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Journal of Economic Science Research
http://ojs.bilpublishing.com/index.php/jesr

REVIEW

History of the Human and Nature Relationship, Discovery of Greenhouse Effect and Awareness of the Environmental Problem

Saoussen Aguir Bargaoui[1*] Fethi Zouheir Nouri[2]

1.Laboratory of Research in Applied Micro economy (LARMA), Faculty of Economic Sciences and Management of Tunis, Tunis El Manar University, Campus University, B.P. 248, El Manar II 2092, Tunisia
2.Faculty of Economic Sciences and Management, Tunis ELMANAR University, Campus University, B.P. 248, El Manar II 2092, Tunisia

ARTICLE INFO

Article history
Received: 21 April 2021
Accepted: 19 May 2021
Published Online: 10 June 2021

Keywords:
Human-nature relationship
Environmental problem
Climate change
Greenhouse gas emissions
Economic awareness

ABSTRACT

The evolution of man and nature relationship during human history has allowed human beings to be sheltered from the threats of their natural environments and has permitted them to exercise their powers there but has against part the breakdown of this relationship because of the excessive exploitation of natural resources, discharges and waste that cause nature pollution. This rupture caused climate change due to the evolution of the production model from the primitive model to the capitalist model. The objective of this paper is to shed light on the evolution of the relationship between human beings and their natural environment and the awareness of the climate change problem. This research allows appreciating and comparing the effectiveness of the resolutions that can help researchers understanding the climate change context, serve as a springboard for empirical studies, and represent a decision tool for policymakers. To this end, we use a knowledge synthesis methodology to make an inventory of our research problem.

1. Introduction

Climate change is one of the current scientific questions that require a study by researchers of all disciplines across the globe because of its importance and its effects on the survival of human beings. This lasting change in the climate parameters of the Earth is caused by transformations caused by human activities and intrinsic transformations. In this sense, "*Man has a story because he transforms nature. Besides, it is even the nature of man to have this ability. The idea is that, of all the forces which set man in motion and make him invent new forms of society, the most profound is his capacity to transform his relations with nature by transforming nature itself*." [3] The man and nature relationship evolved during human history. Indeed, human activities have allowed human beings to be safe from the threats of their natural environments and have allowed them to exercise their powers; but caused the rupture of this relationship following the excessive exploitation of natural resources and the emission of discharges and wastes which cause natural environments pollution.

At the international community level, awareness of climate change is reflected by the breadth of existing litera-

**Corresponding Author:*
Saoussen Aguir Bargaoui,
Laboratory of Research in Applied Micro economy (LARMA), Faculty of Economic Sciences and Management of Tunis, Tunis El Manar University, Campus University, B.P. 248, El Manar II 2092, Tunisia;
Email: aguir_saoussen@yahoo.fr

 DOI: https://doi.org/10.30564/jesr.v4i3.3120

ture across different disciplines. Institutionally, the debate on climate change is dominated by two interrelated issues. First, the future of the global climate objectives set by the Conference of Parties and more particularly that of the Kyoto Protocol, keeping its limitations in view. Second, a general framework conception between developed and developing countries, including a responsibility-sharing agreement considering their different economic situations. Indeed, the Kyoto Protocol is an international agreement aimed at reducing greenhouse gas emissions and which comes in addition to the United Nations Framework Convention on Climate Change. Signed on December 11, 1997, at the third conference of the parties to the convention (COP 3) in Kyoto-Japan and entered into force on February 16, 2005. The fixed objective of the protocol is to reduce during the period 2008-2012, by at least 5% of emissions of six greenhouse gases compared to their 1990 level.

To this end, countries are in the obligation to try to reduce their emissions and recourse to the mechanisms of the protocol that are international trade of emission permits, joint implementation, and clean development mechanism. As for the tradable permit mechanism, it allows companies to permits trade among themselves. This system is stimulating because it encourages companies to invest in R&D to modernize their production tools. In addition, within the framework of tradable permit markets between developed and developing countries, the latter can auction their rights to pollute to countries that have exceeded their limit. This governance should allow quotas to become more and more expensive when countries reach their limit faster. However, the risk is that the less wealthy countries tend to sell their right to pollute very quickly, thus creating a downward distortion of the price of permits.

Concerning the joint implementation mechanism, it focuses on financing industrial or forestry projects with the objective of storing carbon or reducing greenhouse gas emissions and launched by countries of central and eastern Europe. These projects generate emission credits that can be used by investors.

The third flexibility mechanism, the clean development mechanism, was created to allow Westerners to achieve their objectives by investing in projects in developing countries. It represents the response to the demands of developing countries for a financial mechanism that supports economic development by adopting more environmentally respectful production methods. It allows industrialized countries to benefit from carbon credits resulting from investments in clean technologies in GHG emission reduction projects outside their geographic area.

In addition to its unclear and disproportionate responsibility-sharing within developing and developed countries, the Kyoto treaty is contested regularly by various economic lobbies or public figures who consider that global warming is not of human origin and therefore criticize the usefulness and expenditure of the Kyoto Protocol.

At the economic level, relatively recent economic developments in the field of the environment are established and is related to two different approaches: the first concerns the orthodox approach related to the environment, which refers to the school of property rights as well as the neoclassical school also called the economics of the environment. The second relates to the heterodox approach, which includes, in addition to ecological economics, which is based on the criticism of the neoclassical school, the institutional, conventional, and regulation school linked to the environment.

