* permits is released[15] according to a defined level of emissions, up to the point where the acceptable level of emissions is reached.

[14] Removal of trade barriers, currency devaluation/revaluation

[15] There are several ways according to which it is decided how to allocate the permits. One of the most common approaches is that of *grandfathering*, according to which the rights to pollution are determined by the analysis of past emission levels.

Once the polluters have received a certain amount of permits, anytime the polluter reaches a level of emissions lower than the one allowed by its permits, it will receive a credit which will be *tradable*. This system provides a great incentive for polluters to reduce their emission levels: if the marginal abatement costs of pollution are lower than the price of the permits, it will be more convenient for the polluter to reduce pollution levels and commercialize the exceeding permits. Marketable permits systems were introduced in order to grant a greater flexibility to industries who were in charge of controlling pollutant emissions. Empirical studies which analyze the implementation of emission trading in Europe (Stavins, 2001) provide evidence of a positive impact of such a system on total emissions: total abatement costs have significantly decreased than in the absence of environmental trading.

The implementation of this instrument in Developing countries dates back only to the last 15 years. However, it has showed worse results in terms of efficiency. In particular, Coria and Sterner (2008) analyze its adoption in Santiago, one of the first cities outside the OECD to implement such a program in 1997. Their findings highlight a combination of failures that compromised its efficacy: "over-allocation of permits, high transaction costs, lack of clear penalties for sources in violation, and several regulatory changes affecting the tenure over emission permits and hampering trade" (p. 2). The program was a credit-based program, aimed at regulating the emissions of industrial boilers. One of the main differences from marketable permits systems adopted in OECD countries was its strong restriction on the trading of permits on a permanent basis. A consequence of this political choice is reflected in the creation of an "illiquid market where sources are uncertain about the availability of permits in the future and where buyers pay prices close to their top prices, even if in the aggregate there is an over-supply of permits" (Coria and Sterner 2008, pp. 10). Furthermore, the strict restrictions on trade have lead to a sustained increase in transaction costs, as it added the requirement for regulatory approval component. Results show that, although the aggregate cap on emissions had been respected since the implementation of the program, new sources failed to offset their emissions. In general, however, the program has had a positive impact on aggregate emissions which, starting from 2544 kg per day in 1997 decreased to 792 kg per day in 2007. Although the number of sources has decreased from 593 in 1997 to 511 in 2007, the decrease in emissions is still significant. The reduction in emissions is mainly correlated to the incentive provided by the program to switch to cleaner fuels (*e. g.* kerosene and natural gasses). Despite the results, emissions in 2007 were still above the emissions target of 0.0000032 kg/m^3, having decreased only to 0,0001132 kg/m^3.

Variable	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Number of sources	593	583	516	534	495	513	521	526	519	526	511
Existing sources	430	402	332	324	286	277	273	264	251	235	217
New sources	163	181	184	210	209	236	248	262	268	291	294
Aggregate emissions (kg/day)	2544.79	1804.60	865.75	824.55	650.21	603.59	649.76	624.33	688.51	848.59	791.73
Existing sources	1684.27	1214.04	622.29	599.92	465.75	439.43	404.40	445.87	498.61	422.17	467.87
New sources	860.52	590.56	243.46	224.63	184.46	164.16	245.37	178.46	189.91	426.42	323.86

Fig. 9 - Results of marketable permits program in Santiago (Coria and Sterner, 2008)

From this empirical evidence, several lessons can be drawn regarding the applicability and efficiency of emission trading in developing countries. First of all, if compared to similar programs adopted in OECD countries, marketable permits systems adopted in developing countries encounter the significant obstacle of finding a political process willing to introduce market regulations in the management of environmental protection. Secondly, in order to assure its success, it is important to grant the effectiveness of the monitoring capabilities of the government with respect to the tradability. Restrictions on trade can allow for a temporary better management of the permits, but they will lead to significantly higher transaction costs which will compromise the efficiency of the program. Lastly, just like for any other environmental measure to be adopted, government's enforcement power is fundamental as in its absence a significant rate of non-compliance may be found (Coria and Sterner, 2008).

3.4 Regulation and innovation

Throughout this work, I have highlighted several times the importance played by innovation in the development of technological equipment aimed at improving the emissions level of industries. Without innovation, in fact, emission reductions may simply be reflected in a decrease of output. New technological equipment, on the other hand, will allow plants to reduce their level of emissions without necessarily affecting output. In the following section I will analyze how technological innovation can be induced.

3.4.1 *Porter Hypothesis*

Several authors claim that environmental regulations not only induce firms to decrease their emissions, but function as an incentive to improve the technological capabilities through R&D investments.. On this behalf, in 1995 Porter and Linde formulated the so called *Porter hypothesis,* according to which “properly designed environmental standards can trigger innovation that may partially or more than fully offset the costs of complying with them” (Poter and Linde 1995, p. 98). This hypothesis, thus, implies the existence of a regulation-driven innovation mechanism that will induce firms to relocate their R&D expenses. Higher investment in innovation will not only result into a diminishing of polluting emissions, but will also increase productivity, increasing the firm’s profits. In order to test the veracity of such hypothesis, Rexhäuser and Rammer (2013) have developed the following regression[16], which describes the firm’s returns on sale (ROS) as a function of several factors such as overall knowledge stock (KS) and environmental innovation[17] (EI):

$$ROS_i = \alpha + \sum_{r=1}^{2} \sum_{t=1}^{2} \beta_{rt} EI_{rt,i} + \gamma_1 PD_i + \gamma_2 PC_i + \delta'_1 CP_i + \delta'_2 KS_i + \delta'_3 CS_i + \delta'_4 C_i + \varepsilon_i .$$

Rexhäuser and Rammer tested the Porter hypothesis using data retrieved from the German section of the Community Innovation Survey (CIS), which collects data on firms innovation strategies and profitability. Their sample included 7657 German enterprises, that were surveyed through voluntary mail surveys. In the survey, firms were asked whether they had introduced environmental innovations between 2006 and 2008. Following, they were asked whether such innovation were introduced as a response to environmental regulations (taxes, and norms) or other factors (government’s R&D subsidies). According to their findings (*Fig. 10*), however, no clear relation was to be found between environmental regulations and environmental innovation, as also non-regulation induced adoption was found in a significant number of firms.

Nevertheless, despite the failure in demonstrating Porter hypothesis, a positive correlation between regulations and innovation was found. Evidence was found that innovation can have a

[16] Rexhäuser and Rammer (2013), p. 149

[17] Environmental innovation is defined as “a new or significantly improved product, process, organizational method or marketing method that creates environmental benefits compared to alternatives.

direct impact on industries' profitability through product and process innovation. As it comes to process innovation, in fact, "cost reduction may allow the innovator to keep unit costs below the market average, providing sources for extra profits" (Rexhäuser and Rammer 2013, p. 154).

Efficiency-improving innovations	Other environmental innovations			Total
	NO	*REG*	*NOREG*	
NO	1,562	93	120	1,775
REG (regulation-induced adoption ($r = 1$))	102	*	*	768
NOREG (non-regulation-induced adoption ($r = 2$))	425	*	650	1, 075
Total	2,089	759	770	3,618

The cases denoted by * account together for 666 observations that cannot be clearly attributed to one of these cases. The reason is that the firm survey does only offer information whether environmental innovations are induced by regulation but not which certain type

Fig. 10 - Environmental innovation adoption and regulation (Rexhäuser and Rammer 2013, p. 153)

3.4.2 *Environmental subsidies*

Simultaneously to the role played by regulations in inducing innovation, it is clear that public subsidies to clean technologies[18] (*e.g.* low-interest loans, grants and capital loans) may accelerate and further induce technological development by encouraging firms to engage in R&D. Market failures, in fact, may deter private investment for R&D, mainly because of the failure in identifying environmental externalities, spillovers and asymmetric information. Industries will be willing to invest in innovation when its cost are lower than the profits generated; however, as the environmental resources used in the production process are generally not priced and thus not taken into consideration in cost evaluation, imperfection may arise, lowering the propensity of industries to invest in environmental development. Spillovers may constitute a further deterrent because of their related issues of revenue appropriability; asymmetric information, on the other hand, may prevent the firm from investing because of the risk and uncertainty components, which may be reflected in the difficulty of estimating future revenues (Busom *et al.,* 2014). Furthermore, the role of subsidies bestowed by governments may function as a higher innovation-incentive than taxes

[18] There are two conventional ways for governments to improve R&D: (i) performing R&D directly in public institutions and national laboratories, and (ii) providing firms in the private sector with (publicly funded) incentives for performing their own R&D. (Ozcelika and Taymaz, 2007)

because of their ability to be specifically designed for different contexts. The intuition behind this claim is that different industrial sectors hold different degrees of *endogeneity of innovation*, which relates to the firm's ability to respond to changes in environmental regulations (Ferrante, 1998). While for large industries tax incentives may lead to higher private investments in R&D, the same is not true for small and medium-sized enterprises (SME), which are more sensitive to barriers such as financing constraint and availability of capital (Busom *et al.,* 2014).

