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CAUSALITY AND CO-INTEGRATION ANALYSIS OF ENERGY CONSUMPTION, ECONOMIC GROWTH AND CO2 EMISSION IN MADAGASCAR

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DECLARATION

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ABSTRACT

This Master thesis deals with the causality and cointegration relationship between energy consumption, economic growth, CO_2 emissions, energy intensity and index of dirty in the industry, transport and residential sector of Madagascar. Energy consumption is a lever for development and no economy in the world can function without energy. The increase in economic growth must be accompanied by an increase in energy consumption. However, this increase in energy consumption could harm the environment because CO_2 emissions could increase. According to an analysis of the inverse Kuznets environmental U-curve, it is found that as Madagascar's GDP per capita increases, CO_2 emissions per capita will decrease when they reach the optimal point. Therefore, it is good for the Malagasy economy to increase this energy consumption because the level of production that will be done by the weak sectors is still very low.

Compared to the volume of CO_2 emissions that Madagascar should emit by 2030 as envisaged by the COP21, it should be possible to achieve this. Of course, this emission is higher according to KAYA's forecast, so it should decrease as the GDP per capita will increase (seteris paribis). At the moment, the cost of energy from renewable sources is still very high compared to non-renewable energy even though the world is currently in the process of energy transformation. In addition, the subsidy to be provided by the state for the green energy production technology is still very low. For this reason, it is necessary to increase the Malagasy purchasing power to be able to use the green energy in order to stimulate the green growth.

Key words: Causality, Cointegration, Kaya Identity, Environment Curve Kuznets, Panel data, Madagascar

RÉSUMÉ

Ce mémoire de Master traite la relation de causalité et cointégration entre la consommation énergetique, la croissance économique, les émissions de CO 2, l'intensité de l'énergie et l'indice de pollution dans les secteurs industriels, le transport et le résidentiel, respectivement, pour le cas d'étrude de Madagascar. La consommation énergetique constitue un levier de développement et aucune économie dans le monde ne peut fonctionner sans énergie. L'augmentation de la croissance économique doit parrallement être accompagnée d'une augmentation de la consommation d'énergie. Cependant, cette augmentation de la consommation d'énergie pourrait endomager l'environnement carles émissions de CO 2 pourraient augmenter. Selon une analyse de la courbe environnementale U inverse de Kuznets, il est constaté que lorsque le PIB par habitant de Madagascar augmente, les émissions de CO 2 par habitant diminueront lorsqu'elles atteindront un point optimal. Par concequent, il est bon pour l'économie Malgache d'accroitre cette consommation d'énergie tenant compte du fait que le niveau actuel de production pour les secteurs peu développés est encore très faible.

Par rapport au volume des émissions de CO 2 que Madagascar devrait atteindre à l'horizon 2030 tel Qu'envisagé par la COP21 de Paris, il devrait être possible d'y parvenir. Bien sur que cette émission est plus élevée selon la prévision de l'identité de Kaya, alors qu'elle devrait diminuer lorsque le PIB par habitant va augmenter (seteris paribis). Donc, le pouvoir d'achat de la population augmentera et consommera de l'énergie verte. Actuellement, le coût de l'énergie issue des énergies renouvelables est encore très élevé par rapport aux énergies non renouvelables même si le monde est actuellement dans la phasqe de transition énergétique ; ajouter au fait que la subvention à fournir par l'Etat pour la technologie de production d'énergie verte est encore très faible. Pa conséquent, il faudra augmenter le pouvoir d'achat Malagasy pour pouvoir utiliser l'energie verte et stimuler ainsi la croissance verte.

Mots clés: Causalite, Cointegration, Identité de Kaya, Courbe Environnementale de Kuznets, Données de Panel, Madagascar.