This paper aims to present the history of the evolution of the relationship between human being and their environment that caused greenhouse gas emissions and consequently climate change. To shed light on the importance of the environmental problem and draw lessons from experience and overcome the gaps of the adopted solutions, we try to expose the awareness of environmental dilemma at the international level and the proposed solutions by economists.

The rest of the paper is organized as follows: Section 2 provides the history of the human and nature relationship; Section 3 sets out the history of discovery of the greenhouse effect; section 4 presents the awareness of the environmental problem; section 5 exposes the economists' vision of the environmental dilemma and section six concludes.

2. History of the Human Beings and Nature Relationship

The history of the human beings and Nature relationship has evolved considerably. Indeed, in addition to the permanent changes in environments naturally, other transformations are caused by human activities. This story began truly in East Africa there are approximately 2.5 million years ago with Homo Habilis, followed by Homo erectus, then, around 1-1.5 Million years before Jesus Christ (BC), the Homo sapiens developed in Europe (Neanderthal) around 100,000 years BC to finally arrive at Homo sapiens around 40,000 years ago.

For many millennia, human society was characterized by communism where men ate edible plants and lived in the wild. The precariousness and instability of sources of nutrition expressed the weakness men face the nature

DOI: https://doi.org/10.30564/jesr.v4i3.3120

forces. The paleolithic man survived in living conditions quite like those of other large predators. The man was considered as one of the components of the terrestrial ecosystem. Indeed, manhunts gather and fishes. As a result, hunter-gatherers exploit natural resources through fruit harvesting and the destruction of certain species of wild animals through hunting. However, the small number of human beings at that time; makes their impact on nature modest; since the capacity of natural environments to renew themselves exceeds their exploitation by human beings.

The *first break* of the Man and Nature relationship was caused by the *discovery of fire* around 400,000 years ago. That time was marked by instrument development such as the stick and coarse uncut stones, the spear with the stone point, the bow and arrow. Indeed, the economy, at that time, was managed collectively and was known as the clan economy. Hunting, fishing, food preparation, consumption, and dwellings were in common. This way of life allowed them to provide a force to fight against nature. The *second break* in the Man and Nature relationship is the *Neolithic revolution. It* consists of an agriculture-based productive system initiation that entailed a radical change from predation to a production economy.

Global warming occurred about 10,000 to 11,000 years ago, leading to the Ice Age passage, which began about 1.8 million years ago and ended there. 11,400 years ago, (Pleistocene) in the warming era, which has lasted for almost eleven thousand years. This period coincides with the *Mesolithic* (from the Greek meso = middle and lithos = stone) then the *Neolithic* (from the Greek neo = new and lithos = stone) or "*polished stone age*". Some authors have explained the advent of agriculture in Europe by the significant changes in the climate. In this sense, [32] stated that the evolution of the way of life towards agricultural activity and riverside societies of Mediterranean Europe, from Greece to the peninsula Iberian, seems to have been regular and benefited from global warming.

According to some historians, this warming implied changes in economic and social behavior since it resulted in changes in natural environments: a shift from a hot and dry climate to a warmer and more humid one. This climate favors the development of the forests, which caused the disappearance and the flight of the herds of reindeer, bison, and horses towards the north of Europe and made hunting more complicated, leading the populations of that time to seek new sources of food and therefore to the development of the agricultural activity. According to the American economist Douglass North, this mutation has led to a new approach, called the agro-system. This latter consists in the replacement of natural balances destroyed by unstable secondary balances.

Indeed, the agro-system consists of using the natural components for other purposes than the ecosystem functioning. Therefore, the harvest impoverishes the ecosystem and imbalances it. Besides, domestication is at the origin of several consequences on the fauna. In this sense, [33] stated that individuals target plant or animal populations that best suit *their needs* and try new ways to breed plants and *animals* for *specific* desired traits. Consequently, the inability of some species to adapt to unnatural living conditions led to their scarcity and even their disappearance. On the other hand, the increase in agricultural space and the forest declines due to deforestation and grazing caused a reduction in the number of wild species.

Consequently, the development of crops and livestock has led to large-scale deforestation, which has led to the reversal of ecosystem dynamics and structure. The social forms of production have changed during human history development i.e. primitive, communism, slavery, feudalism, and capitalism.

The decomposition of primitive communism is the consequence of the development of breeding and the domestication of animals. Indeed, breeding marks the first social division of labor, allowing barter development between pastoral and other tribes, since it constitutes a permanent source of milk, meat, skins, and wool. Indeed, the agriculture development has strengthened productive sources of plant food creation stability.

Also, the invention of weaving, which made it possible to manufacture woolen fabrics and clothing, the emergence of metallurgy at the end of the Neolithic, the transformation of copper during the Chalcolithic period (Greek word khalkos: copper and lithos: stone), and gold and silver, opened new areas for human labor. The social division of labor, trade and the progress of the productive forces contributed to the transition to slavery. This production model is characterized by trade development, which contributed to city formation, and commercial development. Consequently, producing harmful effects on ecosystems because of deforestation and clearing actions to develop agricultural activity and organize human life as cities.