Takalo *et al.* (2013) provide a theoretical model that describes the subsidies allocation processes on behalf of public agencies. They claim that two of the most important factors to be analyzed by governments when determining the amount of capital to be earmarked for research are technical challenge and its social value. This last factor in particular is very important for the matter of fact that subsidies may be '"easily claimed for projects that yield high private returns and thus would be carried out anyway, while socially valuable projects may not be developed" (p. 573). A third factor taken into consideration by the government is the role played by spillovers which, unlike for private investments on behalf of industries, in the case of public funding is positively related to the value of the subsidy, as it will indirectly benefit a larger set of firms.

An effective example of the strong implementation of public funding for R&D is that of Eastern Germany —at the time considered a transition economy—, whose government in 1998 earmarked approximately 2.2 billion euros for research. According to the research carried out by Almus and Czarnitzki (2003), 60% of firms in Easter Germany received a R&D subsidy. They analyzed 925 industries, of which 622 took part to the R&D subsidies program. According to the results found, "firms that had received public funding have achieved on average a higher R&D intensity than firms belonging to the control group" (p. 235). In particular, a firm with a turnover of 10000 monetary units would have invested 4000 monetary units less if it wouldn't have participated to the subsidy program.

3.4.3 *Subsidies in developing countries*

The role of public funding for R&D is of fundamental importance in developing countries, where pollution levels are significantly higher and where the innovation rate of technology is quite low. In general, R&D is mainly concentrated in the USA, European Union and Japan (UNESCO

2010). In section 2.3.3 I have discussed the difficulties for developing countries to improve the industries' technological equipment because of the lack of human capital. This issue may be partially offset with a joint implementation of policies aimed at improving the level of education and training and of public R&D funding. In particular, Amsden *et al.* (2001), making reference to a wider literature, argue that multinational companies tend to invest very little outside their home base, especially in developing countries —the only exception being Singapore. Such low rates of private investments may be the reflection of an inadequate system of incentives, both legislative and economic. Because of the lack of a strong implementation of environmental norms, industries in developing countries are not incentivized to improve their emissions levels through improvements in the technological equipment. Furthermore, a lower emphasis on R&D in the private sector may be consequence of organizational issues: where industries operate mainly on the local market, competitiveness is reduced, constituting a further disincentive to promote innovation (UNESCO, 2010).

In this context, the government may play a major role in financing research. However, public agencies of developing countries often fail to recognize the importance of implementing R&D policies. Only by the beginning of the Century countries such as South Korea —at the time considered a developing country—, China and Taiwan have started to pursue such policies, achieving remarkable performances in the technology-intensive industries (Amsden *et al.,* 2001). International organizations and developed countries may promote training programs aimed at educating government officials and policymakers of developing countries to a better understanding of the promotion of R&D in an environmental optic (UNESCO, 2010).

One of the most effective implementations of a public-funding program in developing countries is provided by the example of Turkey, analyzed by Ozcelika and Taymaz (2007). From 1992 to 2007, Turkey has establish a national system of innovation, namely the Technology Development Foundation of Turkey, which aimed at providing support to R&D through interest-free "R&D loans". Their findings (*Fig. 11)* —similar to the ones obtained for the implementation of similar programs in OECD countries— demonstrate that "support-receiving firms, on average, exhibit much higher R&D intensities than the non-supported ones" (p. 263).

	Case 1: all observations $RD_t = 0/+$, $RD_{t-1} = 0/+$			
	Treated	Control	DID	n
Change in R&D intensity from time $t-1$ to t				
Support-recipient	2.56	0.06	2.49*	259
Loan-recipient	5.22	−0.11	5.33*	77
Grant-recipient	2.48	0.00	2.49*	253
Change in own R&D intensity from time $t-1$ to t				
Support-recipient	1.95	0.06	1.89*	259
Loan-recipient	3.79	−0.14	3.93*	77
Grant-recipient	1.85	0.00	1.85*	253

Fig. 11 - Effects of R&D support programs in Turkey in 1992-2007

CHAPTER FOUR

THE CHINESE CASE

Today China is the world's largest polluter in absolute terms of CO_2 emissions, having surpassed the USA in 2008 and having held the No.1 spot ever since[19]. In 2013, it reached 10540 million tons of carbon dioxide emissions, accounting for almost 1/3 of aggregate world's emissions. The massive increase in polluting emissions has brought some serious environmental issues to the country, such as progressive lack of safe water, intense air pollution, desertification, loss of biodiversity and severe consequences on human health. In such a scenario of increasing rates of environmental degradation, several scholars have questioned the applicability of the EKC and its future implications. Focusing on environmental degradation in terms of CO_2 emissions, in this section I will briefly provide evidence for EKC hypothesis in China, subsequently analyzing its economic and socio-political explanations. Following, I will discuss the policy implications and the expectations for the future policy measures to be taken by the Chinese government.

4.1 Evidence of EKC hypothesis

Several studies in the last decade have provided empirical evidence of the existence of a EKC relationship in China for CO_2 emissions. In this section I will briefly provide data and findings gathered by the studies of Chen and Chen (2015) and Li *et al.* (2016).

4.1.1 *Li et al. (2016)*

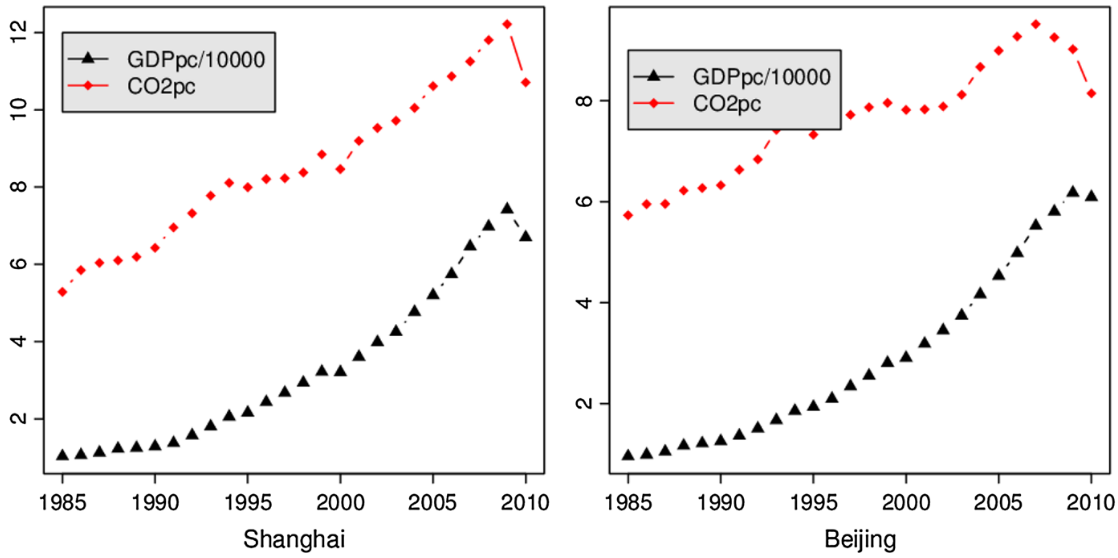
Li *et al.*, using province-level data from 1996 to 2012, have estimated the long-run EKC relationship in China. The data was retrieved from China Statical Yearbook, China Compendium of Statistics and China Energy Statistical Yearbook. They have considered several environmental indicators: CO_2 emissions, waste water emissions and solid waste emissions; thus covering liquid, gas and solid forms of environmental degradation. They have used the natural logarithm of real GDPpc (1980 as base year) to measure economic development. For CO_2 emissions, in particular,

[19] Although in terms of CO2 emissions pc the US is still holding the No. 1 spot —with a total of 17.0 metric tons per capita versus the 6.7 metric tons of emissions per capita in China—, the US Energy Information Administration has projected that by 2035 China may catch up the US. (Morrison, 2015)

their findings[20] show that their level first increases and then decreases after having reached a TP, consistently with the EKC. The TP is found to be at US$7846.8666 (real value, 1980 as base year), which corresponds to (2015) US$10403.96. Such a level of GDPpc is reached only in some high income regions (Shanghai and Beijing). The average GDPpc in 2015 was US$7990.09, thus still lower than the TP identified.