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LIST OF ABBREVIATIONS

CEK	Curve Environmental of Kuznets
CO2	Carbon dioxyde
COP	Conference of the Parties
EC	Enrgy consumption
EI	Energy intensity
GDP	Gross Domestic Product
GHG	greenhouse gas
ID	Index of Dirty
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPCC	Intergovernmental Panel on Climate Change
LED	Light-Emitting Diode
NDEC	Nationally Determined Expected Contribution
OLS	Ordinary Least Squares
OPEC	Organization of Petroleum Exporting Countries
REDD+	Reducing Emissions from Deforestation and Forest Degradation
UK	United Kingdom
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
VA	Value Added
VECM	Vector error Correction Model

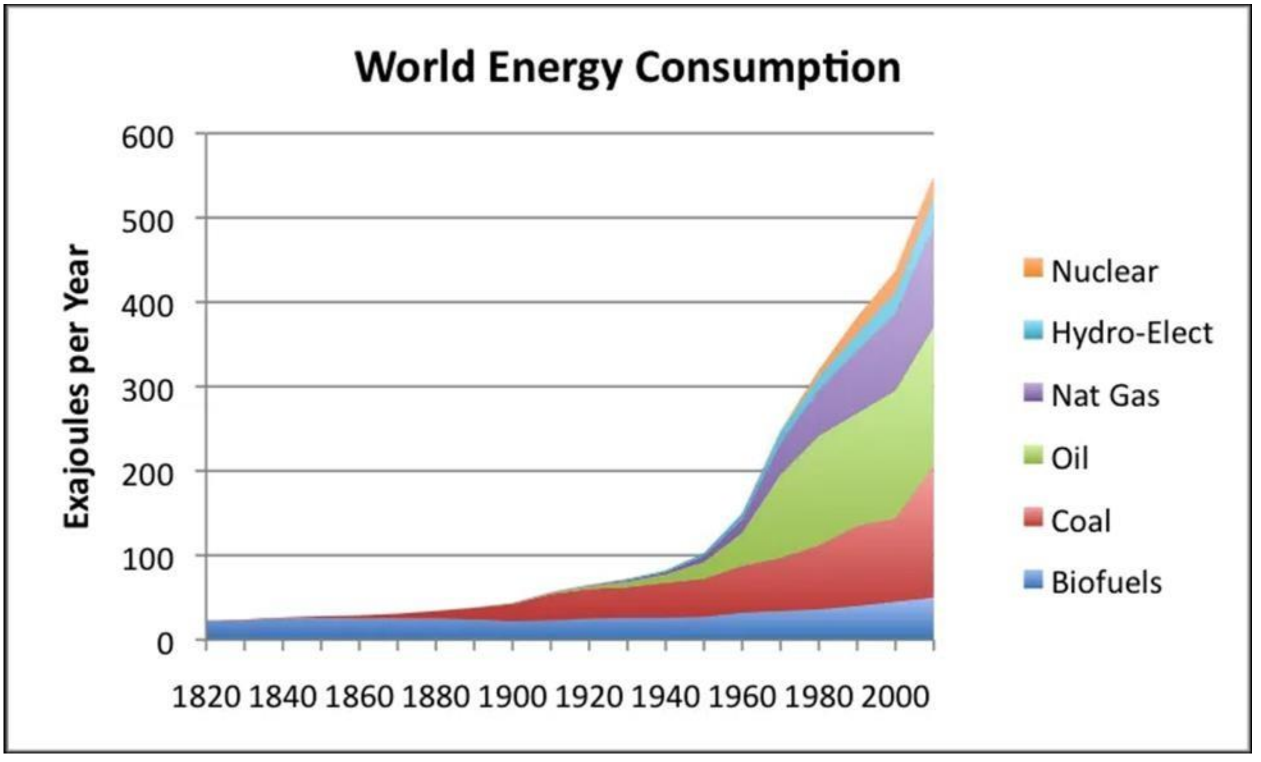
CHAPTER ONE

INTRODUCTION

1.1. Background of the research

According to the Intergovernmental Panel on Climate Change's (IPCC) fifth report on climate change and its future development in 2014, the earth's surface temperature will increase by 1.5°C at the end of the 21st century compared to the period 1850-1990(Djalante, 2019). The synthesis of that report, published on November 2nd, 2014, provided an integrated view of climate change. Thus, the increase in global average temperature from 1.4° to 5.8°C is due to the rising of greenhouse gas (GHG) concentration. According to the third IPCC report, this increase of greenhouse gas concentration in the atmosphere is the cause of the aggravation of the global greenhouse effect, which itself has caused the warming of the average temperature. The following IPCC report talks about the responsibility of human activity in the sense that the problem of global warming has become a real threat that affects the socio-economic development by causing more hydrological cycles such as drought, floods and even health effects, etc. Indeed, the main sources of these emissions are the combustion of fossil fuels, deforestation, biomass combustion, agricultural fertilizers and waste. According to the French Ministry of Ecology, Sustainable Development and Energy, energy is the most important source of emissions, contributing to more than 60% of GHG emissions worldwide. The main GHGs are water vapor, carbon dioxide (CO2), nitrogen, methane, hydrofluorocarbons (HFCs), etc.CO2 comes from the combustion of fossil fuels as well as biomass are the only responsible for 60% of GHG. For these reasons, the fight against climate change has become a global challenge that requires a collective effort from the international community to reduce GHG emissions. Thus, reducing these emissions requires the substitution of fossil energies by renewable energies which are still expensive to use for those countries which want to reach a high economic growth. The constraints are diverse as: the assurance of a sustained and stable growth in order to reduce unemployment to have a good quality of life. Moreover, it is a matter for each country to ensure a sustainable development which takes into consideration climate change especially GHG emissions. In this case, faced with global threats to the environment, the international community has acted to sign multiple conventions and organize conferences to fight against climate change and its impacts on the environment. From the United Nations Framework Convention on Climate Change (UNFCCC) in Rio in 1992, which invited developed countries totake measures to reduce emissions until the Kyoto Protocol where governments agreed on the use of economic instruments to implement their actions, and they are driven