The liberation of slaves following their failure in achieving income for their masters allowed the development of a new category of small producers and the emergence of a new production model within the slave society, the feudal production mode. Feudalism in the West extends between the 9th and 13th centuries. The feudal production mode had an economic basis for the small production peasants that are free artisans. The production was essentially natural. The latter was devoted to meeting

 DOI: https://doi.org/10.30564/jesr.v4i3.3120

the needs of its producers and not intended for exchange. During the period 1050 to 1150, the lords recommended their peasants clear the forests to increase agricultural production. At that time, the clearing was done often using fire, which made the soil very sensitive to erosion. These large and uncontrolled clearings have caused natural disasters such as chain floods, landslides, etc. Another aspect concerns the grazing of herds in the forests.

The latter causes the stripping of small vegetation allowing water to be retained on the surface, causing damage to the soil. The impact of agricultural activities on natural environments changed with the industrial revolution at the end of the 19th century. This change is due to agricultural machinery, which began to proliferate and mineral fertilizer development and plant species improvement, and animal selection from the First World War. Thus, announcing the amplification of the impact of Man in his natural environment. Besides, the steam engine expansion in many sectors of the economy, then the diffusion of electricity, led to a considerable increase in coal withdrawals until the 20th century beginning.

Already, Marx noticed these pressures on the ecosystem. Indeed, Marx affirmed that environmental problems are not considered in an economy that is not planned. In this sense, he testified in a letter he sent to Engels that:" *Agriculture when it progresses in a primitive way and is not controlled consciously, leaves deserts behind - Persia, Mesopotamia, Greece, ...*" [22].

The rapid evolution of demography, the disappearance of small communities such as the tribe, the village, … mark the life of the human species in industrial society and the development of the capitalist mode of production.

The industrial revolution is the set of developments that have taken place in agriculture, demography, urbanization, industry, transport, technology, and commerce. These developments have kept humans away from threats to their natural environment. In fact, from the 18th century, the great famines ceased in Europe. Besides, humans began to exert pressure on their ecosystem that manifests in deforestation, fauna pressure, sea-level rise, fossil waters use, increased energy consumption, …

This human authority over nature has generated:

• The decline of forests, which seriously affects flora and fauna diversity.

• The development of artificialized environments, which modifies the environment of human beings following a change in his perception of natural elements.

• The increase in energy-intensive productive activities and consequently the increase in the withdrawal of natural resources.

• The development of new harmful physical phenomena and substances such as radioactivity.

• Air pollution and the consumption of nonrenewable energy.

Consequently, human activities generate anthropogenic gases in addition to the natural greenhouse effect that causes climate change. The 1st article of the United Nations Framework Convention on Climate Change (UNFCCC) defined climate change as: "*Changes in climate, which are attributed directly or indirectly to human activity altering the composition of the global atmosphere, and which are added to the natural variability of the climate*" [30]. However, the greenhouse emissions discovery is a phenomenon that interested researchers from different disciplines.

3. History of the Discovery of the Greenhouse Effect

The greenhouse effect is a natural process necessary for life. Two-thirds of the energy sent to our planet in the form of solar radiation is absorbed by plants, soil, and the atmosphere. The remaining third is returned directly to the atmosphere. In a steady-state, the Earth does not accumulate energy. Greenhouse gases (GHGs) naturally present in the atmosphere help to increase the Earth's temperature. The essential greenhouse gases are water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). In addition to natural GHGs, industrial GHGs are added, including fluorinated gases such as chlorofluorocarbons (CFCs), hydrochlorofluorocarbons, tetrafluoromethane (CF_4), sulfur hexafluoride (SF_6). For their part, climatologists have tried to predict the concentrations of greenhouse gases to be able to estimate climate change in the coming years through scenario making.

The results of the work of the Intergovernmental Panel on Climate Change (IPCC) were published in 2000 in the form of a "*Special Report on Emissions Scenarios*" (SRES) following the collection of information. Concerning socio-economic modeling to be able to establish scenarios covering a wide range of possible futures. This group estimated the GHG emissions for each scenario. The IPCC announced that "*Since 1750, as a result of human activities, atmospheric concentrations of CO_2, CH_4 and N_2O have increased sharply; they are now much higher than the historical values determined by the analysis of ice cores spanning many millennia*" [17].

The history of the discovery of the greenhouse effect dates to 1780. On this date, Horace Benedict de Saussure, a Swiss naturalist, measured the thermal effects of solar radiation in the basin and at the top of a mountain. In 1774, he invented a solar collector called the Heliother-

DOI: https://doi.org/10.30564/jesr.v4i3.3120

mometer made up of five glass cases containing thermometers nested in each other, which he exposed to daylight. He noted that the measured temperature is higher and higher as one goes towards the center. He understood that the greenhouse glazing catches solar energy and figured that the atmosphere does the same.

Jean Baptiste Joseph Fourier, French mathematician, and physicist, published in 1824 his article "*General remarks on the temperatures of the terrestrial globe and planetary spaces*" in which he interpreted the device of De Saussure and proposes an analogy with the atmosphere, throw the basics of the "*greenhouse effect*". To explain the origins of the temperature of the terrestrial globe, Fourier applied his theory of heat by assuming that it is the consequence of the combination of three sources of heat: solar radiation, the temperature of space, and internal heat. of the Earth. He first announced a greenhouse effect theory claiming that the atmosphere is more transparent to solar radiation than radiation re-emitted from Earth. In 1838, Claude Pouillet, a French physicist, assigned the natural greenhouse effect to water vapor and carbon dioxide and concluded that any variation in the amount of these components should result in climate change. It took until 1861 to discover that carbon dioxide and water vapor are the most important causes of the greenhouse effect, thanks to physicist John Tyndall. He was able to demonstrate the influence of changing components of the atmosphere on climate change. At that time, Tyndall was aware of introducing a new idea by claiming that changes in the active radio constituents of the atmosphere are associated with changes in the earth's temperature [29].