4.1.2 *Chen and Chen (2015)*

Chen and Chen have tested[21] the EKC for industrial CO_2 emissions, focusing on the different patterns observed for different Chinese regions, namely those of Shanghai, Beijing, Guizhou and Gansu. The data used has been provided by the China Statistical Yearbook and the Data of Gross Domestic Product of China, and is relative to the 31 Chinese provinces from 1985 to 2010. CO_2 emissions are estimated according to the aggregate energy consumption of oil, coal and natural gas. Their empirical results show the existence of an inverted U-shaped relationship between CO_2 emissions and the level of GDPpc. Similarly to the findings of Li *et al.*, only the high-income regions of Shanghai and Beijing have already crossed the TP (estimated to be around 2010 US $10000) and are in a stage of environmental pollution reductions since 2005 and 2006 respectively. Guizhou and Gansu, on the other hand, are still far from reaching their peak, implying increasing pollution in the future.



[20] In particular, according to the data estimated, the coefficient of ln(y) is positive and the coefficient ($\ln(y)^2$) is negative. They are both highly significant, consistently across all estimations. For more detailed data see Li *et al.* (2016) p. 142 - Table 2

[21] They have used a non parametric model, thus they have estimated the regression curve expressing the relationship between industrial CO2 emissions and the level of economic development, instead of parameters.

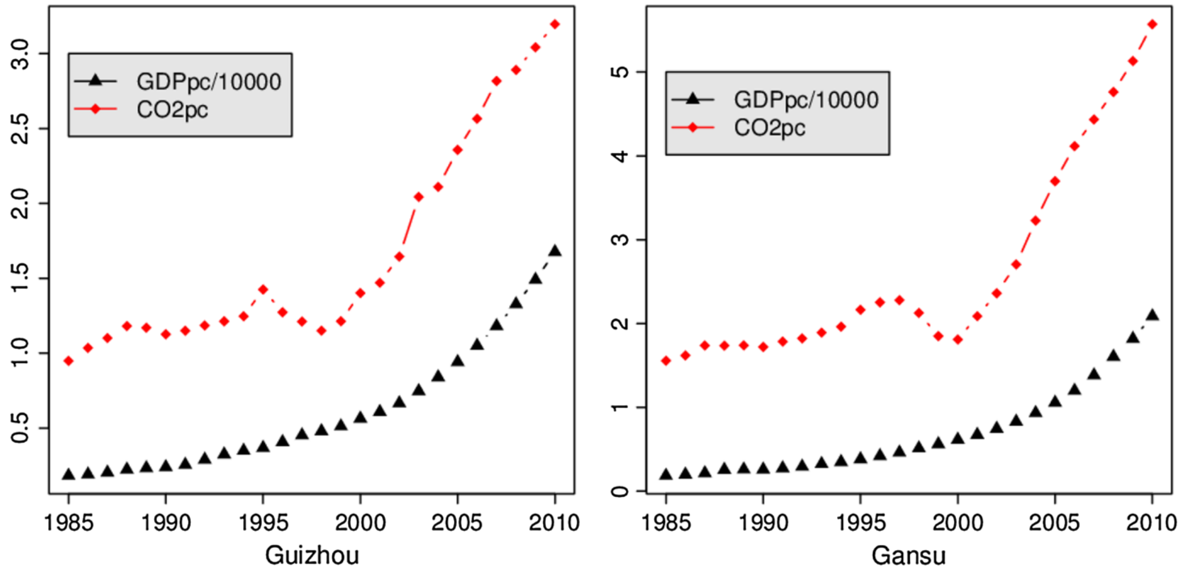


Fig. 12 - Time series of RMBGDPpc/10000, CO2pc (Chan and Chan, 2015).

4.2 Socio-economic explanations

According to the results discussed by Chen and Chen (2015) and Li *et al.* (2016), until the mid-2000s China has been going through a phase of progressive increase of atmospheric degradation. Only some Chinese regions have been able to reach levels of economic development high enough to allow for a reduction in emissions; according to the IMF, in 2015 only 9 out of the 31 Chinese regions had reached a GDPpc higher than the TP identified by Chen and Chen. The pattern of increasing polluting emissions —and their recent partial decrease— is the result of an economic and socio-political framework that has characterized China since the late 1970s.

4.2.1 *Economic framework*

China has been experiencing extraordinary rates of economic growth since the 1978 economic reform proposed by Deng Xiaopong, which introduced capitalist market principles. From 1979 to 2014 the annual Chinese GDP growth rate averaged 10%, implying that China has been able to nearly double the size of its economy every 8 years. In 2014, China's GDP accounted for $10.4 trillion, thus about 60% the size of the US economy. Adjusting it to PPP$, China's total GDP accounted for $17.6 trillion, overtaking the US as the world's largest economy. The IMF has predicted that by 2019 China's economy will be 21.3% larger than the US economy on a PPP basis (Morrison, 2015).

The two main factors to be attributed to such a rapid economic growth are large-scale capital investment and a rapid productivity growth. Rapid productivity growth, in particular, has relied on the expansion of a energy-intensive and highly-polluting industrial sector[22] which, according to the Chinese National Bureau of Statistics (2012) data, is responsible for the 80%[23] of carbon dioxide emissions. Among the industrial sector, manufacturing is considered to be the main source of Chinese emissions (*Fig. 13*), accounting for nearly 47% of China's total carbon emissions. Such a sizable manufacturing sector has made China the world's largest manufacturer: in 2013, the value of Chinese manufacturing was 35.1% higher than the one of the US (UN, 2014; Morrison, 2015).

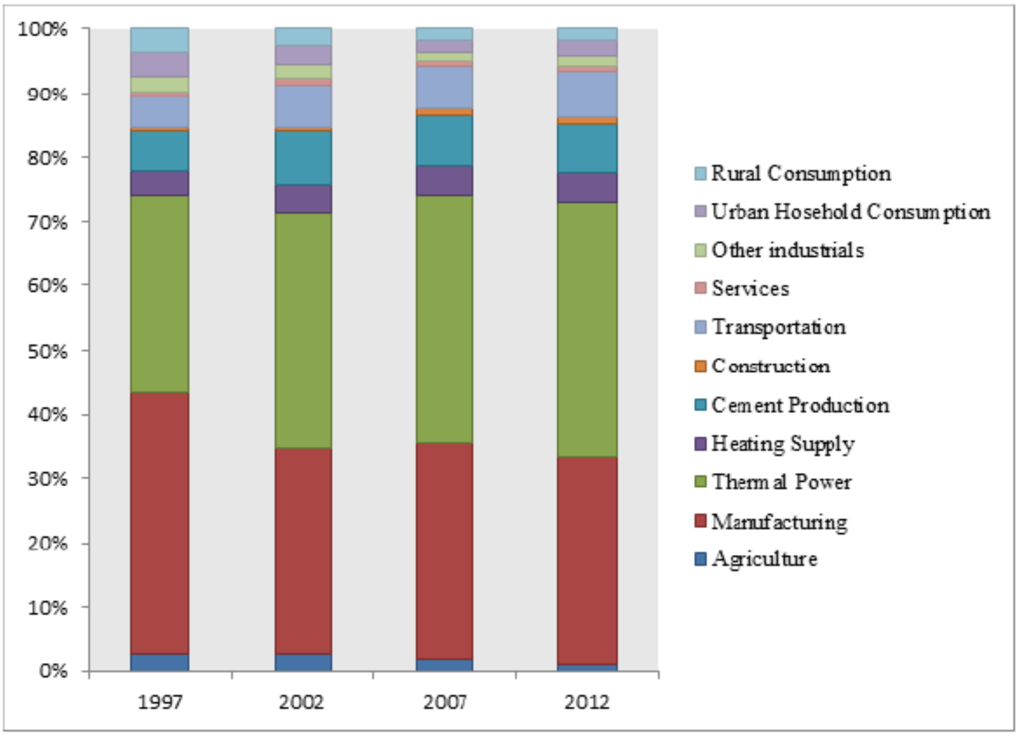


Fig. 13 - Sector share of carbon emissions from China (Liu, 2015)

The rapid and sustained expansion of the manufacturing sector is explained by the openness of China from 1978 onwards to international trade[24], which has allowed the country to significantly increase its production in terms of exports because of its ability to hold a competitive advantage in

[22] In China, industries account for the 45.3% of annual GDP, consolidating its position as world leader for gross value of industrial output.

