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ANALYSIS OF SDG-7: *ENERGY* ACHIEVEMENT RACE IN CHINA, EU AND USA. IMPACT ANALYSIS

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ABSTRACT

This paper aims to show the evolution of countries regarding energy and the impact of that energy consumption in terms of carbon emissions. For that, the world main 3 markets are analyzed during the 1971 and 2014: China, the European Union and the United States of America. During the first part of the study, the different objectives of the Sustainable Development Goal 7 (SDG-7) are analyzed and some predictions are made until 2030 to see if, based on the previous time series, the countries/regions are on the way to achieving the objectives set by the UN. In the second part of the study, an ImPACT analysis is carried out, in which the influence of the different variables, the evolution of the ImPACT analysis by decades, and finally how the two global economic crises suffered during the period observed (the 1973 Oil Crisis and the Great Recession of 2008) have affected the different countries/regions are analyzed.

KEY WORDS AGENDA-2030, Energy Mix, Energy Efficiency, IMPACT analysis, China, European Union, United States

RESUMEN

El presente documento tiene como objetivo mostrar la evolución de los países en lo que respecta a la energía y el impacto de ese consumo de energía en términos de emisiones de carbono. Para ello, se analizan los 3 principales mercados del mundo durante los años 1971 y 2014: China, la Unión Europea y los Estados Unidos de América. Durante la primera parte del estudio se analizan los distintos objetivos de desarrollo sostenible numero 7 y se hacen unas predicciones hasta el año 2030 para ver si, en función de los datos temporales anteriores, los países/las regiones van por el camino de conseguir los objetivos puestos por la ONU. En la segunda parte del estudio, se lleva a cabo un análisis ImPACT, donde se analiza la influencia de las distintas variables, la evolución del análisis ImPACT por décadas, y por último como han afectado las dos crisis económicas mundiales sufridas durante el periodo analizado (La Crisis del Petróleo de 1973 y la Gran Recesión del 2008) en los diferentes países/ regiones.

PALABRAS CLAVE AGENDA-2030, Mix Energético, Eficiencia Energética, Análisis IMPACT, China, Unión Europea, Estados Unidos de América

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1- INTRODUCTION

The era of new technologies has meant the evolution from an environment where information was not very accessible to an environment where we are subjugated to information and can even end up overwhelmed with it. Not long ago, it was impossible to think that we were going to be able to read any kind of scientific researches from our house. However, as technological innovations have taken place, now we are able to access to any kind of information only with our cellphones. As information load is huge, society usually trusts in few sources, depending on the matter. Most of this information is usually true, although in recent years there has been an increase in fake news.

Because of the accessibility to the information, nowadays we are able to be informed about what is happening now and also about the findings in the scientific field. Moreover, in recent years, most of the scientific information society is given by the media is usually about climate science. According to Cook et al. (2013), 97% of the scientists worldwide defend the position of blaming the human's activity of the acceleration of the climate change. Even there is hardly anyone defending the opposite in science, we can find a more spread positioning in the matter between the World leaders. The European Union and China, among others, are concerned in the matter whereas USA and Brazil presidencies do not consider the Climate Change as something urgent and their actual presidents (Trump and Bolsonaro) are even deniers of the climate change or at least the anthropocentric guilt.

Although climate awareness has increased, the enrichment of the global population (such as the exponential increase of the Chinese middle class or the development of developing countries) has meant that energy use has also increased (this influencing the acceleration worsening of the climate). Even though China is concerned with the climate change, during the last years is the polluter number one in the world. Europeans support strikes in favor of climate, but their energy consumptions increase as they become wealthier. To end with these contradictions, the United Nations (UN) aims to raise awareness and meet a set of objectives with the final goal of reducing the human impact in the climate and in nature at all.

UN started to address the climate change as a global threat with the Kyoto Protocol of 1997, where member states accept to decrees the 1990s level of emissions of the greenhouse gases. Moreover, in 2015 with the Paris Agreement, member states agreed to accomplish the goal of not increasing global temperature in more than 2ºC (comparing to the pre-industrialization world).

1.1 Agenda 2030 And Sustainable Development Goals

The Agenda 2030 for Sustainable Development is an action plan born from the commitment of the United Nations Member States, whose main objective is to ensure the protection of people, the planet and prosperity.

In 2000, the member countries of the United Nations agreed to achieve the Millennium Development Goals (MDGs) by 2015. At the end of the MDGs, on 25 September 2015, the UN General Assembly established a new global climate change agreement. On that day, an historic event took place, as 193 Member States from all over the world committed themselves to adopt Agenda 2030, a UN-driven program that is part of the United Nations Development Program, and which addresses 17 **Sustainable Development Goals** (SDGs), which in turn break down into 169 targets to be achieved (Annex 1).

Agenda 2030 is a call for global action over the next 15 years. The countries that make up the United Nations are committed to mobilizing the means necessary for the implementation of the Goals, through partnerships that focus especially on the needs of the poorest and most vulnerable.

The SDGs represents a path to sustainable development covering the different economic, social and environmental spheres, with which to move from commitment to action. Innovation and common action are key to the implementation of the Sustainable Development Goals and therefore involve new actors, the private sector and civil society.

1.1.1 Sustainable Development Goal 7: Energy

Energy is in the heart of almost every major challenge and opportunity the world faces today. It is linked with employment, security, climate change, food production or increasing incomes. That is why universal access to energy is essential.

Working towards the goals of this objective is particularly important as it directly affects the achievement of other sustainable development goals. For UN (2019), it is vital to support new economic and employment initiatives that ensure universal access to modern energy services, improve energy efficiency and increase the use of renewable sources to create more sustainable and inclusive communities and for resilience to environmental challenges such as climate change. To achieve ODS-7 by 2030, according to UNDP (2020) it is necessary to invest in clean energy sources such as solar, wind and thermal energy and to improve energy productivity.

According to the United Nations Development Program -UNDP- (2020), between 2000 and 2016, the number of people with access to electric power increased from 78 to 87 percent, and the number of people without power dropped to just under one billion.

However, as the world's population grows, so will the demand for affordable energy, and a global economy dependent on fossil fuels is causing dramatic changes in our climate.

The main objective of the ODS-7 is the following according to UN (2019):

"To ensure access to affordable, reliable, sustainable and modern energy for all."

The United Nations (2019) defines different **targets for the year 2030** to reach to this optimistic goal:

7.1 Ensure universal access to affordable, reliable and modern energy services.

7.2 Increase the share of renewable energy in the global energy mix.

7.3 Double the global rate of energy efficiency.

7.A Enhance international cooperation to facilitate access to clean energy research and technology and promote investment in energy infrastructure and clean energy technology.

7.B Expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in accordance with the respective programs of support in developing countries and underdeveloped countries.

The first three are quantitative targets (the expected final outcome is known) whereas the last two are qualitative targets (effort of achieving this one cannot be quantified, but improvement of quality is notorious).

Once described the Sustainable Development Goals and more precisely, SDG-7: Energy, the research continues with the theoretical framework related to energy, more concretely, about the energy mix and the energy efficiency. After analyzing different papers related the study, definition and further information about the research targets are going to be given. Furthermore, the methodology is going to be stated and the analysis is going to hold. Finally, the results of the research are going to be studied and final conclusions will close the paper.

2- THEORETICAL FRAMEWORK

On a regular basis, the terms energy and electricity are used as synonyms by most of inhabitants in planet earth. However, into the scientific world, a differentiation between the two terms must hold. The energy is defined in different manners but for our understanding we can say that it is the ability of matter to produce work in the form of movement, light, heat, etc. Taking into consideration this definition, we can say that electricity is a type or form that energy takes when it is transformed.

The final use or consumption that energy has can be classified in 3 main groups: Transportation, industry and household use. Even though in this 3 scenarios energy is used, the characteristics that energy needs to have are different. For example, energy for residential use is usually related to electricity and gas (heating).

The use and/or production of energy is one of the main reasons behind the carbon emissions emitted because of the human activity. Carbon Dioxide (CO_2) emissions, even they are not toxic as other Greenhouse Gases -GHG-, they count as the main GHG emissions in the atmosphere, increasing the greenhouse effect. According to the European Parliament (2018), in 2017 almost 81% of the Greenhouse Gases emissions in Europe were related to the use and production of energy. Moreover, China is the main emitter of carbon to the atmosphere, as China emitted the equivalent of 27.5% of global carbon dioxide in 2018. Even China's GDP counted for the almost 16% of the world GDP in 2018 more than one quarter of global emissions come from China. This is because China holds a coal-based energy mix that makes the carbon intensity ratio (CO_2/GDP) extremely high.

Related to the coal-based energy mix that China holds, Kibria et al. (2019) concluded that fossil fuel share in the energy mix has the form of an inverted U. With this it means that low income countries, have a low access to fossil fuels, so the importance of the energy coming from fossil fuel is low and shared with other alternatives as the biomass. When the income per capita increases, as it is the case of China, the share of the fossil fuels increases too up to reach to it maximum level. And finally, once a country is wealthy enough, starts to diversify its energy mix, because of several reasons: on the one hand, to increase their Energy Security Coefficient in the long run, as shown by Augutis et al. (2015) on his study. On the other hand, because of society and the UN agreements pressures in relation to GHG emissions.

Energy is a recurrent field of study among scientists from different fields (such as geologists or even astronomists) and it is an area that encompasses an infinite number of possible scientific researches. However, our study understands energy in economic terms, and it is based on papers that have a direct relationship with the quantitative SDG-7 targets, that is, related to energy mix (target 7.2) and energy efficiency (target 7.3).

2.1 Energy Mix

According to Planete energies (2015), "energy mix" can be defined as the combination of different primary energy sources that are used to meet the energy needs in a given country or region. Primary energy sources are fossil fuels (coal, oil and natural gas), nuclear energy, non-renewable waste and renewable energies (biofuel, wood, wind, hydro and solar among others). These energy sources are used for the generation of power, to provide fuel for transportation and for the heating of industrial and residential buildings (Planete energies, 2015).

Planete energies (2015) suggests that the composition of the energy mix varies among region/country and this depends on: the energy needs to be met; the availability of resources locally and the ease to import them; and policy choices of the region/ country governance. Because of the influence of the different factors, we can note a wide variation among countries. For example, France was mostly dependable from the nuclear energy in 2015, as it counted for the 42.5% of the total energy mix. United States were mostly dependable of fossil fuels-based energy sources, where oil was leading the energy mix with the 37% of the mix. And last but not least, China's economy, that is primarily coal based as explained before (Planete energies, 2015).

However, it has to be noted that the primary energy mix does not hold the equality with the final consumption of energy, as energy is lost during its transformation process. As stated by Donev et al. (2020), the energy mix or the primary energy supply is an aggregate of the sum of all energy going into the energy sector, whereas total final consumption is composed by energy which is ready to be used to fulfill consumers' needs. The final consumption of energy focuses on energy currencies as electricity that has to be made by power plants. Most of the power plants are heat engine plants and during the process they have a fair amount of waste heat. The difference between the two terms can be understood easily by the image of the Annex 2.

Moreover, energy mix cannot be taken as a synonym of the term Power Generation Mix, which is the amount (or percentage) of different energy sources (fossil fuels, renewables or nuclear) used to generate electricity (Planete energies, 2015). If we take the French and Spanish case as example, it can be seen that the Power Generation Mix in 2018 was the following in each case (Table 1):

Table 1 French and Spanish Power Generation Mix in 2018

Energy generation source	France	Spain
Fossil Fuels and Natural Gas	7.2%	40.2%
Nuclear Power	71.7%	20.7%
Renewable	21%	36.8%

Source: Red Eléctrica de España (2019); Bilan Electrique (2019); International Energy Agency

Note that, in the case of France, nuclear power counts for almost three quarters of the Power Generation Mix and about 45% of the Energy Mix. After the oil crises of 1973, France bet strongly for nuclear power, as it lacked for oil and gas reserves due to geographical location. This political turn related to energy aimed to increase the energy security and control of the government over the supply of energy.

According to Augutis et al. (2015), energy security is understood as *"The assurance of the individual consumer's security, economic interests of the society and the state from both external and internal threats"*. As mentioned by Augutis et al. (2015), if a country wants to ensure the security in energy, different options of energy source are necessary to take into account (diversification of the energy suppliers is necessary).