Later, in 1878, Samuel Pierpont Langley, an American experimental astrophysicist, developed the bolometer which he used to measure the spectral distribution of radiation. His work has focused on the study of the sun and its influence on the Earth's climate. Based on the work of Fournier and Tyndall, Swedish chemist Svante August Arrhenius founded the "*greenhouse theory*" in 1896. Indeed, in his work entitled: "*the evolution of worlds*" published in 1910, Arrhénius recalls the ideas of Fourier, Pouillet, and Tyndall on the atmosphere: "*Their theory bears the name of the greenhouse theory. Hot because these physicists admire that our atmosphere plays the same role as the glass of a greenhouse (...)*" [1].

Therefore, Fourier and Pouillet, admitted that "*the atmospheric belt has close properties of glass in terms of permeability for heat. The elements of the atmosphere which are the causes of this fact are water vapor and carbonic acid* [1]". Arrhenius noticed that the amount of carbon dioxide increases in geometric progression, and temperature increase almost follows arithmetic progression and has shown that a doubling the concentration of CO_2 in the atmosphere causes an increase in the average temperature of the planet by 4°C. In addition, Arrhenius was the first scientist who presented the link between industrial development, fossil fuel consumption, and the concentration of carbon dioxide in the atmosphere increase. He pointed out that: "*The consumption of coal for industrial needs is likely to significantly increase the carbonic acid content in the air* [1]".

As a result, Arrhenius made the first hypotheses suggesting that increasing carbon dioxide concentrations can lead to climate warming. French meteorologist Léon Teisserenc de Bort discovered the existence of the stratosphere in 1902 following the development of sounding balloons, which has helped to understand that ozone is a gas that absorbs solar radiation. The "*international geophysical year*", 1958, marked the beginning of the continuous measurement of the carbon dioxide concentration in the air by Charles David Keeling in Hawaii and the Antarctic, which made it possible to draw the "*Keeling Curve*" (see Figure 1).

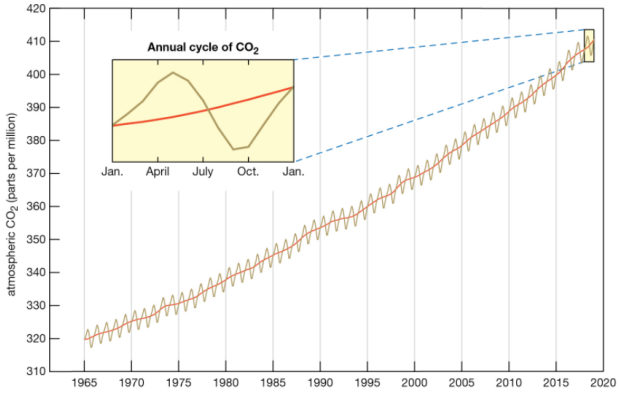

Figure 1. Keeling's curve: atmospheric concentration of carbon dioxide, measured on Mauna Loa (Hawaii), 1965-2020 (in parts per million)

Source: Encyclopedia Britannica, Inc.

This American researcher was able to underline the increase in the concentration of this substance and attributed it to fossil fuels and deforestation increase. In fact, following the industrial revolution, a sharp increase in atmospheric GHG concentrations is due to human activities. The concentration of CO_2 emissions passed from 280 ppm^2 to around 370 ppm^2 between 1750 and 2000, that of N_2O increased by 17%, and CH_4 increased by 1.5 over the same period [16].

According to the IPCC 2001 report, changes that have taken place over the past century are:

• The ground temperature has increased, on average, by about 0.6°C.

• The rise of sea level by 0.1 meters in 100 years.

 DOI: https://doi.org/10.30564/jesr.v4i3.3120

• The increase in precipitation in the mid and high latitudes of the northern hemisphere, from 0.5% to 1% per decade.

• Decrease in frequency of minimum temperatures and increase in the frequency of extremely high temperatures.

Finally, the IPCC has underlined that "*the continuation of GHG emissions at the current rate or a higher rate should accentuate warming and profoundly modify the climate system in the 21st century. These changes will probably be more important than those observed during the XXth century* [16]".

Until the end of the 1960s, the debate on climate change and the greenhouse gas effect phenomenon was dealt with by scientists (physicists, meteorologists, chemists…). However, to enrich the climate change discussions, the scientific and political sides are complementary. In fact, "*networks of scientists and environmental organizations have played a prominent role alongside some international organizations. A few scientists, sensitive to the environment protection, have contributed to the popularization and media coverage of the debate, thus making it possible to familiarize the public and the elites with this theme*" [10].

Indeed, at the international level, the awareness of climate change is revealed the first time by a world climate conference in 1979 in Geneva where a World Climate Research Program was launched, under the responsibility of the World Meteorological Organization, the United Nations Environment Program, and the International Council of Scientific Unions. In 1988, the Intergovernmental Panel on Climate Change is created to perform a regular assessment of climate change. It provides the basis for the development of the United Nations Framework Convention on Climate Change.