[23] This figure is of particular significance if, for example, compared with the USA industrial sector, that in 2012 accounted only for 17% of total emissions.

[24] Since 1979, China has exponentially increased its export flows, whose value has increased from $14 billion to $2.3 trillion in 2014. According to the Economist Intelligence Unit, Chinese global share of merchandise exports has risen from 3.8% to 12.4%, with a projected 20% by 2030.

terms of prices, producing labor-intensive goods. Increase in production of export goods, however, has had significant consequences on polluting emissions: according to the research carried on by Liu (2015), "the 25% of China's carbon emissions are caused by manufacturing products consumed abroad", with a total of 1.7 Gt CO_2 emissions embodied in the international exports. In a global perspective, "China's exported embodied emissions account for the largest share of emissions imported to other countries" (Liu 2015, p. 12). *Figure 14* patterns the emissions shares in international trade.

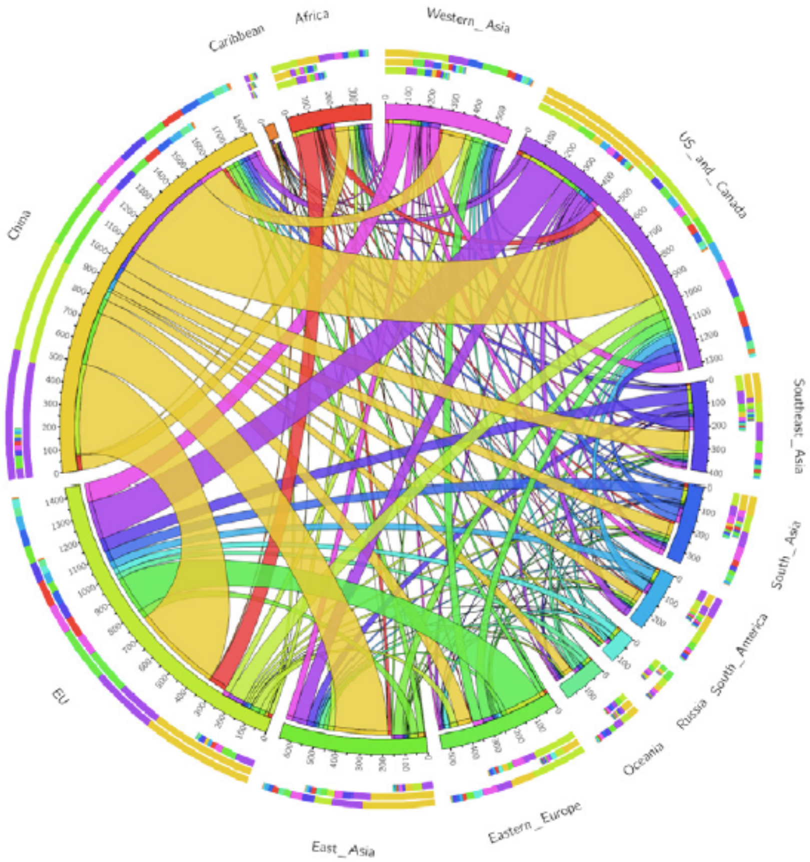


Fig. 14 - Emissions embodied in international trade. The flow represents the emissions embodied in trade, the color represents the original production regions. (Liu, 2015)

4.2.2 *Socio-political framework*

The relative lack of the rule of law in the country is reflected in a high level of government corruption and misallocation of funds in investment activity, other than the difficulty of enforcing rules and regulations. According to the CPI, in 2015 China has scored 37 on a scale from 1 to 100, where 100 refers to a completely corruption-less country. According to the survey by the Pew

Research Center's Global Attitude Project carried out in 2012, it emerges that the 50% of the respondents identified corrupt officials as a major problem; furthermore, the Chinese anti-corruption watchdog in 2009 has declared that 106000 officials were being investigated for corruption. Since his elections in 2012, Xi Jinping —actual President of China, has been carrying out intensive policies anti-corruption. However, many analysts argue that despite the efforts, significant results cannot be achieved unless a system of checks and balances, an independent judiciary and Internet freedom will be implemented (Morrison, 2015).

Because of the austere government's attitude and the limited access to political and social rights, the Chinese population has not been able to properly express its demand for environmental amenities. Especially in the second half of the XX century, the Chinese state has successfully repressed several types of social movements, considered a threat to the CCP regime. In their analysis of the evolution of environmental social movements and of environmental attitudes, Steinhardt and Wu (2015) have noted a higher degree of acceptance of green movements on behalf of the government since the 1992 Rio Declaration at the UN Conference on Environment and Development, that has resulted into a wave of environmental protests since the first half of the 2000s. An example is provided by the activist movement risen as a response to the Chinese project of of Nu River Dam in 2000; its members had been able to develop networks with major environmental NGOs, draw the attention of the media and of other international institutions, eventually compromising the success of the project.

Despite the observed rise in demand for environmental amenities and its related pressure put on the government, Yu (2014) has noted some significant differences of the perception of environmental degradation between rural and urban population. The great distributional inequalities observed between rural and urban areas are reflected in a lower degree of education and lack of environmental knowledge on behalf of the rural population. The lack of access to environmental education compromises rural population's perception of environmental issues. For example, while almost half of the interviewed urban residents were highly concerned with the issue of water conservation, only 8.4% of rural respondents thought of it as a major issues. Urban residents were also on average twice as much concerned about other environmental issues such as loss of biodiversity, soil erosion and desertification.

4.3 Policy implications

The environmental protection system in China is a *top-down* system, according to which "unified national supervision and various levels of government take responsibility respectively, and relevant departments enforce management in accordance with the law" (Fu and Li, 2014). The implementation of norms and regulations is carried out in a cascading manner, where the central government assigns targets to provincial governments who, subsequently, will assign targets to local governments. Over the past 30 years, the Chinese government has taken more than thirty policy actions regarding environmental protection, combining various environmental measures, such as CAC policies, market incentives and voluntary participation. Already with the 11th Five-Year Pan of 2006 for National Economic and Social Development, the government expressed the necessity of intervening on the emission levels, following a dramatic increase in energy consumption in the period from 2001 to 2005[25]. Because of imbalances and inequities in regional development, however, the total target allocation did not take sufficiently into account the different technical capabilities of different areas (Morrison, 2015). This problem has been overcome with the 12th Five-Year Plan of 2010, where national targets with regards of CO2 emissions have been decomposed into provincial and regional targets (Liu, 2015). According to the data gathered by the National Development and Reform Commission, the emissions target set by the 12th and 11th Five-Year Plans have been successfully achieved by all the 31 Chinese provinces. Those results have been achieved not only by shutting down thousands of inefficient factories in terms of energy consumption[26], but also by increasing investments earmarked to technological innovation. In the following sections I will briefly discuss the CAC approach implemented in order to reach such targets and the role played by investments in innovation.

4.3.1 *CAC approach*

Low-carbon emission targets are implemented mostly through a CAC approach, which is operationalized by two main national programs: the Ten Thousands Enterprises Energy Conservation Low-Carbon Program and the Energy Conservation Target Responsibility System (ECTR). The former, established in 2011 by the NDRC, includes 16018 enterprises and governs the relations between state and market on issues such as energy conservation and climate protection. It

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[25] China's energy consumption rose from 1504 to 2360 million tonnes of standard coal equivalents (Lo, 2015).

[26] 'The cumulative impacts of such closures are equivalent to the reduction of 750 million tons of coal use and more than 1.5 billion tons of CO2 emissions' (Lu 2015, p. 6)

works by assigning targets of energy-savings to regulated industries, which are required to achieve 5 types of requirements regarding energy consumption and management (Lo, 2015): establishing leadership for energy conservation; providing incentives to employees to encourage energy conservation behaviors; setting up a sophisticated energy management system; investing in the research development of efficient technologies; obeying the relevant energy laws and regulations. The program distinguishes between state-owned enterprises (the largest and most energy-intensive) and the state-owned enterprisers owned by local governments (smaller and less energy-intensive). Given their large number, however, the government has some difficulties in exercising over them a direct control, so the responsibilities for enforcement have been delegated to local governments.