Energy security of a country depends on a large number of factors, which have different impacts in time and are usually inter dependent of each other. That is why energy mix generation is optimized when it is determined by a multiple criteria approach (Augutis et al. 2015).

Energy security is part of the national security in every country across the globe and national strategy depends on issues in relation to energy (Augutis et al. 2015). Because of it, information related to it is usually partly confidential, so national security and energy security are usually complex areas of research for someone out of the government.

According to Augutis et al. (2015), if a country is looking for an energy generation mix strategy that assures a high degree of energy security, it has to take under consideration new patterns, the geopolitical situation, the analysis of different energy systems reliability, the energy disturbances resistance of the alternative energy sources and the risk analysis among other characteristics.

The multiple criteria approach proposed by Augutis et al. (2015) is based on the analysis of 5 different indexes or indicators: Availability, Affordability, technological development and efficiency, environmental and social sustainability and regulation and governance.

As a final conclusion of the study, Augutis et al. (2015) stated that among different scenarios the optimal energy generation mix is the following one. 50% needs to come from energy generated by renewable sources, 30% generated by nuclear fission and 20% generated by natural gas. With this combination, the energy security coefficient (ESC,) increased in a 12% with comparison to nowadays energy mix situation. ESC, according to Augutis et al. (2015), measures the security level of energy and its variation among time and it enables to access consequences to different scenarios.

Related with the conclusion of the previous article, Brook et al. (2014) mentioned that governments will need to change and reduce its dependence on fossil fuel consumption in the production of energy during the next decades, managing the fulfillment of this before the end of the century. To do it, alternative energy sources will have to be considered by specialists. On the paper *Why nuclear energy Is Sustainable and has to be part of the energy mix,* Brook et al. (2014) stated that only nuclear energy and nuclear plants are able to supply large amounts of energy demanded by the industrial countries within these amounts being clean and sustainable. Nuclear energy is among the energy sources the one that best fits the definition given by the EU while referring to a sustainable energy source[1] (Brook et al., 2014).

Among the society, the concept of nuclear energy is related to unsafe practices. Even though this misconceptions, nuclear fission is the safest energy generation source. As it can be seen in the Table 2, nuclear energy is the energy source with the lowest mortality rate per billion kWh produced (Brook et al., 2014).

Table 2 Mortality rates for each energy source per billion kWh produced

Energy Source	Mortality rate (per billion kWh)	Energy Source	Mortality rate (per billion kWh)
Coal	100	Wind	0.15
Oil	36	Hydro	1.4
Natural Gas	4	Nuclear	0.04
Solar (rooftop)	0.44		

Source: Brook et al. (2014)

[1] Sustainability definition by UN: *"Meeting the needs of the present without compromising the ability of future generations to meet their own needs"*

Moreover, the safety-related improvements in the nuclear fission plants are notorious. As stated by Brook et al. (2014), a new-generation plant has about one hundred times less chances of an accident than a plant of early design.

The main 3 global markets (European -EU-, China and US markets) has its own energy mix, depending on the characteristics of the market, the maturity level of it and the resources available. During the last years, different authors have analyzed the different scenarios regarding the energy mix.

According to Dong et al. (2016), in 2009 China promised that carbon intensity was going to decrease between 40-45% in comparison to the level of 2005 and between 60-65% in 2030. Because of this, changing coal-based energy mix has to change and it is a major challenge that the government has accepted. According to Dong et al. (2016), the Chinese government needs to employ financial incentives and tax benefits to increase the share of other energy sources, such as renewable energies or nuclear energies. Dong et al. (2016) also mentions a cleaner use of coal as a short run alternative should be imposed because it generates less CO_2 while generating a highly effective electricity.

In Europe, countries have different needs, so their role is different while talking about energy. For example, Marrero (2010) analyzed the role of UK and Finland between 1990 and 2009 and he realized that their initial income per capita and growth among the period was similar but the energy consumption increased more in Finland than in the UK.

Marrero (2010) researched about the changes in the energy mix of different countries in Europe in the period of pre-Kyoto and post-Kyoto. He realized that the energy mix coefficients were mostly unchanged in the case of East Europe (Soviet Union countries) whereas for most advanced countries in Europe, changes were notorious meaning a significant advance in efficiency or changes in the energy mix to fewer polluting sources.

Last but not least, Jacoby & Paltsey (2013) analyzed a possible scenario if the US exit the nuclear power generation. It concludes that the exit of this energy source would bring an increase in the carbon emissions to the atmosphere and an increase in prices. As stated by Brook et al. (2014), nuclear fission is known as one of the cheapest energy sources so limiting or prohibiting its use would increase the pricing of energy. Also, it is mentioned by Jacoby & Paltsey (2013) that the impact of the measurement would increase if the carbon emissions are limited as the energy generation excluding or limiting fossil fuels will become more expensive for a country like US, which has large reserves of oil and natural gas.

2.2 Energy Efficiency

Energy efficiency can be defined in different ways. A possible definition is that energy efficiency means using less energy to generate the same output (British Geological Survey, 2020); (Environmental and Energy Study Institute [EESI], n.d.). According to EESI (n.d.), energy efficiency or the efficient use of energy has a variety of benefits: reduction of greenhouse gas emissions, reduction of the demand of energy and lower of costs related to the waste of energy both in microeconomic (household) and macroeconomic (economy-wide) level. EDP (2019) adds some other benefits of energy efficiency: energy security is improved, reduction of energy import dependency (really notorious in some countries as Spain, counting for more than the 80%) and increases the competitiveness of enterprises, as energy costs (one of the most important cost in some industries) are reduced.

The major benefit of energy efficiency, however, is that its implementation is possible in every sector of the economy, carrying out enormous opportunities in sectors as buildings, transportations, industry or energy generation (EESI, n.d.) as illustrated in Table 1.

Table 3 Energy Efficiency per sector

Sector	Efficiency improvements of energy
Buildings	Small efforts: Choosing LED light bulbs and energy efficient appliances. Larger efforts: Upgrade insulation and weatherization.
Energy Generation and Distribution	Combined heat and power systems: reuse the waste heat to provide heating. Smart grid: Application of CIT to the electric transmission and distribution systems.
Vehicles	Energy efficient vehicles require less fuel. Hybrids and electric vehicles are fuel efficient.
Freight	Improve efficiency of rail and truck transportation. Shift long-distance from trucks to rail.
Community Design	Neighborhoods well-designed in terms of accessibility for walking, biking and public transportation are key to reduce the use of personal vehicle.
Human Behavior	30% of potential energy saving is lost because of social, cultural and economic factors. Need of address the factors.

Source: EESI (n.d.). Self-made

In general, the quantitative result of the Efficient use of Energy a country or region is obtained through the calculus of the Energy Intensity. Different definition of Energy Intensity can be found in the literature as the one given by University of Calgary (2018), where energy intensity in measured in MJ/$. In macroeconomics, Energy Intensity can also be defined by the following formula,

(1) ENERGY INTENSITY = ENERGY USE / GDP

where energy intensity of a country or region is equal to the energy used for the gross domestic product (Bathia, 2014); (Martínez et al., 2018).

According to the US office of Energy Efficiency and Renewable Energy (n.d.), Energy Efficiency is just the inverse of Energy Intensity. In other words,

(2) ENERGY EFFICIENCY = 1 / ENERGY INTENSITY

Larger the Energy Intensity of an Economy, lower the Energy Efficiency of the same economy. If an economy wants to increase its efficiency in energy, for the same output it needs to decrease the use of energy. The desired goal is to obtain as lower energy intensity as possible, because it represents an allocation of resources for the generation of wealth a and a higher quality of life (Martínez et al., 2018). Decoupling energy use and economic output (GDP) is necessary to enhance than quality.

Martínez et al. (2018) developed on their book *Energy Efficiency* the process of nations related to the changes they suffered in energy intensity since the industrialization. According to them, during the initial development phases, it is logical to expect that Energy Intensity is going to increase and that GDP and energy use are meant to be coupled. That is because industrialization it is highly related to the intensive use of abundant energy sources as fuels and electricity to generate outputs. During the developing stages, large-scale infrastructure public work is done, in relation to the construction of roads or buildings as well as telecommunication infrastructure among others. These new uses are usually energy intensive. However, once industries are established and development has taken hold, Energy Intensity falls historically due to efficiency gains and less energy intense practices. In this last stage, decoupling between energy use and GDP starts to be more notorious.

Even though there has been an obvious decrease in energy intensity worldwide between 1971-2011, it is really important to analyze the progress of each country/region separated (Martínez et al., 2018). Most advanced countries have reduced their energy intensity by the increase of efficiency but also as they offshore to underdeveloped or developing industrial countries their heavy industries, that account for the energy intensive sectors (Heun & Brockway, 2019); (Kulionis & Wood, 2020).

According to Kulionis & Wood (2020), the improvements in efficiency in the electricity and manufacturing sector in high income countries have played the dominant role historically, but efficiency improvements in the service sector are becoming as important. Kulionis & Wood (2020) also found out that the production structure (offsetting high intensity industries) are starting to play a more important role than the domestic changes in the degree of efficiency.

Moreover, Heun & Brockway (2019) discussed in their paper about the Sustainable Development Goals and Energy Intensity. As a result of their analysis in Ghana's primary energy use and GDP, they reached to the conclusion that Energy Intensity is not an appropriate metric for primary energy reduction. According to the results shown, the increase in GDP (of about 5% per year) will bring an increase of the primary energy required (of 2%). Even energy intensity is predicted to decrease, the increase of energy requirements will lead to higher greenhouse gas emission of Ghana. Consequently, a relative decoupling between energy and GDP is possible (decrease of energy intensity), but at present, absolute decoupling is said to be mission impossible by Heun & Brockway.

2.3 ImPACT Analysis

Energy Mix analysis or Energy Intensity metrics are just two independent metrics that are used for analysis in environmental economics. However, during the last decades, different alternative metrics have been developed. These new metrics can incorporate in the same analysis different independent metrics, with the goal of obtaining a metric that measures the impact of individual metrics in a broader analysis.

During the first years of the 70s decade, due to a paper-based discussion between the researchers Commoner and Holdren and Ehrlich, an identity that defines the impact of population size and growth, production (in terms of GDP per capita) and Technology on pollution was found (Holdren, 2018). The IPAT identity (the name the identity took) was the following.

(3) I (impact) ≡ P (population) x A (affluence) x T (technology)

Or in emissions terms,

(4) I (emissions) ≡ P (population) x A (GDP/population) x T (emissions/GDP)

With this identity function, authors wanted to show that the driving forces interact with each other. For example, the environmental consequences of an increase in population are highly sensitive to the situation (economic and technological) of that population. Environmental impact can suffer no movement due to improvements in technology or worsen of the economic situation (Holdren, 2018). In words of Holdren (2018), overpopulation is one of the main drivers of the environmental worsening, but not the only one.

However, Holdren (2018) stated that the relationship between the variables are much more complex to the ones suggested in the formula. Moreover, during the last three decades, industrial ecologists have started interesting in the term "intensity of use" which is outside the IPAT identity (Waggoner & Ausubel, 2002).

With the aim of offering a more complete identity, Waggoner & Ausubel (2002) introduce the ImPACT identity that is defined in the following way.

(5) Im (impact) ≡ P (Population) x A (Affluence) x C (Intensity of Use) x T (Technology)

In table 2 actors that affect each metric can be found, exemplified by energy emissions.

Table 4 ImPACT identity actors

Category	Symbol	Actors	Dimension
Impact	Im	All	Emissions
Population	P	Parents	Capita
Affluence	A	Workers	GDP/Capita
Intensity of Use	C	Consumers	Energy/GDP
Efficiency	T	Producers	Emissions/Energy

Source: Waggoner & Ausubel (2002)

In accordance with the new model, the different actors of the economy have a responsibility that can be measured while talking about the emission increase. ImPACT shows the environmental impact means on four multiplying forces: the people, the economic muscle, the dematerialization (declining C) and efficiency (declining T); (Waggoner & Ausubel, 2002).