The Summit held in 1992 in Rio de Janeiro is a crucial step in international climate negotiations with the signing of the United Nations Framework Convention on Climate Change. It officially recognizes the existence of climate change and human responsibility for this phenomenon. Its objective is to stabilize atmospheric greenhouse gas concentrations at a level that prevents dangerous human disturbance of the climate system. The highest decision-making authority of the Convention is the Conference of the Parties that is responsible for sustaining international efforts to address climate change. On the third conference of the Parties (COP 3) in Kyoto 1997, the Kyoto Protocol was signed and entered into force in February 2005. This Protocol is an international agreement aimed at reducing greenhouse gas emissions.

However, climate change is not a priority compared to other development issues for most developing countries. They believe that developed countries must act because they are responsible for the current greenhouse gas concentrations increase. On the other hand, one of the reasons for the refusal of the United States to ratify the Protocol is that developing countries do not have a quantified commitment to reduce their emissions in the Kyoto Protocol. As for the effectiveness of Kyoto protocol ratification on emissions reduction, [2] demonstrated that protocol ratification allows emissions reduction, but the magnitude of impact is minor. As Kyoto protocol outcomes do not meet expected results, the conference of parties continues to develop other frameworks to achieve greenhouse gas mitigation targets.

As a result, Paris Agreement was approved by all 195 delegations in December 2015 and entered into force in November 2016. It is an agreement that followed the negotiations held at the 2015 Paris Conference on Climate Change (COP21) that plans to contain global warming by 2100 to well below 2 °C of pre-industrial levels and to continue efforts to limit the rise in temperatures to 1.5 °C.

4. Awareness of Environmental Problematic

Despite some existing contradictions between economic growth and preservation of the natural environment, several attempts at linking these two disciplines have started to be formulated in recent decades. In this sense, Raymond Barre's book, *Political Economy*, published in 1959 offers a definition of economic science, which links the latter to the scarcity of natural resources: "*Economic science is the science of scarce resource administration. It studies the human behavior forms taken by the management of these resources, it analyzes and explains how an individual or a society allocates limited means to the satisfaction of numerous and unlimited needs* [26]".

Moreover, economic activities and natural resources were studied in economic theory before the recent ecological awareness. The economic history of human beings demonstrated that nature has a crucial role in economic value formation. Indeed, the incorporation of environmental problems in economic thought can be attributed to pre-classics and mercantilists. In this sense, William Petty (1623-1687), indicated that "*work is the father and nature is the mother of all wealth and none of this couple can be omitted from the public record*" [23].

Besides, physical constraints represent an economic problem for the French physiocrats, and especially François Quesnay (1694 - 1774), head of the School of Physiocrats. Indeed, Quesney considered the economic activity subject to a natural order and advanced the supposedly natural character of economic laws, the guarantee of a pre-established balance, and the circular character of

DOI: https://doi.org/10.30564/jesr.v4i3.3120

the economic process [24,25].

The Quesnay analysis center is land and natural forces. He considered natural fertility to be the origin of the product and the starting point of wealth and its circuit. On the other hand, Turgot (1727-1781) first enunciated in 1768 the "*disproportionate law, or diminishing returns*", and related the number of production factors with the quantities produced. Therefore, the physiocrats failed to distinguish between natural fertility and the productivity of human labor. As a result, they assumed the autonomy of the presumed economic sphere as a natural organism instead of integrating economics into the biosphere and its constraints on economic activity.

As for classical economists, Adam Smith (1723-1790) assumed that land division and technical progress ensure productivity increase and that nature does not impose limits. On the other hand, in his work entitled "*On Principles of Political Economy and Taxation*", Ricardo developed the idea that natural resources are unlimited and have no intrinsic economic value. He affirmed, "*by ordinary principles of supply and demand, it could not be paid rent for the land, for the same reason that one does not buy the right to enjoy the air, water, or all these other goods that exist in nature in unlimited quantities (...). But no one buys the right to enjoy these natural agents which are inexhaustible and which anyone can use*" [27].

Moreover, Ricardo compares the earth to a series of graduated machines, which exhibit imperishable and indestructible faculties. Nature was presented, by the latter, as being eternal and inexhaustible. Thus, no limit, neither ecological nor economic will affect industrial production according to the conviction of Ricardo. Although he returns to the consequences of the law of diminishing returns in agriculture by advancing that the increase in food needs following population growth will cause human beings to cultivate new lands less and less fertile leading to higher production costs.

Thus, we can deduce that the fertile land scarcity does not allow us to serve a perpetually growing population, a thesis previously defended by Malthus. In fact, [21] showed that growth is limited due to the "*population law*" following the thesis development that the misery origin comes from a gap between two laws: arithmetic progression law and geometric progression law. Indeed, [21] asserted: "*The means of subsistence, under most favorable circumstances to production, can never increase at a rate faster than that which results from arithmetic progression*". While the increase in population evolves according to a geometric progression is indisputable [21]. This imbalance can be absorbed by mortality, lower birth rates, and celibacy. Long ignored by neoclassical economic theory, natural resources were not seen as a production factor explaining economic growth. This school of thought ideas on natural resource scarcity is different from one economist to another apart from their common marginal reasoning.