The second program (ECTR) regulates the central-local relations. It was established in 2006 by the State Council in order to promote local governments' implementation of low-carbon policies. It's key feature is the "establishment of territorialized carbon budgets by the disaggregation of the national energy intensity targets" (Lo 2015, p. 154). Local governments have also to establish an energy conservation fund aimed at developing ecologically efficient technologies and at supporting low-carbon initiatives.

The empirical findings gathered by Lo (2015), however, show that such a system in China has been inefficient in controlling local government behavior. The complexity of the governing structure, in fact, is a serious challenge as it comes to the collection of information; the central government, in order to evaluate the conduct of local governments, relies mainly on self-reported information, which is exposed to the risk of false reporting and may lead to low quality of local statistics. According to the NDRC report (2014) on such issue, "the mismatch between local and national statistics is seriously undermining the attainment of the national energy conservation target"[27]. A second fundamental problem with a CAC approach regards its inability to provide effective incentives for local government to successfully implement policies of emissions reduction, as the forecasted penalties are not harsh enough[28]. Finally, a third issue regards the partial

[27] For example, while the National Bureau of Statistics reported a 5.5% decline in energy intensity in 2012, local statistics identified a decline of 7.7%

[28] According to an official of Changchun Department of Industry and Information Technology, "there is no punishment for failing to achieve the energy conservation targets, other than a public announcement in the newspapers about the failure. You can say it is voluntary, because the enterprises can choose to comply if they want to, can choose not to comply if they do not want to" (Lo, 2015)

inadequacy of using energy intensity as indicator, which is computed as units of energy consumed per unit of GDP; thus, if GDP grows faster than the consumption of energy, energy intensity will continue to decrease enabling plants to partially meet the energy intensity targets. To conclude, although China's top-down environmental policy has been been fundamental in "stimulating a low-carbon transition in Chinese cities" (Lo 2015, p. 158) as it has allowed the achievements of the targets, the growing size of the Chinese economy and its progressive development will lead to increasing environmental pressures due to the related increase in emissions, thus requiring the implementation of a more effective policy approach (see paragraph 4.4).

4.3.2 *Investment, subsidies and technological innovation*

Following the economic reform of 1978, the Chinese government has understood the importance of promoting R&D activities, consistently with the endogenous economic growth theory. Since the late 1990s, in particular, the country has been trying to transform its economy from a one based on low-cost of labour to a one based on knowledge and innovation (OECD, 2012). Concrete policy measures has been reflected in the increase in the government's expenditure for R&D —which has risen from US$4 billions in 1994 to US$91 billions in 2009— and the implementation of tax incentives for industries carrying out activities of R&D. Simultaneously to an increase in R&D investment, the government has implemented policies aimed at promoting the development of human capital; in particular, from 1992 to 2010 the number of full-time equivalent R&D personnel has risen from 0.06% of the population to 0.19% (Mah and Yeo, 2014). Furthermore, starting from 1992, the Chinese government has increased its efforts aimed at attracting foreign direct investment (FDI) implementing tax-incentives to foreign enterprises. As a result, FDI inflows has significantly increased (Mah and Yeo, 2014).

One of the main environment-related innovation areas in which the Chinese government has been investing since the early 2000s, is the renewable energy sector. Already in 1999 the government bestowed public subsidies for the development of renewable energies, but it was only in 2005 that it became a policy issue, with the implementation of the Renewable Energy Law (REL). In particular, article 24 of the REL established a "long-term, stable subsidization system that requires the central government to set up a public fund for renewable energy development" (Wang *et al.,* 2010), to be financed with taxes revenues. Furthermore, the REL encourages other economic incentives aimed at supporting the investment in renewable energy; for example, the government has to implement tax benefits on projects aimed at the development of renewable energy. The program has resulted in significantly positive results: *fig. 15* shows the progressive expansion of the Chinese renewable energy sector. By the end of 2012, all RE sectors accounted for the 29,6% of the electricity generation capacity of the country (Dent, 2015).

	Installed capacity, MW										
	2005	2006	2007	2008	2009	2010	2011	2012	Global installed capacity, MW (2012)	China % share of global total	Sector targets
Power generation											
Hydropower[a]	117,390	130,290	148,230	172,600	196,290	216,060	232,980	248,900	990,000	25.1	325 GW, inc. 41 GW pumped storage (2015); 430 GW (2020)
Wind	1060	2599	5912	12,210	25,810	44,733	62,634	75,374	282,587	26.7	100 GW, inc. 5 GW offshore (2015); 200 GW[b], inc. 30 GW offshore (2020)
Solar PV	0	80	100	145	373	893	3093	8300	102,156	8.1	39 GW (2015); 47 GW (2020)
Biomass	2000	2500	3000	3270	4600	5500	7000	8000	83,000	9.6	13 GW (2015); 30 GW (2020)
Geothermal	24	24	24	24	24	24	24	24	11,700	0.2	110–120 MW (2015) geothermal and tidal; 50 MW ocean (2015)
Ocean (tidal and wave)	3	3	3	3	3	3	3	3	527	0.6	
Concentrating solar power (CSP)	0	0	0	0	0	0	0	0	2550	0.0	1 GW (2015); 3 GW (2020)
RE total	120,477	135,496	157,269	188,252	227,100	267,213	305,734	340,601	1,472,520	23.1	Non-fossil fuel (inc. nuclear): primary energy 11.4% (2015), 15% (2020); electricity generation capacity 30% (2015)

Fig. 15 - China's RE profile (Dent, 2015)

4.4 Future expectations

On March 5th 2016, the draft for the 13th Five-Year Plan has been released. Following the success in achieving the targets set in the 11th and in the 12th Five-Year Plans, the Chinese government has developed an ambitious plan to be followed in the next five years that will be focusing more on *quality* of growth rather than on *quantity*. The new concept of development introduced by the plan allows for a growth rate of 6.5%, thus significantly lower than the previous growth rates. Despite the past achievements in carbon emissions reduction, atmospheric degradation remains a principal issue for China: today, only 1/5 of Chinese cities meets the air quality standards set by the government. With the 13th Five-Year Plan, the goals is to grant such standards to the 80% of Chinese cities and to decrease the number of polluted days per year by 25%. In order to do so, the government aims at decreasing energy and carbon intensity by another 15% and 18% respectively; the latter reduction, if achieved, will result in a 48% decrease in carbon intensity if compared to 2005 levels. This point, in particular, will be a first step towards the Paris Agreements, which demand a reduction in carbon intensity of 65% by 2030. In order to achieve such targets, Chinese government will mainly focus on technological innovation and a new program of emission trading to be implemented in 2017.

	12th Five-Year Plan Targets (compared to 2010)	**12th Five-Year Plan Achievements**	**13th Five-Year Plan Targets (compared to 2015)**
Energy Intensity (energy consumption per unit of GDP)	-16%	-18%	-15%
Carbon Intensity (carbon emissions per unit of GDP)	-17%	-20%	-18%
Non-Fossil Fuel Percentage	11,4%	12%	15%
Sulfur Dioxide (SO_2)	-8%	-18%	-15%
Nitrogen Oxides (NO_X)	-8%	-19%	-15%
Ammonia Nitrogen	-10%	-13%	-10%
Chemical Oxygen Demand (COD)	-10%	-13%	-10%
Forest Coverage	22%	22%	23%

The new program of emission trading, in particular, will substitute the CAC approach as the key policy instrument that will allow China to commit to its ambitious target of peaking carbon emissions by 2030. A prototype of an emission trading system (ETS) was already introduced with the 12th Five-Year Plan and comprehended only 7 pilots (two provinces and five cities). By 2017 the program will expand to a nationwide coverage, constituting a single environmental market which will comprehend almost 10000 enterprises in 31 provinces, becoming the world’s largest ETS. Its size and a common set of rules will help the increase and maintenance of market liquidity. In order to avoid a crash of prices and to maintain a reasonable price for carbon, industries regulated by such a system will have to comply with a more stringent cap than the one set by the national target: compared to 2005 levels, carbon intensity will have to be reduced by 40% before 2020 and by 60% before 2030. In order to provide an incentive for compliance to the program, companies taking early actions will be rewarded (Song, 2016).