environmental policies(United Nations, 2019). One of the impacts of the UNFCCC is that nations which ratified the convention meet every year in a host city for the Conference of the Parties (COP) to find ways to reduce GHG emissions. In 1995, the first COP was held in Berlin where the participating states strengthened the commitments of developed countries and policies to mitigate emissions for all parties. In 1997 in Kyoto, COP 3 was held and resulted in the adoption of the Kyoto Protocol(Romeo-Stuppy et al., 2021). This is an international regulatory agreement which sets quantitative GHG reduction targets for industrialized countries. This protocol set a precise and collective target for the 35 industrialized countries to reduce their emissions by 5.2% between 2008 and 2012, compared to the level of emissions in 1990.In 2009, the 15th edition of the COP, the participants followed the writing of Kyoto and they discussed about the problem of fixed threshold of emission allowances for developing countries as well as financing. In 2015, the COP 21 was held in Paris, where the threshold of emission allowances for all countries was announced and that of Madagascar should be reduced to 220 million metric tons by 2030. In other words, according to the Nationally Determined Expected Contribution (NDEC) of the Republic of Madagascar, Madagascar's CO2 emissions are expected to reach 414 million metric tons by 2030, based on the year 2000 but with the absorption of an estimated 192 million tons then Madagascar's CO2 could reach 220 million tons by 2030. In terms of financing, Madagascar is already part of the REDD+ project (Reducing Emissions from Deforestation and Forest Degradation) which costs 50 million dollars to save 10 million tons of carbon. As can be seen, Madagascar is involved in this project because according to Global Forest Watch in 2017, Madagascar ranked 4th in terms of deforestation with 510,000 hectares destroyed in one year, which is 3.8% of Malagasy forests(Brimont et al., 2015). However, if we consider the main driver of Madagascar's CO2 emissions accumulation then the transport sector takes the first place with its part of 50.4% in the emissions, followed by the industrial sector with 24.8%. According to these data published by the World Bank in 2016, Madagascar should implement several reduction projects in these areas above to reach the target by 2030. Indeed, energy consumption is increasing in function of human needs in an acceleration way. This requires a frequent use of fossil fuels and this will affect the increase of the greenhouse effect which can damage the whole world. Of course, this problem is far from being considered as a purely energy problem, but it is rather an economic, environmental and social problem. The challenge is therefore how to ensure economic and technical progress with the current momentum while simultaneously taking into account three aspects: socio-economic, environmental and energy. Despite the heavy constraints of capital and labor, energy remains an indispensable element for the development of countries. Historically, there has been a significant relationship between economic growth and energy consumption, as economic growth has inevitably led to a concomitant growth in energy needs. However, the increase of Gross Domestic Product (GDP) and the increase of energy consumption are more or less proportional, depending on the development stage of a country. This situation explains the penetration of risk analysis to the study of energy problems.