In this sense, in his book "*The Coal Question*", extended these concerns to energy resources and particularly to mineral resources by his observations on the physical limits of coal deposits in England through the denunciation of the dependence of the British coal economy as a cheap and exhaustible source [19]. Furthermore, [19] in his work "*Political Economy*" discusses the relationship between the natural resources scarcity and their value and puts forward the idea that shortage alone does not create value. There are many rare metals and minerals, of which we have never had more than a few fragments, but their value remains low until the day when some uses are discovered for them.

Moreover, through his proposal for the theory of land prices, [31] anticipated the extension of private property rights to the environment and recommended studying the social side, a postulate presented in the debate on sustainable development.

Studying the relationship between economic development and its impact on natural environments became crucial. Indeed, the current development model is imposed by the capitalist production mode, by seeking capital accumulation, and profit. This production model leads to ecosystems degradation, the inequalities worsening, and the traditional lifestyles disappearance. In this sense, "*the type of development that prevails in the world is driven by the search for profit to accumulate capital, by a major degradation of ecosystems, by a considerable inequalities aggravation, by the exclusion of a majority of human beings from the possibility of satisfying their most basic needs (...), by the destruction of traditional life modes*" [18].

Past economists integrated indirectly environmental aspects in their developments. However, their ideas do not address effective solutions to this problem. Since the beginning of the twenties, solutions to environmental problems started to be developed by economists. Indeed, at the beginning of the 20th century, neoclassical no longer saw in the land a necessary input for production. Nevertheless, two economists participated in creating, what will be called around the 1970s, the economy of natural resources via the analysis of the exploitation of exhaustible resources of Hotelling and the environmental economy of Pigou through the economy of well-being and externalities analysis. The impact of human activities on natural resources begins to find its analytical bases in the 1920s with Arthur Cecil Pigou, who is the first who proposed to set up a tax to internalize negative externalities, which will make it

 DOI: https://doi.org/10.30564/jesr.v4i3.3120

possible to change the economic behavior of individuals.

In his seminal paper on *Growth Theory* published in 1928, Ramsey laid the foundations for calculating and choosing the discount rate to treat present and future generations equally [27]. Later, Hotelling introduced in 1931 the relation price - the rate of natural resource extraction in his article: "*The Economics of Exhaustible Resources*" through a balance between the safeguard of the natural heritage for future generations and the influence of monopolies [15]. The response to environmental problems is developed in the following section.

5. Economists Respond to Environmental Problem Consciousness

Economist environmental problem consideration was developed concomitantly with the awareness by the international community. Two different visions were developed, which are the orthodox and the heterodox approach. The orthodox approach is composed of the property rights school and the neoclassical school. As for the school of property rights, several writings are the basis of their analyzes, especially the article by Ronald H. Coase: "*The Problem of Social Cost*". The school of property rights, which belongs to the extreme Orthodox, sees the inadequate property rights structure related to the environment as the cause of its degradation. Indeed, the absence of private property leads to nature degradation [13]. Property rights of economists recommend environment privatization to achieve optimal pollution levels [28]. In this sense, the bargaining between producers and consumers of environmental externalities allows efficient distribution of the latter provided that the information is available, transaction costs are zero, and property rights are well defined [5].

Moreover, Coase argued that: "*the internalization can be realized without the government intervention, except the establishment of property rights, by market negotiation between the polluted and the polluters regardless the initial rights distribution between them*" [5]. Unlike Coase, Pigou puts forward the idea that externalities require government intervention since both sides of the externality will make a deal.

After forty years, the neoclassical approach imposed itself despite being severely criticized and even rejected by some pioneers during the 1970s. The contemporary neoclassical analysis notes the overexploitation of natural resources, whether concerning inputs or outputs. Indeed, they present the absence of a price system as the cause of the ecosystem overexploitation on the input side. As for yield, the increase in pollution and waste costs is due to the absence of their price.

This approach is based on the concept of weak sustainability. The origin of this approach was attributed to Hotelling and was developed by Hartwick, who established the compensation rulemaking it possible to guarantee equity between the current and future generations. Indeed, this rule stipulates that the difference between the price and the marginal cost of resources corresponds to rents which must first be withdrawn progressively with the depletion of resources, then reinvested in the production of a substitute for the depleted resources, and finally increased at the discount rate each period [14].

In this sense, the objective of sustainability is achieved only by transmitting a capacity to produce economic well-being for future generations that is at least equal to that of present generations. That is the maintenance of a constant flow of wealth over time which requires that the stock of natural capital remains intact from one generation to the next as the stocks of equipment, knowledge, and skills, the general level of education and training, and the available natural resources stock form the production capacities of an economy.

Neoclassical economists have tried to integrate the environment first into their general equilibrium models, referring to the tradition initiated by Harold Hotelling in 1931, who considers nature as a particular form of capital. Jacobs distinguished two stages of neoclassical thought. The first stage, which constitutes the radical school, consists of determining the pollution level via theoretical economic tools. The second, representing the applied school, lies in the economic instruments use in public policies.

Thus, from the point of view of radical neoclassical theorists, environmental problems are presented as particular cases of externalities. In a competitive context, the existence of negative externalities leads to a sub-optimal resource allocation. Economically, Greenhouse Gas emissions are considered as negative externalities. Since total surplus maximization with the equilibrium quantity is not achieved. The emissions presence in a market makes it inefficient.

In response to the polluter pays principle, the applied neoclassical school recommended the environmental policy instruments. Thus, the polluter pays the marginal damage costs caused by his activity to limit the external costs of pollution: this is the internalization of negative externalities.