As it comes to technological innovation, China will continue to develop its policy of renewable energy promotion and of the establishment of *ultra low emission* plants, replacing coal with electricity or natural gasses in the majority of the industrial sectors and installing continuous emissions monitoring systems (CEMS) on all power plants and on several large industries. Looking to the future, switching to renewable energies will become a fundamental strategy that will overcome the efforts made to reduce carbon intensity. The targets set foresee a further expansion of the share of non-fossil fuels in electricity, reaching a total installed capacity of 250000 MW of wind power and 150000GW for solar power. In order to address the problems, US$355 billion will be invested in such a project and will increase its R&D expenditure to 2.5% of national GDP.

CONCLUSIONS

In order to assure a sustainable development of world's economy and society, it is fundamental to take into consideration the environmental component. Failure to do so, will not only result into the exhaustion of the ecosystem's carrying capacity, but also in an unequal share of wellbeing, as —given the regressive nature of environmental degradation— the Underdeveloped world will be the most affected by environmental depletion, falling into a vicious cycle of progressive lack of fundamental resources and ever-increasing pollution. To properly take into account the natural capital, a major role is played by external agents —such as governments and international organization— which, behaving as *benevolent social planners*, should address the presence of environmental externalities in policymaking, thus correcting existing imperfections.

The ability of such external agents to do so, as it has been discussed throughout this dissertation, is strongly related to the degree of development of a country. High levels of income, in fact, will result not only into a higher level of financial resources to be earmarked for environmental protection, but also in a higher availability and appropriateness of clean technologies and in a higher predisposition of the population to exercise pressure on the polluting agents, indirectly influencing the level of environmental pollution. At this point, however, it is important to stress the role played by international programs in aiding the underdeveloped world to undergo such a development. The current rates of environmental degradation in many situations —air pollution and climate change, for example— are dramatically high, and need to be addressed in the near future. The failure of a rapid intervention on such issues will compromise the sustainability of today's economic system and human development not only in underdeveloped countries, but also in developed ones. Given the transversal nature of environmental degradation, in fact, the whole planet will be affected by the collapse of the ecosystem.

Most importantly, it is also necessary to develop a comprehensive worldwide consciousness regarding the environmental problem. The necessary condition to canalize the socio-economic development of a country towards environmental protection is, in fact, the existence of a pervasive awareness of the dangers of environmental degradation and the creation of an environmental market that would correctly estimate the value of environmental resources. Since environmental degradation is generally characterized by its long-term effects, and because the resources offered by the environmental are not priced, economic agents will tend to *discount* their real cost, behaving in a way that will result into an inefficient allocation. In this context, again, benevolent social planners aware of the need of promoting environmental protection can guide economic agents in decision making.

To conclude, the fact that countries which have always implemented policies promoting unrestricted economic growth —such as China— are now reconsidering their economic and political decision making by designing programs aimed at preserving the environmental capital and at stimulating technological progress towards greener choices, is index of a general global trend towards a more environmental consciousness which could lay the foundations for a truly sustainable development.

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RIASSUNTO

La relazione tra ambiente e sviluppo è stata oggetto di dibattito sin dalla seconda metà del XX secolo quando, di fronte al progressivo aumento dello sfruttamento delle risorse naturali, al fine di sostenere la crescita economica, l'umanità si è trovata a dover fronteggiare dati allarmati inerenti le capacità rigenerative dell'ecosistema. Il funzionamento del sistema economico, infatti, si basa sull'estrazione e sulla trasformazione di risorse naturali offerte dall'ambiente, e sulla capacità di quest'ultimo di assimilare ingenti quantitativi di risorse consumate e chimicamente trasformate. In questo senso, l'attività economica è vincolata alle capacità degli ambienti naturali. Tale capacità dipende principalmente da due fattori: la crescita della popolazione, positivamente correlata al consumo di risorse e quindi di sfruttamento ambientale, e le scelte tecnologiche che, se correttamente direzionate, possono limitare e rendere più efficiente lo sfruttamento di tali risorse.

La relazione di vincolo esistente tra ambiente e sistema economico ha portato alla formulazione di teorie riguardanti la possibile esistenza di *limiti alla crescita*. Il concetto di limite in questo senso ha origine nelle opere di economisti come Malthus e Ricardo che, già nel XVIII secolo, teorizzavano il problema di un'economia in crescita, e del relativo incremento del consumo, che avrebbe infine superato la crescita dei mezzi di sussistenza. Questi stessi concetti sono stati ripresi nel 1972 dal Club di Roma nel report sui limiti allo sviluppo, nel quale veniva sottolineata l'urgenza di trovare una soluzione alla crescita esponenziale della popolazione, e al correlato incremento del consumo. Secondo le stime proposte nel report, i limiti alla sviluppo imposti dall'ecosistema sarebbero stati raggiunti nel giro di un centinaio d'anni. Il modello proposto dal report, tuttavia, è stato fortemente criticato negli anni seguenti, in quanto non teneva conto non solo che la scarsità avrebbe portato a generare meccanismi di prezzamento delle risorse ambientali che ne avrebbe regolato lo sfruttamento, ma soprattutto del fattore tecnologico.

A questo proposito, diversi studi (Lucas and Romer 1960; Nordhouse 2002; Beckerman 1992) fanno riferimento alla *New Growth Theory.* Tale teoria rimanda al concetto di innovazione indotta, riguardante l'impatto dell'attività economia su sviluppo e ricerca e sulla diffusione delle nuove tecnologie. Nello specifico, l'innovazione tecnologica nel lungo periodo comporterà uno sfruttamento più efficiente anche delle risorse ambientali e, quindi, un minore impatto ambientale delle attività economiche soprattutto se l'innovazione è orientata da un sistema di prezzi che

attribuisce valore a queste risorse. A questo proposito, tuttavia, va sottolineato il fatto che gli investimenti nella ricerca possono costituire un fattore ostacolante per le economie sottosviluppate, che non dispongono dei mezzi finanziari necessari per l'innovazione. Inoltre, nonostante l'impatto benefico dello sviluppo tecnologico a livello ambientale sia stato assodato, è necessario ricordare che, fintantoché un mercato per le risorse ambientali non verrà sviluppato, le aziende saranno restie a investire in ricerca e sviluppo a sostegno dell'ambiente. In merito alla questione tecnologica si è quindi sviluppato un dibattito che vede da un lato i sostenitori del cosiddetto *ottimismo tecnologico* —ovvero coloro che in ogni caso vedono nelle nuove tecnologie l'unica soluzione ai limiti alla crescita— e dall'altro i sostenitori del *pessimismo tecnologico* —che invece sostengono l'esistenza di alcuni vincoli naturali inevitabili che nemmeno lo sviluppo tecnologico potrà evitare.

Tenendo in considerazione i fattori discussi finora e data l'incertezza di possibili scenari futuri, nel 1987 la World Commission on Environment and Development ha sviluppato il concetto di *Sviluppo Sostenibile*. Tale concetto, se visto in chiave ambientale, si rifà all'idea che qualsiasi percorso di sviluppo, affinché possa essere considerato sostenibile, debba garantire il mantenimento o l'incremento di un certo quantitativo di *capitale* —che in questo caso deve comprendere anche il capitale naturale— alle le generazioni future. Affinché ciò sia possibile è necessario adottare una visione più comprensiva della performance del sistema economico odierno, che includa l'internalizzazione dei costi ambientali nelle scelte politiche e di mercato e che preveda un'equa redistribuzione delle risorse naturali e dei costi ambientali tra i diversi paesi.

Il problema di una diseguaglianza nella distribuzione dei costi ambientali è descritto dalla *Curva Ambientale di Kuznets* (EKC), secondo la quale il cambiamento del livello di degradazione ambientale è funzionale al reddito procapite. Nello specifico, la EKC descrive una relazione a forma di U inversa: ad un iniziale aumento del reddito procapite aumenta anche il livello di inquinamento ambientale, fino al raggiungimento di un determinato punto di svolta, dopo il quale l'inquinamento ambientale diminuirà all'aumentare del reddito procapite. La relazione descrive quindi un processo dinamico rappresentate i vari step dello sviluppo di un'economia. L'equazione stimata per rappresentare tale relazione è quella di un indicatore di inquinamento ambientale regresso su reddito procapite, reddito procapite al quadrato e altre variabili che hanno un'incidenza sull'inquinamento ambientale. Uno dei principali problemi legati alla teoria della EKC, tuttavia, riguarda la multidimensionalità dell'inquinamento ambientale, che non consente l'utilizzo di un unico indicatore, spaziando da indicatori ambientali riguardanti standard umani ad indicatori ambientali relativi a condizioni ecologiche. Le prime evidenze empiriche relative all'esistenza della relazione descritta dalla EKC sono quelle fornite dagli studi di Panayotou (1993), Shafik e Bandyopadhyay (1992) e Grossman and Krueger (1993), che hanno testato l'ipotesi per diversi indicatori ambientali ottenendo risultati positivi per gli indicatori riguardanti l'inquinamento atmosferico (quindi livelli di SO_2 e SPM).