On their paper, Waggoner & Ausubel (2002) used the ImPACT identity to analyze world data regarding emissions between 1950-1990 and 1990-1997. The authors observed that during the first 4 decades the impact (dimensioned as emissions) was higher due to the increase in GDP mostly. However, during the last 7 years observed, a change is notorious due to the increase in the dematerialization (or decrease in C) and the increase in efficiency (decrease in T) and a declining increase in the GDP per capita worldwide (Waggoner & Ausubel, 2002).

To reach the goal for reaching to a sustainable positioning, Waggoner & Ausubel (2002) stated that C and T should be the sustainability lever as the decreasing of population is something that is more relating to the moral and Affluency increase is part of sustainability (because sustainability includes a better life for all so human's ambition for income must be accepted).

Continuing with a more actual case, Brizga et al. (2013) analyzed former Soviet Union countries individual performances between 1990 and 2010 using an expanded IPAT analysis. Results showed out that there was an increase of 20% on carbon emission between 1971 and 2010 with main driving forces being population and affluency. However, between 1990 and 2010 a decoupling between affluency and emissions occur.

For the sample, Brizga et al. (2013) found out that affluence and energy intensity both were the most important drivers of change in carbon emissions. However, after the 1998 shock, during the economic growth years other drivers (such as carbon intensity, industrialization and energy mix) played a bigger role as their coefficients were higher.

Furthermore, Brizga et al. (2013) stated that the fall of the Soviet Union and the consequent economic crisis former Soviet republics faced brought the de-industrialization in most of the countries. This effect lead to emission reduction, especially in the first decade of the 21st Century. In relation to industry, carbon intensity trajectory varies among the countries, depending on the heavy industry that remains in them. Countries with more heavy industry (as Russia or Ukraine) have a higher carbon intensity ratio. Last but not least, energy mix did not suffer a big change with respect to the increase of share of the renewable energy sources, as they increase accounted for an increase of 0.6% over the 20 years. Most important change in the energy mix structure has been the partly swap from coal to natural gas, becoming the region with biggest reliance to natural gas in the world Brizga et al. (2013).

3- OBJECTIVES

Paper is based on the study of the main markets (China, EU and USA) in world between 1971-2014. The paper has two main objectives:

In first place, with the data available an estimation of the metrics involved in the SDG 7.1, 7.2, 7.3 will hold with the goal of analyzing if it is possible to achieve the Sustainable

Developing Goals for the year 2030 in the main markets. Moreover, an analysis of the energy mix will hold, and a research will state if those countries are able to manage to reach to the objectives. For that purpose, an historic overview of the metrics is going to hold in the first part of the results, so clear conclusion can hold.

In second place and related to the metrics used for the study of the SDGs, the IMPACT analysis of the countries/regions will hold. The objective is to give the reader a broader view of the countries in terms of population, energy use, technology, GDP and emissions historically and nowadays. Once the analysis is made, discussion will be opened with the opinion of the author.

Also, different alternatives will be proposed if marked SDG are not manageable, related to structural changes (not reached to the objectives) or metric related changes (if used metric does not give full information or if it is not good enough).

4- DATA AND METHODOLOGY

4.1 Methodology

The paper discussion is divided in two as the objectives can be distinguish more easily. The first part of the study is related to the analysis of the main world markets and the data involved in the SDG-7. During the second part of the study, an extended IPAT analysis holds for the three markets.

In relation to the study of the Sustainable Development Goals that are related to energy (SDG-7), the analysis that it holds is the study of the specific dataset required for each goal, through the observation of data available (that it takes between 1971 to 2014). Using this data, forecasts of the following 16 years are going to take place, so it can be seen the possible outcome in the year 2030 for the different markets.

The variables that are analyzed during the study of the SDG-7 are shown in the following Table 5.

Table 5 Variables for the analysis of SDG-7

SDG-7	Indicator	Metrics
7.1	Access to clean and cheap energy	% population with access to electricity % population with access to clean energies
7.2	Energy Mix	% Renewable energy in total consumption of energy
7.3	Energy Efficiency	Energy Intensity

Source: Self-made with data from United Nations

As stated previously, an independent analysis of the variables holds related to the different goals they are linked to and a forecast will hold with the data available. Forecast will be dependent only for historical data (no policy changes or political promises are going to take into account for the analysis). The forecasts show the image of the three markets (the Chinese, the EU and the US market) following the pattern they had between 1071-2014(44 years long data).

Once these different variables are analyzed in a separate manner, the study follows the stream for the achievement of the second main goal, which is related to an IPAT Identity analysis. The objective with this analysis is obtaining a multidimensional answer to the changes involved in the emissions. In other words, the IPAT analysis will help understanding better the changes in emissions.

The IPAT Identity analysis that holds is an extended version of the historical one, the extended IPAT analysis that was also used by Waggoner & Ausubel (2002) for their paper: The ImPACT identity.

(6) Im (impact)≡ P (Population) x A (Affluence) x C (Intensity of Use) x T (Carbon Efficiency),

where, in this case is defined by the following Dimensions

Table 6 Impact Identity Dimensions

Category	Symbol	Dimension
Impact	Im	Emissions (Tons of CO_2)
Population	P	Capita
Affluence	A	Real GDP ($ 2010)/Capita
Intensity of Use	C	Energy (kg oil eq)/ Real GDP ($ 2010)
Carbon Efficiency	T	Emissions (Tons of CO_2)/Energy (kg oil eq)

Source: Self-made through data in Waggoner & Ausubel (2002)

During the analysis of the ImPACT Identity, the Energy Intensity and Energy Mix structure are analyzed in a multidimensional manner (Intensity of use and Efficiency are related to these variables), so both are observed and studied in two different scenarios: individually and collectively.

Microsoft Excel has been the main program used to carry out the statistical analysis of the variables. Microsoft Excel is a spreadsheet program that is included in the Microsoft office package and it enables the user to manipulate tables of values arranged in rows and columns mathematically using both simple and complex arithmetical functions and operations. Graphs and numeric illustrations (tables) appearing in the following section (Section 5) have been made using Microsoft Excel programme.

Additionally, SPSS was used to complete the study. SPSS is a popular software programme from IBM that it is used to perform data analysis and to create tables and graphs with complex data. It is used for a wide range of statistical analyses, such as descriptive statistics (e.g., means, frequencies), bivariate statistics (e.g., analysis of variance, t-test), regression, factor analysis, and graphical representation of data. SPSS is known for its ability to handle large volumes of data. Forecasts from Section 5.1 were obtained running the program.

4.2 Data Sample and Available Data

Regarding the data used for the study, mention that it was obtained through the DataBank, the open dataset from the World Bank. The DataBank is a tool for the visualization and analysis of time series of data on a variety of topics that is open for the general use. A dataset was created through the data obtained from the DataBank.

The sample of the data used for the study contains the data from the 3 markets we are concerned in the study (the Chinese, the EU and the US). Availability of data regarding all the variables concerned in the study was full. However, for further analysis, it was not possible to find a time series data regarding the energy mix (only renewables share in the total energy mix was obtained).

In regard of the time series length, mention that this depends on the variable we are concerned. The Maximum length of the time series is 44 years long (from 1971-2014) and the minimum one is 26 years long (from 1990-2015). This is due to differences of availability of data in the DataBank.

5- RESULTS

Results of the study are divided in two sections. During the first section (Section 5.1), markets are going to be analyzed under one dimension (the one stated for the analysis of the SDGs) and the following forecast will be held. During the second section (Section 5.2), the extended IPAT Identity analysis (ImPACT Identity analysis) will hold.

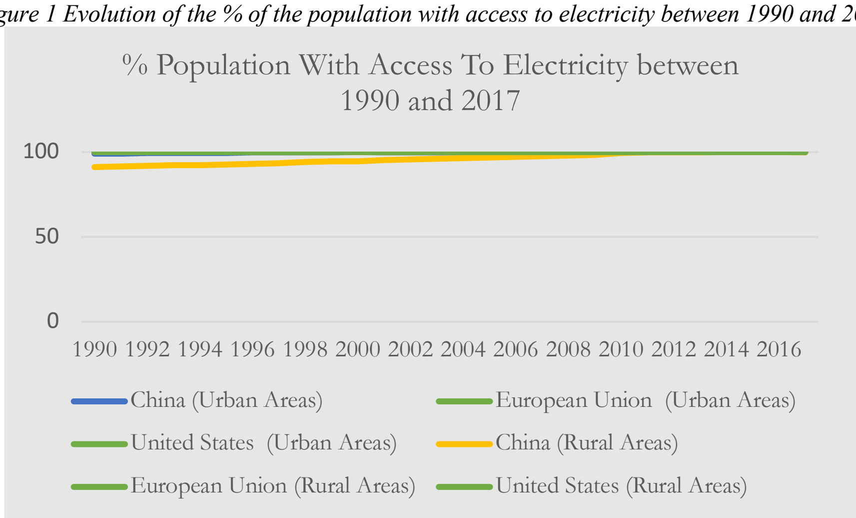
5.1 Results related to SDG-7

As stated previously, Sustainable Development Goals 7 is compound by 5 different objectives. The study only concerns on the ones that have quantifiable objectives (3 out of 5).

5.1.1 SDG 7.1

Sustainable Development Goal 7.1 states clearly that the objective is the achievement of total access to clean energy by the inhabitants of a Country. Even energy and electricity are not same, this time the accessibility of inhabitants to energy is analyzed by access to electricity (primary energy output used by families), as stated by the United Nations. The first part of the objective is the access for all the population for electricity and the second one is obtaining that electricity in the cleaner manner possible. In Figure 1 it can be seen the evolution of the access to electricity between 1990 and 2017 of the countries and regions observed (China, EU and USA) divided into rural and urban areas.

Figure 1 Evolution of the % of the population with access to electricity between 1990 and 2017