The government can determine the optimal pollution level if it has the necessary information. Then implement regulatory or economic measures involving changing the behavior of economic agents towards a decentralized balance.

Initially, legislation was adopted widely as a tool for

DOI: https://doi.org/10.30564/jesr.v4i3.3120

environmental protection. Regulatory instruments represent an institutional measure aimed at constraining the behavior of the polluter on the pain of sanctions; the norm is one of these instruments [9]. However, the goal of the planner is only achieved when specifying the standard correctly. If the latter is very lax, economic agents are not encouraged to reduce their emissions; consequently, the pollution level remains high. On the other hand, if it is too strict, the pollution level will be lower than its optimal level. However, from the end of the 1980s, the use of economic instruments alongside regulation was recommended by economists. Indeed, economic instruments modify prices, and market signals allow encouraging specific modes of consumption and production that respect the environment. Besides, resorting to negotiation between polluted and polluters on the emissions permit market can eliminate environmental externalities. Indeed, even in the presence of negative externalities and independently of the initial allocation of wealth, market mechanisms are sufficient to guarantee the optimum [5].

The heterodox approach related to the environment was based on the criticism of the orthodox approach. This approach includes ecological economics, industrial ecology, institutional, conventionalist, and regulations approaches.

Regarding ecological economics, it was based on a critique of the postulate of perfect substitutability between natural and technical capital proposed by environmental economics. Indeed, unlike the standard approach where the environment takes on an external dimension to economic analysis, ecological economics seeks to give it a central place within the latter. This current of thought seeks to give commencement to a new discipline allowing the integration of economy into ecology by defending the precaution principle and the stock of natural resources maintenance over time. Ecological economics is defined as "*a new field of transdisciplinary study which in a general sense addresses the relationship between ecosystems and economic systems*" [6]. Within this framework, some authors have tried to reconcile economic growth and environmental protection. In this sense, they recommended natural resources use if the capacity for renewal of natural resources is not exceeded. The concept of robust sustainability associated with this new discipline includes two schools: the London School and the American School.

The economists of the London school admit the dependence between the economy and the environment characterized by the irreducibility of *natural capital* to artificial capital and therefore adopt limited substitution because of the existence of critical natural capital for which there is no substitute and advance the idea of complementarity between the different capital forms. This school gathers several economists from the London Center for Environmental Economics, i.e. Barbier, Markandya, and Turner. According to these economists, the economy must better assess the environment by assigning fair values to the services it provides [20]. However, many services are free, which leads to overexploitation of natural resources. No market could reveal their real values because of buy and sell actions since they are common property resources. Nevertheless, according to London economists, the natural capital stock constancy is defined as an essential but not sufficient condition for sustainable development. This condition requires a nonnegative change in the natural resources stock and environmental quality.

Several measures have been adopted to define the stock of natural capital in economic terms. The London School considers three: The first consists of valuing each type of resource in monetary terms and calculating its total aggregate monetary value①. The second is to consider the unit value of the services provided by natural capital in real terms, thus making it possible to keep the prices of natural resources constant in real terms. The third is to think of the constant value of the resources flow from the natural capital stock. This latter differs from the case of constant prices because the quantity would be allowed to fall and the price to rise, keeping constant value (Pearce and Turner, 1990, cited by Lauriola, 1997, p 80)②.

Despite the monetary valuation of natural resources problems, London School economists attempted to monetize the natural capital stock, using the shadow prices determined with a total economic value of Pearce. The political weight acquired by experts and researchers at the London School in natural resource and environmental economics justified the importance given to the foundations of this school.

However, [20] has shown, by focusing on the basic assumptions and methods of calculation of the London School, that the latter is much less fundamental than it postulates. London economists use an economic evaluation that presupposes various capital types of substitutability instead of measuring them in physical terms. In addition to the methodological problems linked to the analysis, data measurement, and collection, questions concerning the effects of the economic assumptions and interpretations③. Furthermore, the concept of total economic value suggested by Pearce leads to a fundamental inconsistency. Indeed, the stock economic value can remain constant due to the failure to consider resource depletion even if the total economic value of natural resources increases with its

① Pearce and Turner, 1990, cited by Lauriola, 1997, p 80.
② Pearce and Turner, 1990, cited by Lauriola, 1997, p 80.
③ Pearce et al., 1989 cited by Lauriola, 1997, p 81.

 DOI: https://doi.org/10.30564/jesr.v4i3.3120

scarcity [20].

As for the American school, it occupies a much more radical position by assuming the non-substitutability of natural resources [7,8] and by highlighting the idea of complementarity between "natural capital" and other factors of production, in contrast to the position defended by neoclassical economists. Hence a model of "*strong sustainability*" is based on the need to maintain, over time, a stock of "*critical natural capital*" [11] whose future generations cannot happen. Maintaining a natural capital in each physical composition serves as the basis for determining environmental standards [4].

For this, three criteria allowing the preservation of natural capital [8]:

• The rate of exploitation of renewable resources must equal the regeneration rate.

• The waste emissions rate must be equal to the natural absorption capacities of ecosystems.

• The exploitation of nonrenewable natural resources must be done at a rate equals to their substitutions by renewable resources.