Dietro la relazione descritta dalla EKC, vi sono diversi fattori responsabili della forma ad U rovesciata della curva. Ognuno di questi fattori è strettamente legato ad un crescente livello di reddito e quindi allo stadio di sviluppo economico di un paese. Un'economia crescente, infatti, in genere porta a effetti socio-economici positivi che sia direttamente che indirettamente influenzano il livello di inquinamento ambientale di un paese. Diversi studi hanno identificato cinque fattori principali che spiegano la EKC: mutazione nelle preferenze e nella domanda per una maggiore qualità ambientale in funzione del reddito, dimensione e struttura dell'economia, tecnologie disponibili, commercio internazionale e integrità del governo.

- Il primo fattore, ovvero la mutazione nelle preferenze e nella domanda per una maggiore qualità ambientale è dovuta all'elasticità di quest'ultima rispetto al reddito una volta superata una modesta soglia; una volta raggiunto un determinato livello di reddito procapite, la domanda per una maggiore qualità ambientale aumenterà all'aumento del reddito. A maggiori livelli di reddito, infatti, corrisponderanno diverse priorità e una maggiore percezione degli effetti negativi dell'inquinamento ambientale. L'aumento della domanda per maggiore qualità ambientale influenza il livello di inquinamento di un paese in modo indiretto in quanto, dal momento che i singoli consumatori non possono direttamente comprare qualità ambientale, eserciteranno pressioni sulle aziende attraverso una maggiore domanda di beni con caratteristiche ambientali (*effetto di sostituzione)* e sul governo per introdurre politiche di controllo ambientale. Munasinghe (1999), d'altro canto, tenta di spiegare tale effetto come una funzione dell'interazione tra costi marginali (CM) e benefici marginali (BM) dei costi di abbattimento. In una prima fase, all'aumentare del reddito, i CM cresceranno più velocemente rispetto ai BM. Ciò avviene per due motivi: la pressione esercitata sull'ambiente andrà via via aumentando man mano che l'economia si espande ed inoltre a bassi livelli di reddito l'informazione relativa ai benefici di un ambiente più pulito è scarsa. Una volta raggiunto un punto di svolta, i CM inizieranno a crescere ad un tasso minore rispetto ai BM, in quanto l'economia disporrà di tecnologie più efficienti e la popolazione sarà più informata.

- Il secondo fattore, dimensione e struttura all'economia, si rifà all'idea che il livello di inquinamento ambientale —non considerando il fattore tecnologico— crescerà all'aumentare della dimensione dell'economia in quanto necessiterà di un maggior numero di risorse. La dimensione dell'economia, a sua volta, è correlata alla sua struttura. A stadi iniziali di sviluppo, l'economia di un paese sarà basata principalmente sullo sfruttamento di risorse come agricoltura e legname (deforestazione). A stadi intermedi di sviluppo, l'economia aumenterà progressivamente il numero di fabbriche inquinanti. Infine, negli stadi più avanzati di sviluppo l'economia sarà prevalentemente basata sul settore dei servizi e della manifatturiera leggera.

- Il terzo fattore, ovvero quello tecnologico, è basato sull'idea che all'aumentare del reddito e della scarsità di qualità ambientale di un paese aumenterà anche l'investimento nell'innovazione tecnologica indirizzata a migliorare l'efficienza ambientale dell'economia. Tecnologia e capitale umano sono però fattori complementari. Condizione necessaria per l'innovazione tecnologica è infatti la presenza di personale qualificato in grado di poter mantenere e implementare tale innovazione. Diversi studi (Mincer, 1981) sostengono che il livello di capitale umano di un pese sia funzionale al reddito di quest'ultimo, in quanto verrà data maggiore importanza all'educazione.

- Il quarto fattore, il commercio internazionale, è legato al fenomeno di dislocazione delle industrie ad alto consumo di energia verso i paesi sottosviluppati (*pollution heaven hypothesis*). La spiegazione di tale fenomeno è principalmente dovuta al fatto che le economie sottosviluppate possiedono un vantaggio competitivo a livello di prezzi. La loro capacità di produrre a prezzi minori è legata al basso costo della manodopera e dell'assenza di efficaci norme ambientali che rendono non necessaria l'implementazione di costose tecnologie non inquinanti. La competizione commerciale incontrollata tra paesi sviluppati e sottosviluppati con diversi standard ambientali eserciterà una pressione verso il basso sulle regolamentazioni, facendo sì che paesi a basso reddito, pur di mantenere un vantaggio competitivo, diminuiscano man mano i loro standard ambientali, producendo maggiori livelli di inquinamento (*race to the bottom*).

- Il quinto fattore, integrità del governo, è legato principalmente al livello di corruzione di un paese —generalmente più alto nei paesi sottosviluppati, come dimostrato dai dati forniti da Transparency International. Diversi studi (Leitao 2010, Mitra e Lopez 2000) hanno dimostrato la relazione esistente tra corruzione e inquinamento in quanto a maggiori livelli di corruzione il governo sarà più inefficiente nell'implementazione di stringenti norme ambientali.

Con riferimento a quest'ultimo fattore, l'evidenza empirica indica la presenza di una forte correlazione tra la forma della EKC e l'abilità e la volontà del governo di adottare ed implementare politiche e norme mirate alla protezione ambientale. Nonostante diversi economisti sostengano che l'unica soluzione all'inquinamento ambientale sia lo sviluppo economico, altri sostengono l'importanza di guidare i paesi sottosviluppati nell'implementazione di norme e regolamentazioni a tutela dell'ambiente sin da subito, in quanto gli attuali tassi di sfruttamento ambientale potrebbero non essere sostenibili in un futuro prossimo. Come nota Panayotou (1993), infatti, vista la persistenza e il carattere cumulativo di diversi fattori di inquinamento ambientale, i paesi sottosviluppati potrebbero impiegare diverse decadi prima di raggiungere il punto di svolta oltre il quale il livello di inquinamento si riduce. Per individuare le corrette norme da applicare è necessario innanzitutto tenere in considerazione costi e benefici totali del controllo dell'inquinamento. Un livello di protezione ambientale efficiente massimizzerà la differenza tra costi totali e benefici totali. Esistono due principali tipi misure da implementare a tutela dell'ambiente: misure di mercato e munire non di mercato.

Una delle principali misure non di mercato usate in ambito ambientale è il cosiddetto approccio *command and control.* Tale approccio si riferisce ad un qualsiasi tipo di regolamentazione ambientale che determini i livelli di abbattimento. Esso opera tramite l'implementazione di standard ambientali, ovvero un livello massimo di inquinamento imposto dalla legge. Un esempio efficiente dell'applicazione di questo approccio è dato dall'US Clean Air Act, che vede in azione un mix di diversi standard ambientali. Si tratta di un approccio largamente prediletto all'interno del policymaking in quanto necessita di un minor numero di informazioni riguardanti il costo dell'inquinamento ambientale e favorisce la cooperazione tra stato ed industria. Critiche a questo approccio, d'altro canto, si riferiscono in particolare alla sua inefficienza nei paesi sottosviluppati nei quali l'alto livello di corruzione e l'assenza di un governo stabile rendono l'applicazione di tali standard del tutto inefficiente. Una seconda misura non di mercato è quella della *public discolure*. Diversamente dal precedente approccio, questa non necessita un alto livello di applicazione dal momento che stimola un maggiore livello di protezione ambientali tramite canali secondari come l'aumento dell'informazione delle industrie riguardo inquinamento e metodi di controllo. Secondo Dasgupta, Wheeler e Wang (2007) tale approccio è sensibilmente più efficiente nei paesi in via di sviluppo.