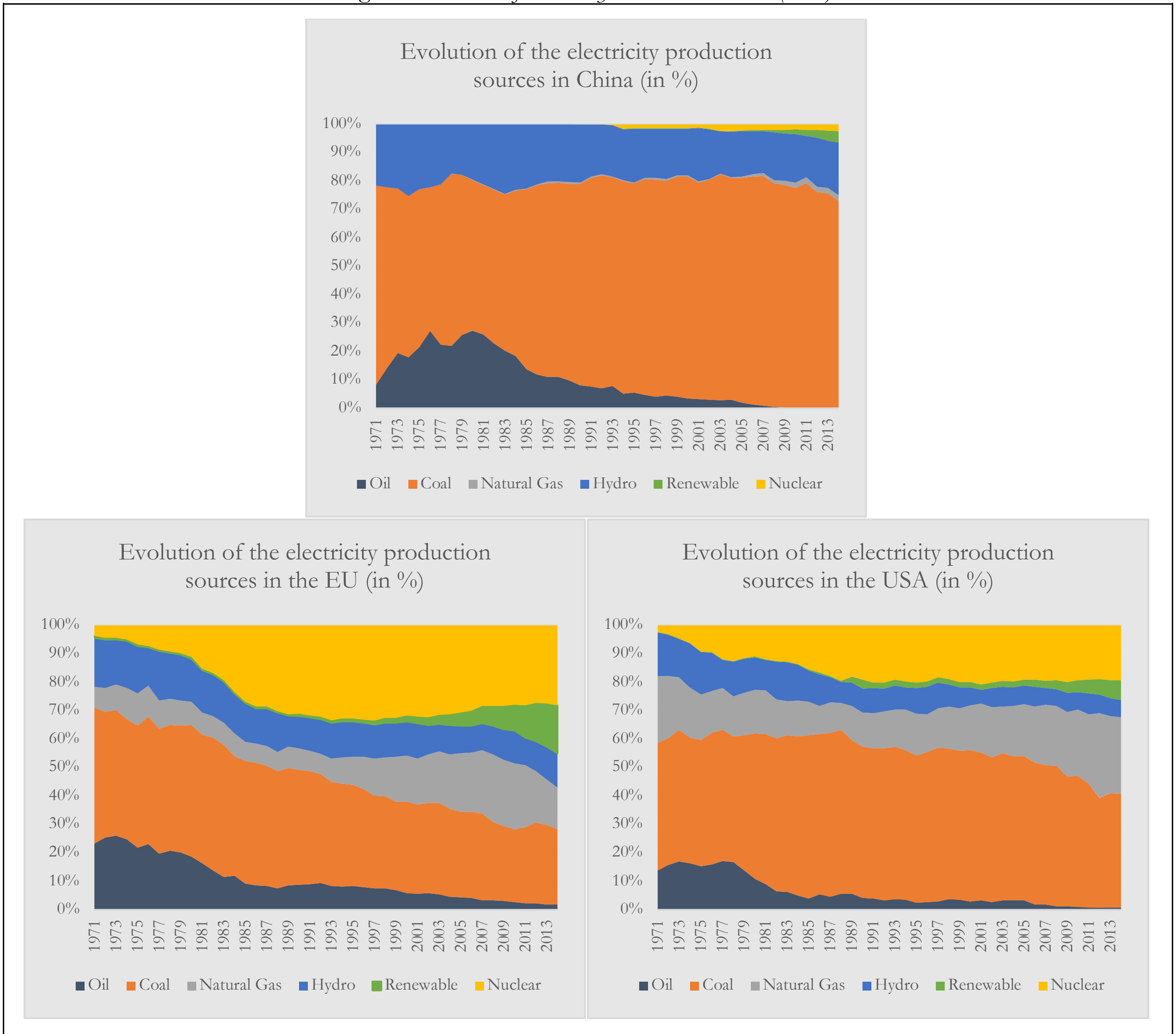


Source: Self-made with data from World Bank

From the figure it can be stated that the European Union and the United States of America have achieved the first part of the objective as all the population has had access to electricity since the day data was started to collect, without any differences between rural and urban areas. However, China's case was different. During the 90s, most of the population had access to electricity (with a slightly difference between urban and rural areas), but with the evolution of times, China managed to ensure the electricity access to the whole population, reaching to score the higher level possible (100% of population both in rural and urban areas with access to electricity). Under normal circumstances, no changes in the percentage of population with access to electricity is expected from the 3 regions observed.

Once the quantitative objective is achieved, the qualitative part of the objective needs to be analyzed. Regarding this case, the analysis focuses on the electricity production sources and the evolution they suffered during the period analyzed (1971-2014). Figure 2 illustrates the evolution for all three cases regarding the sources of production of electricity.

Figure 2 Evolution of Electricity Production Sources (in %)



Source: Self-made with data from World Bank

Without taking into account the exact impact in each case, if we compare the three markets, clear trends could be obtained for each source. A descendent trend on hydro and oil usage for electricity generation and a positive trend on natural gas, renewable and nuclear energy usage for production of electricity.

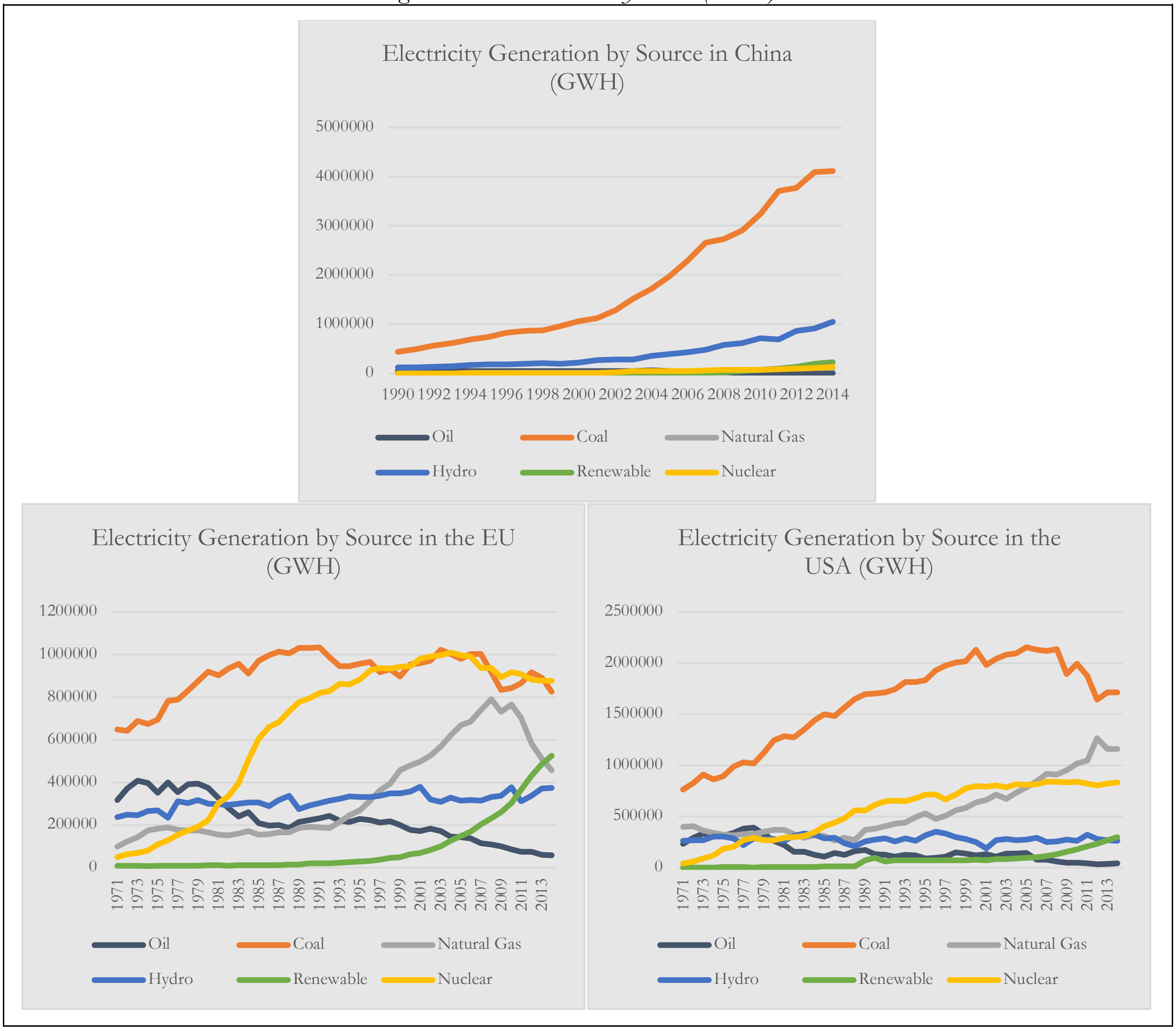
Chinese clean electricity production is the one out of the three studied with the minor evolution (in percentage). China is a country with a strong carbon-energy basis. Coal high usages (around 70% of electricity produced) makes the country the world most CO_2 emitter. However, a positive trend for renewable energies can be observe from 2006 on. Nuclear and natural gas usage for electricity generation looks to be residual and without a clear trend of increasing the share.

In the case of the European Union, different trends define the evolution of power generation in relative terms. Oil and Coal use for electricity generation have lost the share they had initially, and oil has become a residual source for electricity generation during the last years. However, and even though coal usage has diminished its share, it is one of the main sources of power generation Natural Gas usage had an increase during and the years after the first oil crisis (1973). However, it recovered the initial levels (1971) and maintained on them during the second part of the 80s and until 1992. After this year, the increase in the share was permanent up to reach to a maximum of 22.95% of share in 2009 and a descend that followed it until the last year observed. Hydroelectric based electricity generation has had a downward trend during the period. The hydroelectric energy lost a 5% share between 1970 and 2014. Nuclear energy was the one that suffered the biggest increase in the time period observed as the EU moved from a share of 3.54% in 1971 to a share of 27.74% of total power generation in 2014 (with a maximum share of 33.07% in 1993). This increase in the share can be understand among other reasons by a response of the member states to the oil crises and ensuring energy in their countries. During the last years of the period observed, electricity obtained through fission was the main one with coal-based electricity. Last but not least, electricity generated by renewable sources have suffered an exponential increase since the 1990s. European Union environmental policies are stated to be the main drivers of this increase.

The evolution of the USA is alike to the evolution of the European Union but with some remarkable changes. Oil- and coal-based electricity have declined their share. As in the case of the European Union, oil-based electricity generation became residual while coal-based power generation maintains the lead in the share of power generation. Regarding natural gas, it looks like a U, as during the first 20 years studied the share declined but after it a recovery can be observed, with a final share higher than the initial one (23.49% in 1970 compared to 26.89% in 2014). During the last year of the observation (2014), it was the second source with the biggest slice in the electricity generation pie. Hydroelectric generation had a higher share lost during the period than the EU, as 9% decrease was reported (5% in the case of EU). Lastly, Renewable and Nuclear power generation suffered similar trend increases during the period, but in the case of United States, these increases were milder.

The former analysis, which was based on relative terms (in percentages of sources), a short analysis of the power generation by sources in absolute terms needs to be hold if all the pic wants to be understood. In Figure 3, it can be observed the evolution of electricity generation by sources in absolute terms for the three markets.

Figure 3 Power Generation by Source (GWH)



Source: Self-made with data from World Bank

On the one hand, we have China. In the case of China, it can be observed a clear increase of coal-based electricity production up to reach to its highest level in 2014 (more than 4 million GWH of electricity produced through coal). The second largest source of electricity has been electricity produced through hydroelectric power plants. Even though it had a share of just 18% during 2014, in absolute terms it produced more electricity than the first source in the EU (around 1 million GWH produced through hydroelectric power plants in China vs 876 thousand GWH produced by atomic fission in the European Union in 2014). By the end of 2014, it can be stated that China is the major producer of electricity worldwide with a power production of 5.6million GWH.

On the other hand, we have the EU and the USA. In this case, the increase of electricity production through the period observed has not been as big as in the case of China. Coal-based electricity has been the main driver of the electricity production in both cases. Nevertheless, differences can be observed regarding other sources. In the case of the

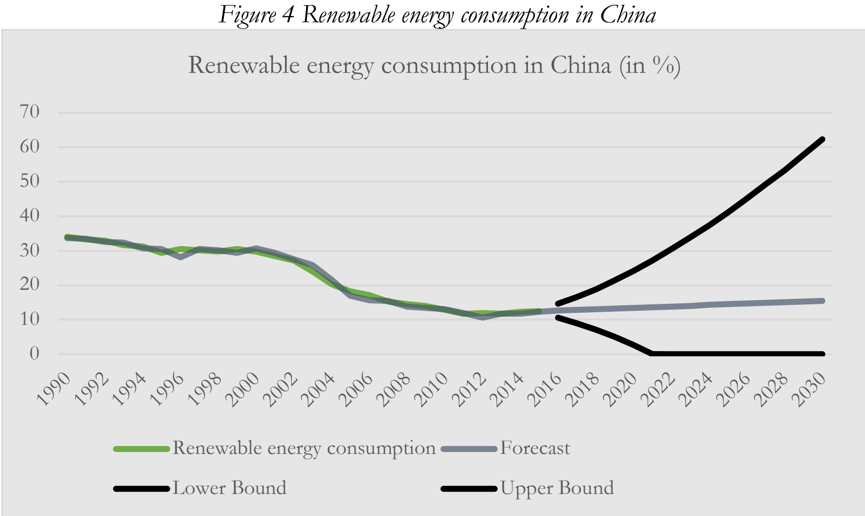
EU, the diverse sources are converging between them (except from oil). Additionally, the effort of the European Union to use renewable sources as energy references is starting to become true as during the 21st century the exponential increase on renewable based electricity can be observed (it has the highest production of electricity through renewables of the study). In the case of the USA, this move toward a greener production of electricity started later (2006 on).

In all three cases it can be observed that due to the pressures of environmental concerns, the production through these channels is increasingly without yet reaching to the maximum capacity of power generation.

5.1.2 SDG 7.2

Sustainable Development Goal 7.2 sets the goal of increasing the share of renewable energies in the Energy Mix. The analysis is made using the variable described in Table 5 (% Renewable energy in total consumption of energy). On this case, the data observed is from 1990 to 2015 and a forecast[2] up to 2030 is represented on the graphs. Assuming that the analysis is made under a 95% of confidence, lower and upper bounds are represented in black. Each country/region is analyzed individually and in alphabetic order after the presentation of its graph.