Besides, economists from the American school advance the idea that only the absence of quantitative growth makes it possible to ensure sustainability, the result of which is a plea for a stationary economy obtained under the pressure of interventionist measures [4]. The economic stationarity condition is that a subsystem included in a closed system cannot develop indefinitely. Thus, by opting for zero growth, the American school does not renounce development but distinguishes it from growth. For Daly, growth is quantitative on a physical scale, while development is a qualitative improvement. An economy can grow without developing or develop without growing [8].

Other schools of thought tried to offer more practical solutions to the environmental problem seeing it from resource scarcity and excess waste point of view. Industrial ecology school whose supporters have tried to develop a strategy that makes it possible to respond to four challenges, namely: waste recovery, products dematerialization using increasing the productivity of resources, energy decarbonization, and cycles closing by minimizing rejections.

Concretely, industrial ecology was defined in 1989 in an article entitled *Viable industrial strategies* by Robert Frosch and Nicolas Gallopoulos, managers of General Motors, which appeared in a special issue of the *journal Scientific America* intended for the management of the planet earth. However, this notion was only recognized and institutionalized following the Washington colloquium in May 1991, sponsored by the *National Academy of Science* and a specialized journal publication titled the *Journal of Industrial Ecology* since 1997. Industrial ecology offers solutions that must be designed at the scale of cooperating companies to reduce their environmental impacts. However, institutionalist and conventionalist approaches do not directly address the environmental problem but incorporate social institutions.

Indeed, institutionalists reject the hypothesis of methodological individualism, arguing that individuals have endogenous and changing preferences. Also, they invalidate the maximization behavior hypothesis of economic actors, arguing that human behavior is influenced by culture, social norms, and values. In this perspective, other objectives such as the definition of resources transmitted to future generations considering ethical criteria, and the analysis of institutions responsible for natural resources management was set by this school of thought. The institutionalist approach attempts to conceive integrated social management of the environment by integrating environmental values into the institutional renewal process.

Institutionalists state that public regulatory mechanisms and international institutions are incapable of solving environmental problems, given that they are confronted with the diversity of logics and actors. Among the difficulties posed the treatment of environmental problems, which have to be realized at the international level while the national agencies deal with them at a regional level. To overcome this dilemma, institutionalists proposed to renew institutions by integrating environmental constraints and challenges, especially at the international level. However, the institutionalist analysis suffers from some shortcomings, especially concerning the process of institutionalization as a variable of social transformation. Furthermore, the institutional mutations recommended by some theorists of this approach should not only reflect social values but rather the entire social dynamic of which values represent only one component. On these points, the conventionalist current can make a considerable contribution.

Concretely, the conventionalist reading of environmental problems makes it possible to consider social intervention in ecological phenomena. It overcomes the ecological economics limits by considering economic agents, and it represents a complement to the institutionalist approach by theorizing the evolution of social structures in terms of representations and values. In this sense, the conception of environmental policy is influenced by the behavior of economic agents, whose choices guide scientific development and environmental problems [12]. To deal with these problems characterized by a high level of uncertainty, Godard uses the term controversial universe and follows a different approach based on environmental conventions since convention-

DOI: https://doi.org/10.30564/jesr.v4i3.3120

alists present conventions as a set of collective behavior rules in a radical uncertainty situation.

To conclude the conventionalist analysis linked to the environment, it should be noted that the negotiations on the greenhouse effect and the Rio conference characterized by conflicts of interest and asymmetries of power. Hence the need for a new configuration of dominant and dominated social relations. In this regard, regulations analysis makes it possible to highlight this type of relationship in the study of environmental problems.

The regulation school, inspired by the Marxist and Keynesian school, is a socio-economic school of thought found around 1975 by French economists (Billaudot, Lipietz, Boyer, Aglietta, ...) at the time of the oil shock. The regulation school tries to study the macroeconomic and mesoeconomic levels (territorial and sectoral analysis). The regulationist analysis allowed the development of several concepts, such as regulation mode. The regulation mode is a set of procedures and behaviors, individual and collective, which has the property of reproducing fundamental social relations through the conjunction of historically determined institutional forms; support and steer the current accumulation regime; ensure the dynamic compatibility of a set of decentralized decisions, without the need for the internalization by economic actors of the principles of adjustment of the entire system. Among the regulatory methods: the use of less polluting technology or the relocation of an activity by a company to comply with environmental regulations.

6. Conclusions

This article is interested in the evolution of the human and natural environment relationship. This evolution represents the transition from the primitive mode of production to the capitalist mode of production. This transformation led to perverse effects on the environment in terms of excessive exploitation of the exhaustible natural resources and waste and discharges that causing the degradation of the ecosystem's quality.

Using a knowledge synthesis methodology to make an inventory of our research problem, we tied to study the discovery history of climate change and the greenhouse gas phenomenon, which took 150 years, and the awareness of the political, social, and economic level; we sought to allow researchers and policymakers to evaluate the existing strategies and measures. Indeed, this research allows appreciating and comparing the effectiveness of the resolutions that can help researchers understanding the climate change context, serve as a springboard for empirical studies, and represent a decision tool for policymakers.

As for the economic level, the orthodox and heterodox approaches were developed by economists to understand and bring solutions to environmental issues. The peculiarities, advantages, and limitations of the schools that make up these two doctrines presented to provide support for future researchers to overcome their limitations through the development of new solutions that are applicable in the field and that allow more satisfactory results in terms of improving the environmental impact of human activities since developed economic solutions do not all contain practical and measurable tools to ameliorate economic incidence on the natural environment.

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