Per quanto riguarda gli strumenti di mercato, essi operano attraverso tre diverse forme: interventi diretti su prezzi e costi, interventi indiretti su prezzi e costi tramite strumenti finanziari e fiscali e infine la creazione di un mercato per l'ambiente. Un intervento diretto su prezzi e costi avviene quando viene applicata una tassa su emissioni, prodotti o processi di produzione e che tenga in considerazioni i costi ambientali provocati dall'inquinamento. La prima idea riguardante l'introduzione di una tassa ecologica fu avanzata da Pigou (1920), da cui il nome di *tasse pigouviane*. L'implementazione di tali tasse sulle emissioni è desiderabile per due motivi: innanzitutto permette allo stato di raccogliere fondi da investire per il lenimento dei danni ambientali ed in secondo luogo altera il comportamento degli agenti inquinanti, che dovranno rivedere i loro CM tenendo conto delle esternalità ambientali, migliorando l'efficienza dell'allocazione delle risorse ambientali. Grazie alle tasse pigouviane le industrie, nel lungo periodo, modificheranno le loro decisioni in merito a investimenti e programmi di innovazione, dal momento che sarà più profittevole adottare tecnologie più efficienti dal punto di vista ambientale. Critiche all'introduzione di tali tasse, tuttavia, riguardano il loro carattere regressivo sul piano della distribuzione. Difronte a domande altamente inelastiche per beni inquinanti (*ad esempio, la* benzina) l'imposizione di una tassa verrà scaricata sul consumatore tramite un incremento di prezzo. Quest'ultimo, non potendo ricorrere ad altri beni sostitutivi, sarà costretto all'acquisto. La parte di popolazione a basso reddito, dunque, sarà fortemente svantaggiata. Un altro strumento di mercato riguarda l'implementazione di politiche macroeconomiche che tengano in conto delle esternalità ambientali. Corrette tempistiche e combinazioni di diverse politiche (es. liberalizzazione del commercio insieme all'applicazione di tasse ambientali) possono portare ad un'efficace protezione ambientale. Infine, un ultimo strumento di mercato riguarda la creazione di un mercato per l'ambiente. Questo approccio può —ad esempio— consistere nel creare un sistema di diritti di emissione e di un mercato finalizzato al loro scambio (*emission trading*). Tramite questo sistema, un determinato numero di permessi scambiabili, determinato sulla base del livello di emissioni desiderabili, verrà rilasciato ai diversi agenti inquinanti. Questi ultimi, ogni volta che raggiungeranno un livello di emissione minore rispetto al numero di permessi ricevuti potranno commercializzare i permessi avanzati, ricavandone profitti. Nonostante diversi studi (Stevins, 2001) ne abbiano verificato l'applicabilità nei paesi sviluppati, altri (Coria and Sterner, 2008) hanno appurato che nei paesi sottosviluppati l'implementazione di tale sistema potrebbe risultare inefficiente in quanto necessità di grandi capacità manageriali e di controllo da parte del governo.

A questo punto è necessario ricordare che, affinché le sopracitate misure e regolamentazioni agiscano in modo dinamicamente efficiente , condizione fondamentale è che conducano allo sviluppo di tecnologie 'verdi'. Nel 1995 è stata popolarizzata l'*ipotesi di Porter*, secondo la quale le regolamentazioni ambientali sarebbero servite da incentivo per l'innovazione, stimolando gli investimenti in ricerca e sviluppo. Nonostante questa ipotesi non abbia trovato un pieno riscontro empirico, diversi studi (Rexhauser and Rammer, 2013) hanno individuato una correlazione tra i due elementi. Gli stessi studi hanno anche individuato un altro fattore che può incidere sullo sviluppo di tecnologie meno inquinanti, ovvero la presenza di sussidi ambientali da parte dello stato. L'elargizione di questi ultimi, infatti, accelera e induce lo sviluppo tecnologico incoraggiando le industrie a fare ricerca. Come detto precedentemente, le imprese sono spesso poco incentivate a investire in uno sviluppo verde in quanto, essendo l'ambiente una risorsa non prezzata, esse non tengono conto dei costi ambientali dovuti allo sfruttamento di quest'ultimo. Inoltre, data la possibilità di spillover e data la difficoltà nel rivendicare brevetti su queste tecnologie, per le imprese sarà difficile stimare i profitti futuri. Tramite i sussidi elargiti dal governo, queste difficoltà verrebbero ridotte, portando allo sviluppo e all'adozione di tecnologie più pulite. I sussidi governativi, inoltre, sono ritenuti più efficienti della mera implementazione di tasse e regolamentazioni in quanto possono essere progettati e ritagliati in funzione dei diversi contesti tecnologici. A questo proposito va infine sottolineato il fatto che i sussidi governativi sono di fondamentale importanza nel contesto dei paesi in via di sviluppo, dove i livelli di innovazione tecnologica sono particolarmente bassi. Questo è dovuto sia alla mancanza di capitale umano che alla mancanza di fondi da destinare a ricerca e sviluppo. Programmi internazionali mirati all'educazione dei governi e policymakers dei paesi sottosviluppati che promuovano la necessità di investire in ricerca e sviluppo potrebbero risultare positivamente significativi.

Una validazione empirica dell'ipotesi della EKC e delle relative implicazioni per quanto riguarda la risposta politica alla maggiore domanda di protezione è dato dalla dinamica delle emissioni di CO2 in Cina. Diversi studi (Chen and Chen 2015, Li *et al.* 2016) hanno dimostrato l'esistenza di una relazione a forma di U capovolta tra reddito procapite e livello di emissioni di biossido di carbonio nel paese, considerato oggi il maggiore inquinante atmosferico[29], producendo 10540 milioni di tonnellate di emissioni di CO2, ovvero 1/3 delle emissioni totali mondiali. Secondo tali studi, il punto di svolta oltre il quale dovrebbe verificarsi una riduzione nelle emissioni (identificato nel 2015 in US$ 10403.96) è stato raggiunto solo da alcune delle 31 provincie cinesi, presupponendo quindi un incremento di emissioni totali nel prossimo futuro. Ripercorrendo le spiegazioni teoriche alla base della EKC discusse nella tesi, appare chiaro che il fatto che la Cina si trovi ancora nella prima metà della curva è il risultato di un determinato quadro economico e politico che ha caratterizzato il paese sin dalla riforma economica del 1978. Da allora, infatti, la Cina ha visto tassi di crescita estremamente alti (in media del 10% annuo). Un livello di crescita così alto è dovuto principalmente all'espansione industriale del paese, che ha visto il proliferare di industrie manifatturiere ad alto consumo di energia, quindi ad alto livello di emissioni. L'espansione di tali industrie è stata favorita anche dall'apertura della Cina al commercio internazionale e della sua capacità di produrre beni a basso costo, che ha permesso la dislocazione di diverse fabbriche straniere nel paese, aumentando i livelli di inquinamento. Secondo diversi studi, infatti, il 25% dee emissioni cinesi sono causate da prodotti consumati all'estero. Al quadro economico si aggiunge un quadro politico, caratterizzato da un governo austero e con un elevato tasso di corruzione, che non solo rende difficile l'implementazione di normative ambientali, ma impedisce la libera formulazione di una domanda per una maggiore qualità ambientale da parte dei cittadini. Nonostante ciò, già dagli inizi del XXI secolo il governo cinese si è impegnato in forti politiche di abbattimento delle emissioni. Il principale approccio adottato in merito è quello di tipo *command and control*. Analisi empiriche, tuttavia, ne dimostrano l'inefficienza, vista la difficoltà manageriale nel gestire un paese dalla struttura organizzativa cosi complessa. Dalla meta degli anni 2000,

[29] Questa assunzione si riferisce a quantità di emissioni in termini assoluti, non procapite. Tenendo conto di emissioni di CO2 procapite, gli USA detiene il record di maggior inquinante.

inoltre, la Cina si è impegnata con ingenti investimenti a favore dello sviluppo delle energie rinnovabili, ottenendo risultati significativi. Nonostante la positività dei risultati ottenuti, per abbattere il livello di emissioni, la Cina risulta ancora essere uno dei maggiori inquinanti al mondo. Con il 13° Piano Quinquennale approvato a Marzo di quest'anno, la Cina si propone nuove sfide ambientali che vedono l'innalzamento degli standard relativi alle emissioni di anidride carbonica, l'espansione del settore rinnovabile, e la progettazione di un sistema di *emission trading* che possa soppiantare il datato approccio di *command and control*.