Figure 4 Renewable energy consumption in China



Source: Self-made with data from World Bank

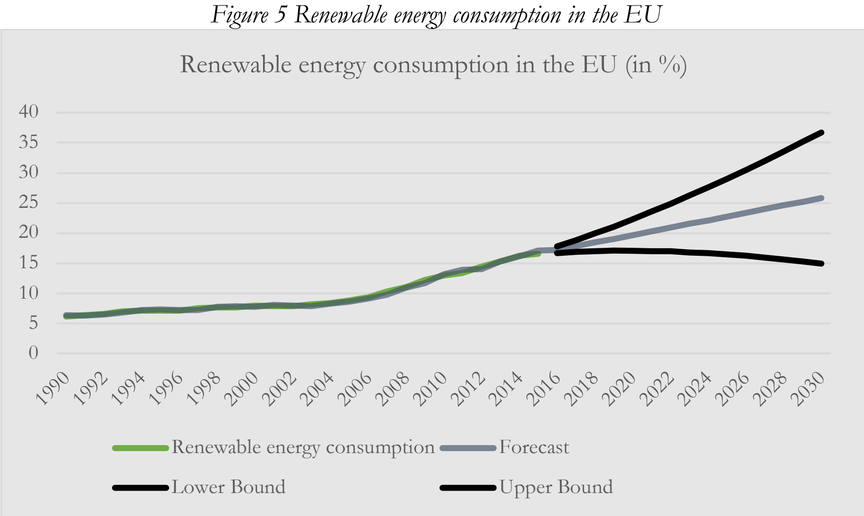
China. In regards of the evolution of the renewable energy consumption in China, it can be observed that during the 26 years long period of time a decline in the share of renewable energy consumption occurred. During the first year observed (1990), around a

[2] Forecasting made under the assumption of time series analysis: time series forecasting is based on known past events. See *Annex 3* for SPSS data outputs regarding objective 7.2

third of total energy consumed was based on renewable energies. However, during the last year observed, the share of renewable energy in total was of 12%. The minimum share was achieved during the 2011, when it reached to the point of 11.7% of total share. The last 4 periods of time observed a small recovery in relative terms can be observed.

Regarding the forecast of the 15 years remaining until 2030, it can be observed that the trend under our model is an upward trend. It states that the share of renewable energies will increase in the near future for China. However, we can ensure at a 95% of level of confidence that the level of Chinese renewable energy consumption in relative terms will vary between the two black lines (our confidence interval). Under this confidence interval, we cannot ensure that Chinese renewable energy consumption will increase (even the positive trend that it follows).

Figure 5 Renewable energy consumption in the EU

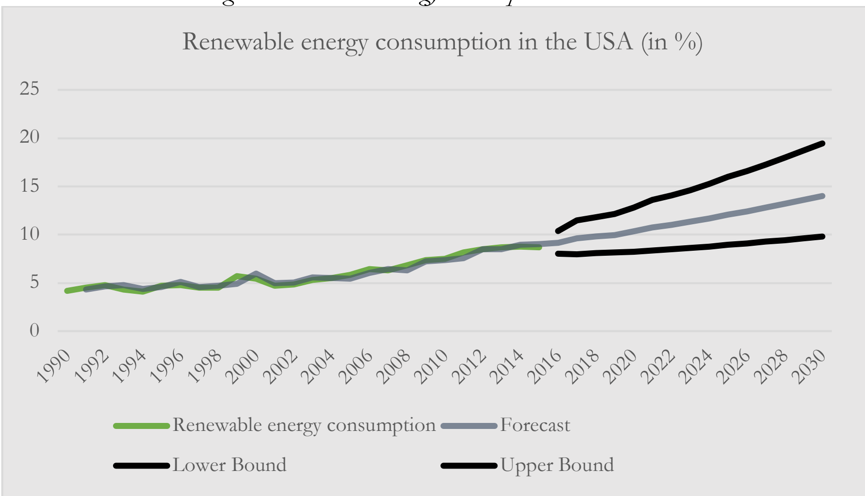


Source: Self-made with data from World Bank

European Union. An ascendant trend can be observed in the case of the European Union between the years targeted in the study. During the 90s and until mid 2000s the increase in the share of renewable energies in the total consumption has been slow but constant and during the last decade of the data recorded, the increase in the share started to look steeper. In relative terms, during the 26 years, the share has increased in more than 2.5 times (initial level was 6.1% of share in 1990; final observation in 2015 gave renewable energies a 16.5% of share).

Taking into account the record of the renewable energies' consumption in the EU during the last period observed, the forecast estimates an increase up to the 25% of the total share in 2030. As represented in the graph, it can be seen that the trend is up warding. However, and under a 95% of confidence interval, it cannot be said that in 2030 the share of renewable energies in the total consumption are going to be above the level of 2015.

Figure 6 Renewable energy consumption in the USA



Source: Self-made with data from World Bank

United Stated. Between 1990 and 2015, a positive trend towards the consumption of renewable energies can be seen in the Figure 6. Rather than the evolution of the EU, in the US the evolution was more progressive. It cannot be observed any interannual big change but the total change between 1990-2015 supposed to double the rate of renewable energy consumed respect to the total.

With respect to the forecast, it can be observed that the forecast follows an upward trend. According to it, the share of renewable energy consumption is supposed to increase another 5% until 2030. However, this increase can me more or less (95% of confidence interval can be observed between the 2 black lines). In the case of the US and according to our forecast, we can assure that an increase is going to hold with a 95% of confidence, as the lower bound level in 2030 is higher than the last data observed (9.04% of share observed in 2015 vs 9.8% is the lower limit of the confidence interval in 2030).

In sum, according to our data and under the 95% of confidence interval, we can state that only the increase in the US is assured. However, the tendencies and forecasts indicated that it is probable that increases in share also will occur in China and EU.

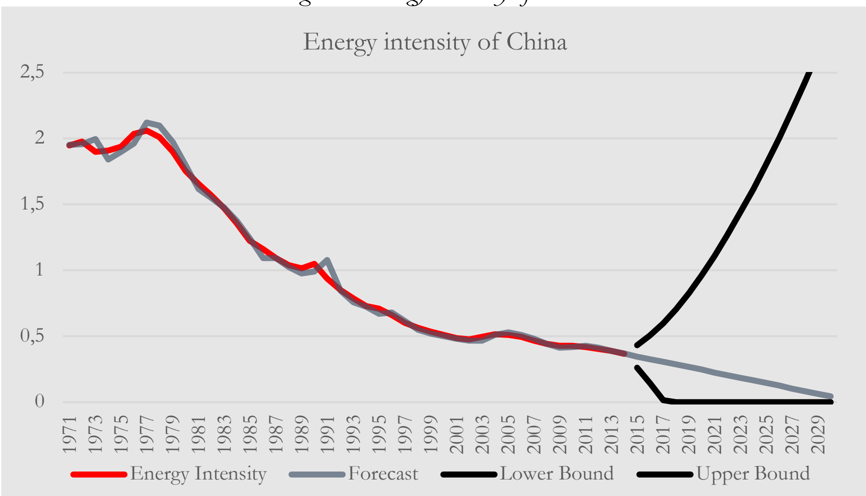
5.1.3 SDG 7.3

Sustainable Development Goal 7.3 sets the goal of doubling the global rate of energy efficiency. For that, the analysis is hold using the inverse of energy efficiency, which is energy intensity (as indicated in Section 2.2). To fulfill the Goal, each region/country needs to cut to the half its level of energy intensity (at least). The data used is from 1971 to 2014 and forecasts[3] up to 2030 are represented on the graphs. As in Section 5.1.2, analysis is made

[3] Forecasting made under the assumption of time series analysis. See *Annex 4* for SPSS data outputs regarding objective 7.3

under a 95% of confidence (lower and upper bounds are represented in black) and alphabetic order is followed for the individual analysis of each region and relative analysis.

Figure 7 Energy Intensity of China

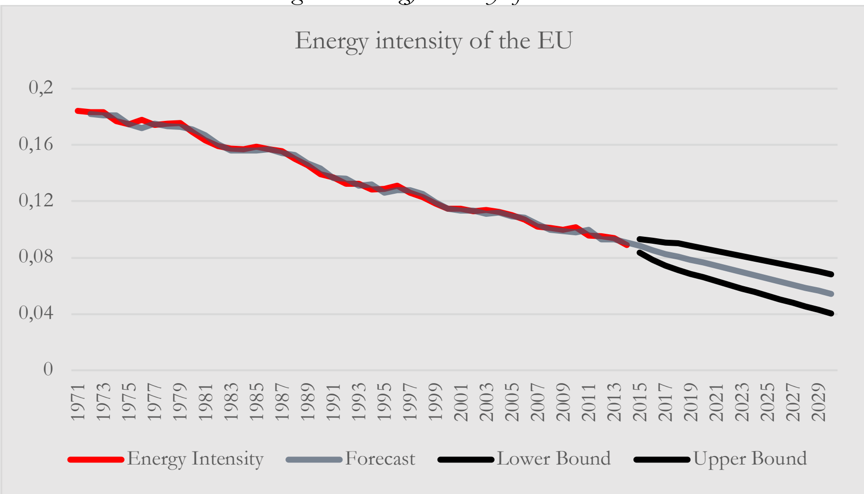


Source: Self-made with data from World Bank

China. Energy intensity in China between 1971 and 2014 has suffered the biggest decrease between the three markets that are being analyzed. Energy intensity level in 2014 is the equivalent of just 18% of the level that was observed in 1971. It can be said that it decreased more than 5 times. This drop has been quite constant along the period even though some peaks can be observed (1972-1977, 1990 and 2003-2004) where energy intensity increased.

In regards of the forecast, the trend of decreasing the energy intensity is followed in the forecasted years and until 2030. Under the model, it is forecasted to achieve easily the objective of cutting to half the energy intensity of the region (it is forecasted to be 0.04 in 2030 and it was 0.37 in 2014). However, under a 95% confidence interval it cannot be assumed that the drop is going to happen, as the confidence interval envisages the possibility of a rise in the energy intensity up to 2030.

Figure 8 Energy Intensity of the EU

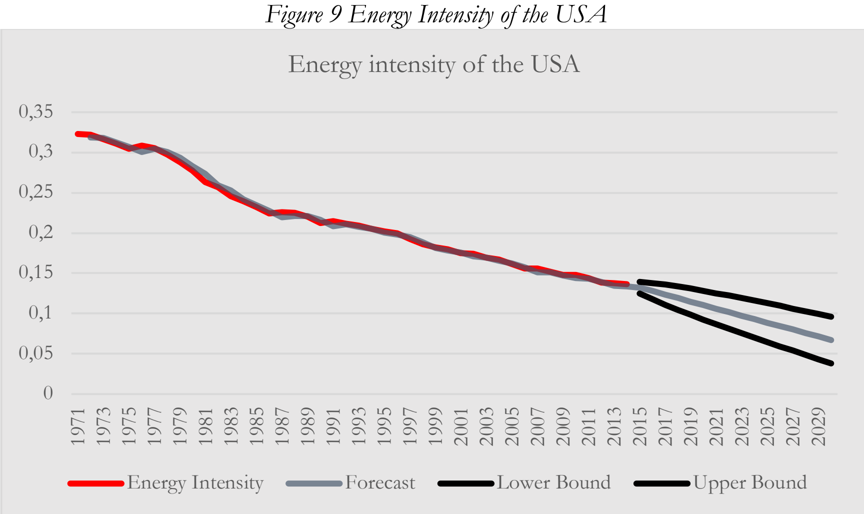


Source: Self-made with data from World Bank

European Union. As in the case of China, during the period a drop in the energy intensity can be observed between 1971 and 2014. In relative terms, the drop was the minimum one between the three regions/countries (in 2014 EU energy intensity corresponded to the 48% of the level observed in 1971). The drop has been constant along the time with some peaks (1975-1979, 1985, 1993-1996 2001-2003 and 2010) where energy intensity increased.

Regarding the forecast, the trend continues to be the same. In other words, the energy intensity is supposed to followed to decrease. Under a 95% of confidence, it can be stated that the energy intensity is going to decline in the period 2014-2030. However, this decline will not be enough to reach the objective of 50% of energy intensity decrease according to the forecast values (confidence interval envisages the possibility of this being fulfill as lower bound in 2030 is 0.04 and the objective is to reach to the half level of 2014, 0.09).

Figure 9 Energy Intensity of the USA



Source: Self-made with data from World Bank

United States. Energy intensity graph for the period 1971 and 2014 for the US looks really similar to the one analyzed for the EU before. However, energy efficiency win was a bit higher for the US than for the EU as energy intensity drop in 2014 to the 42% of its level in 1971. As in the other two cases, the drop has been constant with some peaks (1976, 1987 and 1991) that have meant energy intensity increase.

In regards of the forecast, a decrease for the period 2014-2030 is expected. Under a 95% of confidence, we can assume that the energy intensity is going to decrease. If the forecasted values are right, the goal will be achieved by 2030 (but cannot be assumed under the 95% confidence interval).

In general, it can be stated that there is no evidence that the particular objectives of reducing to the half the energy intensity will be achieved in the 3 cases. However, it looks easier for China and US to achieve the objectives. However, energy intensity level is really low if we compare the level of the EU with China. In other words, doubling the energy efficiency in the EU will be harder than doubling it in China, as energy efficiency was 4 times higher in the European Union than in China in 2014.

5.2 ImPACT analysis

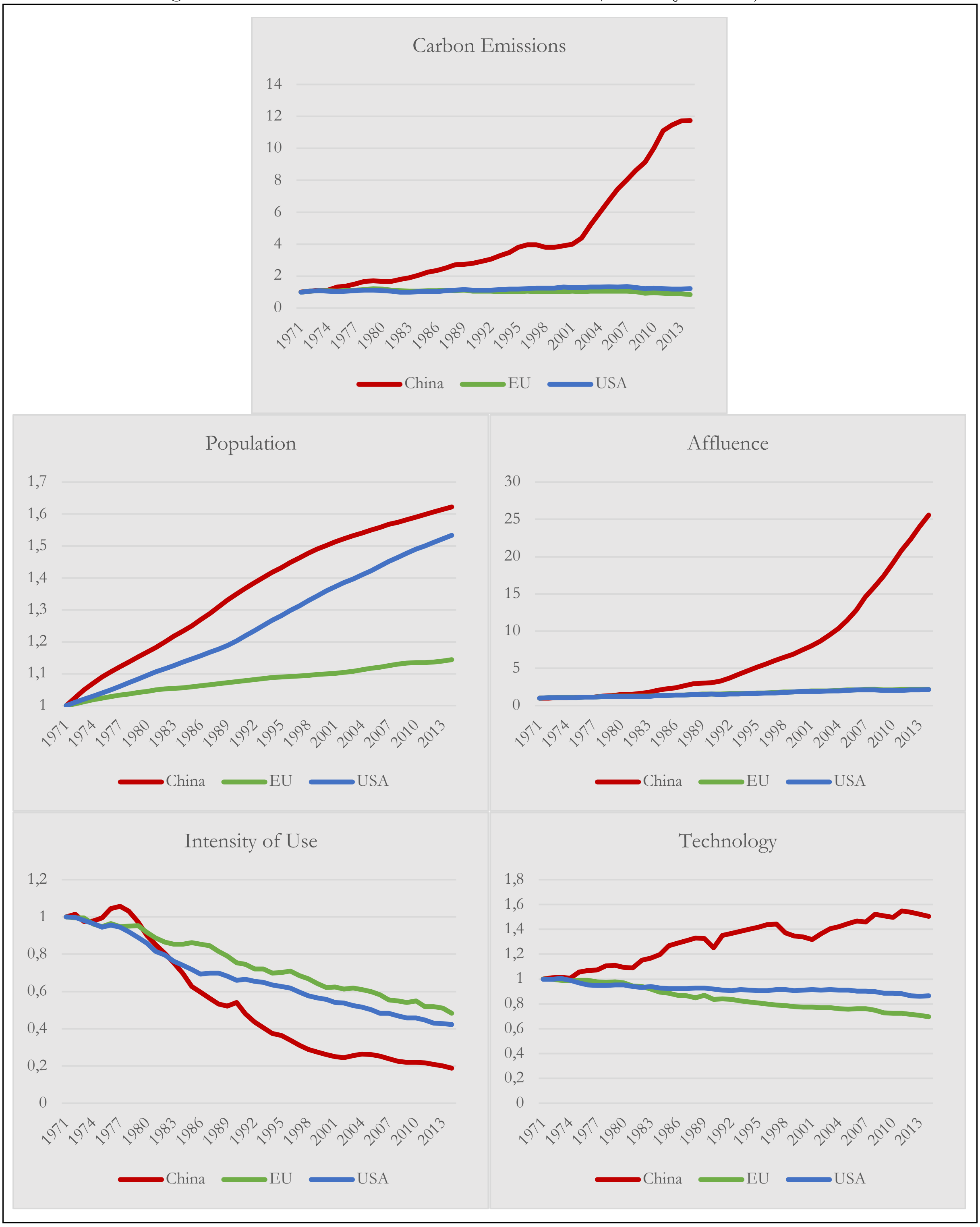
ImPACT identity analysis can be made in different ways. In our case, taking into account the characteristics of the study, the analysis is going to be divided into 3 parts. The first part is an individual analysis of the evolution of the variables. The second part will hold an analysis of countries evolution decade by decade and main drivers per each decade/country are going to be observed. Last, but not least, two economic crises are going to be analyzed through the model and its impact is going to be studied through the data on the ImPACT identity. For that, available data used is data from the World Bank dated between 1971 and 2014.

5.2.1 CO_2 emission and the drivers' evolution

The evolutions of the variables that are going to be analyze in this section are represented in the Figure 10.

Carbon Emissions. There have been two main trends related to carbon emissions: on the one hand, China and USA has increased its emissions through the period. In China, the increase in emissions has been massive, as they increased 1074% in 2014 with respect to the levels of 1971. The trend has been positive through all the period but after the 2000 the increase rate in carbon emissions has been higher. The United States suffered an increase of 20% toward the time period. However, it reached to its maximum level of emissions in 2007 and after that age it started decreasing. On the other hand, the EU decreased their carbon emissions. The European Union accounted in 2014 for just the 84% of the carbon emissions that were emitted in 1971. Carbon emissions reached to its maximum in 1979 (20% increase in comparison to 1971) and after that year, it started decreasing.

Figure 10 ImPACT variables evolution between 1971-2014 (Normalized in 1971)



Source: Self-made through data in the World Bank

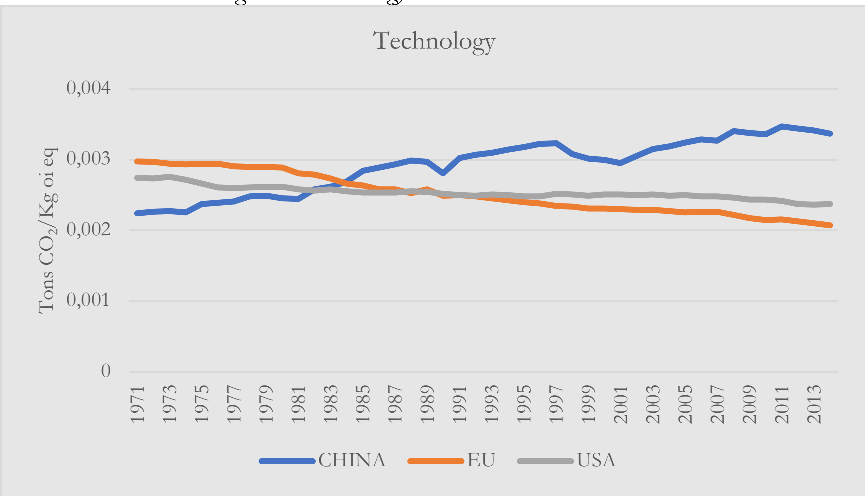
Population. It can be seen that population has increased in the three regions but in different speeds or rates. China has suffered the biggest increase as its population has increased a 62% with respect to data of 1971. The US has had also a big increase in its population as its population has increased a 53% during the period. However, the European Union increase has been weaker as its population has increased only in a 14%.

Affluence. Regarding the affluence (or the GDP per capita), all the regions studied suffered an increase in their GDP per capita. However, this increase was not the same in all three regions. China has suffered an exponential increase in its GDP per capita during the period observed as it has increased to the level of being 25 times higher in 2014 (comparing to the level of 1971). US and EU also increased its GDP per capita but the increase has been humbler as GDP per capita has increased 115% in the case of the United States and 119% in the case of the European Union.

Intensity of Use. In deep analysis hold in *Section 5.1.3*

Technology. In regards of technology (or carbon emissions/energy use), a definition of the term is needed before the trend observation. In the ImPACT identity we refer as Technology to the carbonization/decarbonization process that could suffer any country/region. The increase in T is considered as something negative, as the region would be suffering a carbonization process, as carbon emissions per union of energy used would be higher. A decrease in T is considered as a synonym of the decarbonization effect, as it means that carbon emissions per unit of energy used would decrease through the period observed. In the case studied, two trends can be observed. On the one hand, we have China that increased its ratio of carbon emissions in terms of energy used. Even though the evolution has not been constant among the period (with positive periods and other recovery periods) at 2014 its level was 50% higher than in 1971. This means than for producing one more unit of energy, China has become 50% more polluter. On the other hand, the EU and USA have improved their ratio of gas emissions per unit energy used. In 2014, the EU was emitting 44% less carbon for one unit of energy produced and the US 16% less. Despite the analysis of the Energy Mix has not been made, in the Electricity Generation Mix (*Section 5.1.1.*) it can be observed the carbonization of process of China due to the use of coal, and the decarbonization process of EU and USA due to the use of cleaner (or at least less polluter) energy sources. The different processes related to technology can be observed in the figure 11, that shows the evolution of technology in absolute terms between 1971 and 2014, or in other words, the carbonization/decarbonization process faced by the countries/regions.

Figure 11 Technology evolution in Absolute terms



Source: Self-made through data in the World Bank

It can be observed that during the first years analyzed, China can be considered the most decarbonized country among the three studied, as it shows the lower ratio of carbon emission by energy used. USA and EU are shown as more carbonized countries, being the later the most carbonized region among the three. However, during the time period the data is analyzed, a change in the trends can be observed. In the last year observed, the region that showed to be the most carbonized has managed to be the most decarbonized one (the EU) while China moved to be the most carbonized country. United States, as said before, suffered a decrease in T (decarbonization effect) during the period observed, but not as intense as the EU.

5.2.2 Evolution by decades

In this section, and with the help of the Table 7, an analysis of the emissions and the main drivers of the trend emissions had will be analyzed into separate decades and with comparisons between the regions concerned. Five different decades are analyzed with the data available in the World Bank database (Even though the last decade analyzed is incomplete).

Table 7 Evolution by decades of the emissions represented in the ImPACT identity

	CHINA				
	1971-1980	1981-1990	1991-2000	2001-2010	2011-2014
Im	1,67	1,68	1,33	2,52	1,06
P	1,17	1,14	1,10	1,05	1,01
A	1,46	2,02	2,25	2,39	1,23
C	0,90	0,63	0,54	0,88	0,87
T	1,09	1,15	0,99	1,14	0,97

	EUROPEAN UNION				
	1971-1980	1981-1990	1991-2000	2001-2010	2011-2014
Im	1,17	0,96	0,95	0,93	0,91
P	1,04	1,03	1,02	1,03	1,01
A	1,26	1,24	1,21	1,09	1,01
C	0,92	0,85	0,84	0,88	0,93
T	0,97	0,89	0,92	0,93	0,96

	UNITED STATES				
	1971-1980	1981-1990	1991-2000	2001-2010	2011-2014
Im	1,08	1,06	1,18	0,96	0,99
P	1,09	1,09	1,12	1,09	1,02
A	1,21	1,24	1,26	1,08	1,04
C	0,86	0,81	0,84	0,84	0,95
T	0,95	0,97	1,00	0,97	0,98

Source: Self-made through data in the World Bank

1971-1980. During the period, the variation of carbon emissions was positive in all three regions. This increase can be explained by the increase in affluence and the increase in the population for the three regions. Technology in the Chinese case help to the increase in the emissions but in the case of the EU and USA a decrease on technology variation can be observed. The decrease in the intensity of use in all the cases help to decrease the impact of carbon emissions during the decade.

1981-1990. Variation of the emission coefficient was positive in the case of China and the US, but the European Union managed to decrease its emissions for the first time in the period observed. Even though it had an increase of 24% in the GDP per capita, population did not increase much, and the intensity of use and technology dropped to the 85% and 89% (respectively) of the initial levels (1981). In the case of the US, a 6% increase in the emissions can be observed. If we compare to the EU, Americans were not able to diminish Technology driver as much as the Europeans and this made them increase the share of emissions. However, China continued with its high emission variations, as it suffered a 68% increase through the period. The main driver of the increase was the affluence. Moreover, except for the intensity of use (that declined to the 63% of the 1981 levels) all other drivers contributed to the emission rise.

1991-2000. Variation of emissions continued to the same trend as in the previous decade but with some changes. In the case of China and the US the ascendant trend continued but it became stronger in the US and weaker in China. In the case of US, they moved from a 6% increase in emissions in the previous decade to a 18% increase in emissions in the actual one. This increase is explained by the worsen of all the drivers observed. In the Chinese case, they moved from a 68% increased to a 33% increase in emissions. This decline is understood under the assumption of a decrease in the intensity of use and technology and a slighter increase in the population than in the previous period. In the case of the European Union, the emissions continued to decline during the decade, and this decline was bigger than the decline of the previous decade (a decrease of 4 % in the decade 1981-90 vs a decrease of 5% in the decade 1991-00). As in the previous decade, the main drivers of the decrease were the decrease in the intensity of use and technology, even there was an increase of 21% of the GDP per capita.

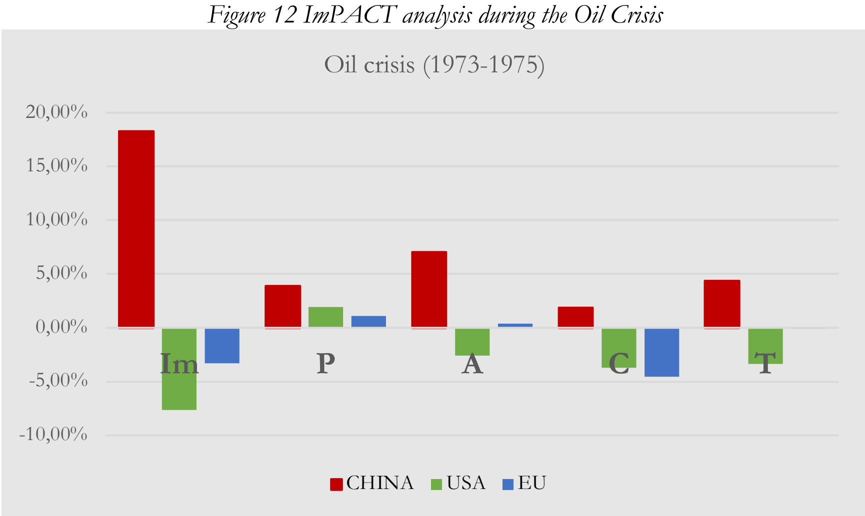
2001-2010. During the first decade of the millennium, the US left the tendency of emission increases and joined the EU in the group of countries that reduced its variation of carbon emissions. The decline of the US emissions occurred because affluence increase was not as strong as in other decades (only an 8% increase) and because intensity of use and technology variation were negative through the period. The EU reduced even more than in the previous decade its emissions through the period (8% less emissions than in the previous decade). In the European Union case, the GDP did not grow as much as in other decades, but intensity of use and technology continued decreasing in similar percentages. However, during the last years of the decade the financial crisis that took place may have helped countries to reduce its emissions, due to a deceleration of the economy in developed countries. This crisis had no impact on China or in its emissions, as they recorded their record increase in emissions during the period, through an increase of 152% of their carbon emissions. The main driver of the increase was the affluence, as an increase of 139% of GDP per capita can be observed.

2011-2014. During the 3 years observed, a change in the Chinese emissions can be observed as they increased just for a 6% during the period. The main driver continues to be the affluence but decreases in intensity of use and technology helped to emission increase rate to be low. With respect to the US, it has decreased its emissions only by a 1% during the period. The decrease is mainly due to the intensity of use decrease, as other drivers have had a stable period. Last but not least, in the EU there has been a great reduction in the carbon emissions in 2014 with respect to the levels of 2011 (a 10% decrease). This decrease was mainly due to the decrease in the intensity of use and improvement of technology.

5.2.3 Evolution of emissions in crisis periods

During the previous section, it was mentioned that during the 2008 the great recession exploded. However, this was not the only economic crisis the world suffered during the years observed. In 1973, the oil crisis had its impact around the globe. In this section an analysis will hold based on the year of the start of the crisis and the following two years. The years analyzed through the ImPACT identity can be seen in Figure 11 and Figure 12.

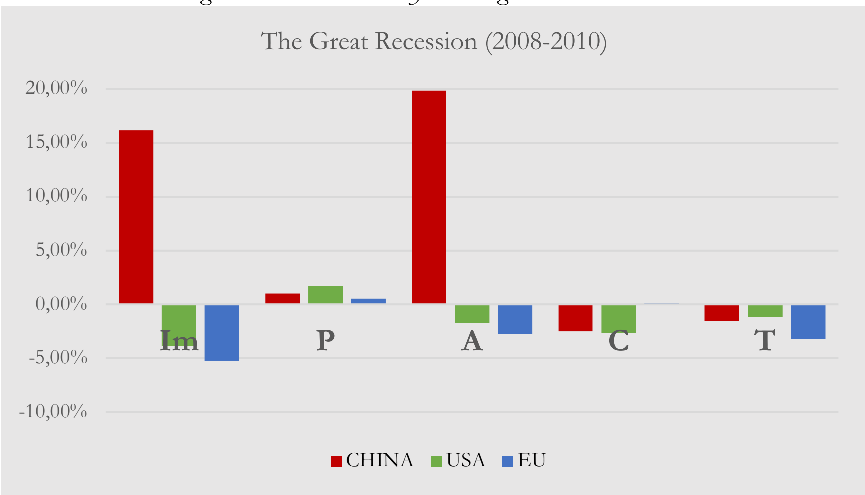
Figure 12 ImPACT analysis during the Oil Crisis



Source: Self-made through data in the World Bank

The oil crisis has its major economic impact in the US, as the Affluence or GDP per capita decreased more in the United States that in any other option studied. The Affluence in the US decreased by a 2.61% during the period. However, this helped to the USA to be the leader in emission reduction through the period, as carbon emissions decreased more than 7%. Take note that there was no other pace of time studied in the previous section in which United States obtained a greater descend in carbon emissions than the EU in relative terms. During the oil crises and following two years, EU did not suffer a recession, but a major in deep analysis is lack of (country by country analysis would be needed for a good analysis due to the disparity of situations that each country was facing during that period and also because actual UE has nothing to do with the begging years of it). Even though this, in general it can be stated that UE reduced the emissions during the period due to the stability in affluence and Technology, the small increase in population and the efficiency increase in the intensity of energy use. In the case of China, it feels like the oil crisis had nothing to do with them as their GDP continued increasing through the period, and carbon emissions increased by a higher multiplier than only the affluence, as the increase in other drivers helped to increase the emissions a 18% during the two-year period.

Figure 13 ImPACT analysis during the Great Recession



Source: Self-made through data in the World Bank

In the case of the Great Recession, the region that was most punished was the EU. In this case, 2 years later the start of the great recession the GDP per capita was 2.75% lower in the EU, with respect to 1.73% lower in USA and a 19.85% astonishing increase of China. After the 2010, the USA started recovering from the recession, but the EU needed until 2012 to recover the levels of 2008 in terms of GDP per capita. As in the case of the oil crises, the country that was more hit by the economic effects achieved the greater decrease in carbon emissions. During this crisis, the EU reduced its emissions by 5.25%, in comparison to the Chinese increase (16.19%) and the US weaker decrease (-3.89%). The main driver of the reduction of emissions in the EU (along with the decline of affluence) was the improvement of technology (decrease of 3.21%). In the case of the US, the decline in the carbon emissions was more related to the gain on efficiency obtained than the reduction in affluence. Lastly, China was able to keep the level of carbon emissions growth below the level of GDP per capita growth, because the population did not grow much and decreases in energy intensity and technology helped.

6- CONCLUSION

We are aware that there are innumerous opportunities of study regarding energy, carbon emissions and all the subjects that could be related among them. However, the study followed the analysis of China, the European Union and the United States of America regarding the Sustainable Developments related to energy and also, the extended IPAT identity analysis between 1971-2014. Results discussion is going to take place in this section. After it, the analysis limitations and further study lines are going to be proposed.

On the one hand and with respect to the Sustainable Development Goals related to energy (SDG-7), it can be said that they do not really take into account the reality of each country. More specific goals divided by level of development for example, would be better if we want all the countries to make efforts. Additionally, they are not binding to national legislations, so countries could decide not to obey them, as no sanctions can be taken. The excuse that a supranational organism cannot write binding legislations cannot longer hold, as the EU has its own environmental legislation, which is legally binding in the union countries.

While analyzing SDG-7.1, it was observed that the whole population of the studied countries has achieved to have access to electricity. However, this objective was achieved by the developed economies the first year observed, in 2017, so targeting to obtain it has no much sense.

Moreover, the second part of the universalization of electricity contemplated that the energy needed to be as cleaner as possible. Regarding this aspect, we realized that in relative terms all the regions are advancing to cleaner sources of electricity. However, due to the increase in the intensity of electricity, the use of fossil fuels has increased in the three cases. Despite UE, China and USA finished 2014 with coal as main source of electricity generation (in Europe it was second source after the nuclear energy). All three cases are far from reaching the optimal scenario of energy generation described by Augutis et al. (2015), where generation distribution was distributed in the following way: 50% from renewable sources, 30% nuclear sources, and 20% natural gas. The EU is the country or region which is closer to achieve the optimal scenario of energy security. It has to take into account that EU countries have few sources of fossil fuels and after the oil crises, they started to move to nuclear energy for electricity generation (to decrease foreign dependency).

With regard to SDG7.2 (where the objective is to increase the share of renewable energy consumed), under the assumptions of 95% of confidence, only USA is estimated to fulfill the requirements. However, we were not able to discard that neither China nor the EU were going to fulfill the requirements, as according to the forecasted trends, both are going to complete the goal. BP (2019) supports the idea that the three regions are going to increase their renewable energy contribution in the energy mix for the 2040.

To finish with the Sustainable Development Goals and regarding the SDG7.3 (in which the goal is to double the energy efficiency) there is no evidence that each country will, at least, double its energy efficiency. However, it is not the same the actual level of energy efficiency of the EU or the energy intensity of China. The United Nation cannot require the same to one of the most efficient regions or to the most inefficient regions. The increase in efficiency in the EU it is possible but doubling the efficiency is asking for too much. Developed countries, with regard to this objective, should give aids and transfer knowledge and resources to the economies that are highly intensive in energy.

On the other hand, regarding the extended IPAT analysis (ImPACT) and after analyzing the results obtained, a difference in trends is notorious between the developed economies (EU and USA) and developing countries (China; nowadays considered by some as developed). Through the period, China has increased its wealth without taking into account any effects on the environment as the emissions have multiplied by more than 10 during the period. However, the increase in wealth in developed countries have taken into account the economic impact up to a degree as there has been a controlled increase in emissions in the case of US, and a decrease in the EU.

Additionally, the study of the main drivers of emissions hold per decade. In the EU case, the main drivers of the decreases in the emissions have been the improvements in the energy efficiency and technology (note that, a negative technology means that less CO_2 was emitted for the same energy amount used). In the case of the USA, the main driver while emissions were increasing was the affluence. During the last decade, in which emissions decay, the main driver of it was the gain in energy efficiency. Lastly, in the Chinese case, the main driver of the emission increases has been the increase in affluence, and this has been swabbed by the energy efficiency improvements.

As a final remark, an ImPACT analysis under a financial crisis hold in the results section. According to the results we have obtained, we have seen that the country that was most affected in wealth has been the one that decreased most the carbon emissions. During the oil crisis, it was the US economy that suffered the most, but its region also suffered a positive impact regarding the reduction of emissions. The same happened with the EU while the Great Recession, its economy suffered the most but the decrease in emissions was the highest among them.

Despite a complete analysis has been made, different questions arise regarding the reality. Is the EU decarbonization due to its green policies or due to the outsource that has suffered the European economy (in which industry weight has decreased because of the deindustrialization and services are now the main sector). Our ImPACT analysis did not take into account the energy consumption in the origin of the products consumed in the EU (or in China and USA) but the energy used in their regions production. The image could be really different if the origin of the goods consumed and pollution data were added to our data.

While the study was underway, much of the world had to shut down its economies and industries due to the covid-19 pandemic. Much of the SDGs are going to be achieved because of the lockdown and not because specific policies to achieve the goals.

Moreover, alternatives to work from home arose during the quarantine period and even though an economic downturn is going to hold, the environmental consequences due to the pandemic need to be analyzed in the near future. Under our ImPACT model, if ceteris paribus, the worsen of Affluence will bring a decrease in the emissions. An analysis regarding C and T needs to be done for the analysis of the hypothesis that states that working from home and increasing house electricity use will emit less carbon emissions than working from the office. A complex but meaningful analysis could be obtained.

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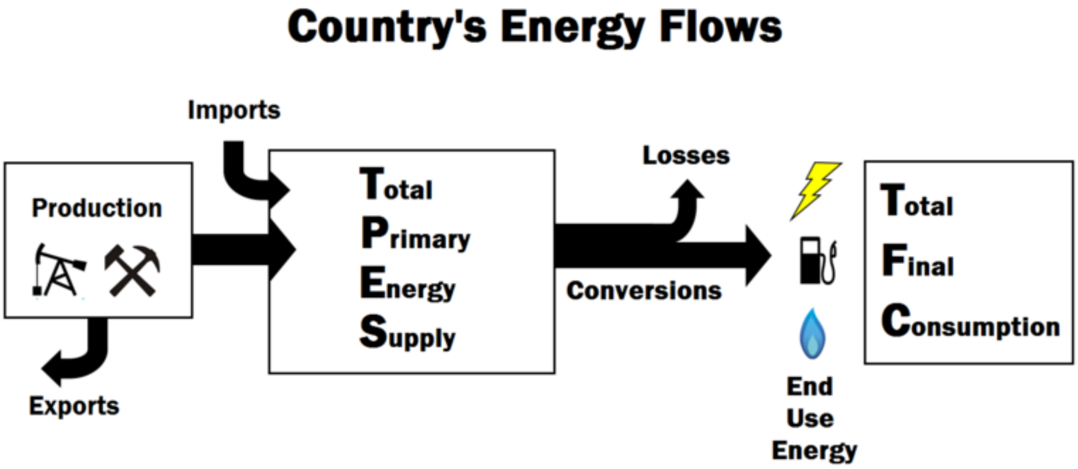
ANNEXES

Annex 1 Sustainable Development Goals (SDGs)

Source: UNDP (2020)

Annex 2 Diagram of Total Primary Energy Supply and Total Final Consumption



Source: Donev et al. (2020)

Annex 3 SPSS output regarding forecast of Renewable Energy Consumption

Descripción del modelo

			Tipo de modelo
ID de modelo	China	Modelo_1	Brown

Resumen del modelo

Ajuste del modelo

Estadístico de ajuste	Media	SE	Mínimo	Máximo	Percentil 5	10	25	50	75	90	95
R cuadrado estacionaria	,175	.	,175	,175	,175	,175	,175	,175	,175	,175	,175
R cuadrado	,987	.	,987	,987	,987	,987	,987	,987	,987	,987	,987
RMSE	,984	.	,984	,984	,984	,984	,984	,984	,984	,984	,984
MAPE	3,623	.	3,623	3,623	3,623	3,623	3,623	3,623	3,623	3,623	3,623
MaxAPE	11,364	.	11,364	11,364	11,364	11,364	11,364	11,364	11,364	11,364	11,364
MAE	,770	.	,770	,770	,770	,770	,770	,770	,770	,770	,770
MaxAE	2,355	.	2,355	2,355	2,355	2,355	2,355	2,355	2,355	2,355	2,355
BIC normalizado	,094	.	,094	,094	,094	,094	,094	,094	,094	,094	,094

Estadísticos del modelo

Modelo	Número de predictores	Estadísticos de ajuste del modelo: R cuadrado estacionaria	Ljung-Box Q(18): Estadísticos	DF	Sig.	Número de valores atípicos
China-Modelo_1	0	,175	10,751	17	,869	0

			Tipo de modelo
ID de modelo	EU	Modelo_1	Brown

Resumen del modelo

Ajuste del modelo

Estadístico de ajuste	Media	SE	Mínimo	Máximo	Percentil 5	10	25	50	75	90	95
R cuadrado estacionaria	,259	.	,259	,259	,259	,259	,259	,259	,259	,259	,259
R cuadrado	,993	.	,993	,993	,993	,993	,993	,993	,993	,993	,993
RMSE	,276	.	,276	,276	,276	,276	,276	,276	,276	,276	,276
MAPE	2,287	.	2,287	2,287	2,287	2,287	2,287	2,287	2,287	2,287	2,287
MaxAPE	4,839	.	4,839	4,839	4,839	4,839	4,839	4,839	4,839	4,839	4,839
MAE	,219	.	,219	,219	,219	,219	,219	,219	,219	,219	,219
MaxAE	,543	.	,543	,543	,543	,543	,543	,543	,543	,543	,543
BIC normalizado	-2,452	.	-2,452	-2,452	-2,452	-2,452	-2,452	-2,452	-2,452	-2,452	-2,452

Estadísticos del modelo

Modelo	Número de predictores	Estadísticos de ajuste del modelo: R cuadrado estacionaria	Ljung-Box Q(18): Estadísticos	DF	Sig.	Número de valores atípicos
EU-Modelo_1	0	,259	10,946	17	,859	0

Descripción del modelo

			Tipo de modelo
ID de modelo	USA	Modelo_1	ARIMA(2,1,0)

Resumen del modelo

Ajuste del modelo

Estadístico de ajuste	Media	SE	Mínimo	Máximo	Percentil 5	10	25	50	75	90	95
R cuadrado estacionaria	,380	.	,380	,380	,380	,380	,380	,380	,380	,380	,380
R cuadrado	,952	.	,952	,952	,952	,952	,952	,952	,952	,952	,952
RMSE	,357	.	,357	,357	,357	,357	,357	,357	,357	,357	,357
MAPE	4,925	.	4,925	4,925	4,925	4,925	4,925	4,925	4,925	4,925	4,925
MaxAPE	13,971	.	13,971	13,971	13,971	13,971	13,971	13,971	13,971	13,971	13,971
MAE	,282	.	,282	,282	,282	,282	,282	,282	,282	,282	,282
MaxAE	,798	.	,798	,798	,798	,798	,798	,798	,798	,798	,798
BIC normalizado	-1,805	.	-1,805	-1,805	-1,805	-1,805	-1,805	-1,805	-1,805	-1,805	-1,805

Estadísticos del modelo

Modelo	Número de predictores	Estadísticos de ajuste del modelo: R cuadrado estacionaria	Ljung-Box Q(18): Estadísticos	DF	Sig.	Número de valores atípicos
USA-Modelo_1	0	,380	7,038	17	,983	0

Source: Self-made through data from Databank

Annex 4 SPSS output regarding forecast of Energy Intensity

Descripción del modelo

			Tipo de modelo
ID de modelo	China	Modelo_1	Brown

Resumen del modelo

Ajuste del modelo

Estadístico de ajuste	Media	SE	Mínimo	Máximo	Percentil 5	10	25	50	75	90	95
R cuadrado estacionaria	,019	.	,019	,019	,019	,019	,019	,019	,019	,019	,019
R cuadrado	,995	.	,995	,995	,995	,995	,995	,995	,995	,995	,995
RMSE	,042	.	,042	,042	,042	,042	,042	,042	,042	,042	,042
MAPE	2,760	.	2,760	2,760	2,760	2,760	2,760	2,760	2,760	2,760	2,760
MaxAPE	14,923	.	14,923	14,923	14,923	14,923	14,923	14,923	14,923	14,923	14,923
MAE	,029	.	,029	,029	,029	,029	,029	,029	,029	,029	,029
MaxAE	,140	.	,140	,140	,140	,140	,140	,140	,140	,140	,140
BIC normalizado	-6,240	.	-6,240	-6,240	-6,240	-6,240	-6,240	-6,240	-6,240	-6,240	-6,240

Estadísticos del modelo

Modelo	Número de predictores	Estadísticos de ajuste del modelo: R cuadrado estacionaria	Ljung-Box Q(18): Estadísticos	DF	Sig.	Número de valores atípicos
China-Modelo_1	0	,019	19,415	17	,305	0

Descripción del modelo

			Tipo de modelo
ID de modelo	UE	Modelo_1	ARIMA(0,1,4)

Resumen del modelo

Ajuste del modelo

Estadístico de ajuste	Media	SE	Mínimo	Máximo	Percentil 5	10	25	50	75	90	95
R cuadrado estacionaria	,150	.	,150	,150	,150	,150	,150	,150	,150	,150	,150
R cuadrado	,993	.	,993	,993	,993	,993	,993	,993	,993	,993	,993
RMSE	,002	.	,002	,002	,002	,002	,002	,002	,002	,002	,002
MAPE	1,492	.	1,492	1,492	1,492	1,492	1,492	1,492	1,492	1,492	1,492
MaxAPE	4,271	.	4,271	4,271	4,271	4,271	4,271	4,271	4,271	4,271	4,271
MAE	,002	.	,002	,002	,002	,002	,002	,002	,002	,002	,002
MaxAE	,006	.	,006	,006	,006	,006	,006	,006	,006	,006	,006
BIC normalizado	-11,898	.	-11,898	-11,898	-11,898	-11,898	-11,898	-11,898	-11,898	-11,898	-11,898

Estadísticos del modelo

Modelo	Número de predictores	Estadísticos de ajuste del modelo: R cuadrado estacionaria	Ljung-Box Q(18): Estadísticos	DF	Sig.	Número de valores atípicos
UE-Modelo_1	0	,150	16,935	17	,459	0

Descripción del modelo

			Tipo de modelo
ID de modelo	USA	Modelo_1	ARIMA(0,1,0)

Resumen del modelo

Ajuste del modelo

Estadístico de ajuste	Media	SE	Mínimo	Máximo	Percentil 5	10	25	50	75	90	95
R cuadrado estacionaria	2,220E-16	.	2,220E-16	2,220E-16	2,220E-16	2,220E-16	2,220E-16	2,220E-16	2,220E-16	2,220E-16	2,220E-16
R cuadrado	,996	.	,996	,996	,996	,996	,996	,996	,996	,996	,996
RMSE	,004	.	,004	,004	,004	,004	,004	,004	,004	,004	,004
MAPE	1,264	.	1,264	1,264	1,264	1,264	1,264	1,264	1,264	1,264	1,264
MaxAPE	3,803	.	3,803	3,803	3,803	3,803	3,803	3,803	3,803	3,803	3,803
MAE	,003	.	,003	,003	,003	,003	,003	,003	,003	,003	,003
MaxAE	,010	.	,010	,010	,010	,010	,010	,010	,010	,010	,010
BIC normalizado	-11,172	.	-11,172	-11,172	-11,172	-11,172	-11,172	-11,172	-11,172	-11,172	-11,172

Estadísticos del modelo

Modelo	Número de predictores	Estadísticos de ajuste del modelo: R cuadrado estacionaria	Ljung-Box Q(18): Estadísticos	DF	Sig.	Número de valores atípicos
USA-Modelo_1	0	2,220E-16	18,144	18	,446	0

Source: Self-made through data from Databank