Figure 1: World Energy Consumption by Source



Source: Gail Tverberg, World Energy Consumption Since 1820 in Charts, 2012

This figure 1. above shows that the increase in energy consumption in the world is positively correlated with the 30 glorious years. The latter corresponds to the prosperity of economic growth in developing countries today. The boom of this period is situated around the years 1945 to 1975 and as you can see on this picture, it was at this moment that the exponential increase of the energy consumption in the world started(Malanima, 2020).

1.2.Problem Statement

Many countries in Sub-Saharan Africa still use various energy sources that release high levels of CO_2, such as the use of coal, diesel, petroleum in economic activities as well as the use of charcoal. In the case of Madagascar, according to InStat, all sectors consume an estimated 1,116,540 m3 of fuel and 58% of this volume is consumed by the transport sector. However, Madagascar is among the countries with low levels of CO_2 emissions because according to the World Bank in 2016, this emission was around 0.157 tons per capita while the average was around 4.55 tons per capita in the world(Arias-Ortiz et al., 2021). Philipe Busquin affirms that "energy is a vital need for today's society" but when we look at Malagasy energy, it is still low; for example, the level of access to electricity has Madagascar is still around 15% which is quite low. The United Nations Development Programme (UNDP) announced in 2015 that "modern energy services are needed to stimulate human development", which means that Madagascar's energy consumption should be increased significantly in order to stimulate economic growth which leads towards human development.

If only the relationship between energy and growth is to be analyzed in this research, it would be good for Madagascar because just an energy increase is enough to stimulate economic growth, but it is highly impossible to ignore the impacts of the Environment. For the past 7 years, Madagascar has been facing water supply problems during the winter season, this is due to the lack of rain during the summer season so the supply of water underground and on the surface cannot satisfy the demands(Rakotoarisoa et al., 2016). Of course, when there is not enough water, it also results in a reduction in agricultural yield. In the last 7 years, the price of rice has risen sharply during the summer season due to insufficient rainfall, and the government has to constantly import rice and inject it into the market at a reasonable price in order to satisfy the population's needs. For all these reasons, this research aims to stimulate economic growth by increasing energy consumption under environmental constraints.

1.3.Research questions

- How can energy be used as a development leverage for Madagascar?
- What are the impacts of increased energy consumption on Madagascar's economic growth

in the short, medium and long term?

- How to stimulate green growth in Madagascar?
- Is the environmental Kuznets theory valid in Madagascar?
- How to determine a pragmatic energy policy in Madagascar to achieve energy efficiency?

1.4.Research hypothesis

- Energy is not part of the three functions of economic growth which are capital, labor and technology
- Only the transport, industry and residential sectors will be included in the analysis
- Energy consumption can directly influence economic growth
- All CO_2 emissions are due to the direct or indirect use of energy

1.5.Objectives

1.5.1. General Objective

The overall objective of this study is to provide a model of the relationship between energy consumption, economic growth and CO_2 emissions in Madagascar.

1.5.2. Specific objectives

- To identify the causal relationship between energy consumption, economic growth and the environment.
- As energy consumption in Madagascar is still low and does not respond to economic needs, that is why the GDP of Madagascar is still low. Therefore, part of the objective of this master's thesis is to identify potential energy sources and increase supply.
- Apply the Kuznets environmental curve theory to Madagascar.
- Propose adequate energy policies to achieve energy efficiency in Madagascar

1.6.Interest of the subject

Firstly, it is important to note that the research on the environmental problem is a very relevant subject since years, because the researches in this topic have objectives to show that if the world does not adopt sustainable solutions for the different economic activities, then the future generations will have problems in term of natural resources. According to the definition of sustainable development, it is important to analyze the environment and the economic activities of Madagascar so that the natural resources can satisfy the needs of the present and without damaging those of future generations. This analysis will be carried out through the study of the causal relationship between energy consumption and the economic situation as well as the emission of CO_2. From 1996 to 2009, three periods mark a contrasted evolution of the two quantities which are GDP and energy consumption: 1996-2001, 2003-2008 and 2009. It is observed during these three periods a parallel evolution of the GDP and the energy consumption. The period 1996-2001 is marked by a positive economic growth (started in 1995). This period coincided with the implementation of the export-driven growth strategy. A sharp increase in energy consumption was recorded from 1997 onwards (+12.7% compared to 1996), reflecting the government's desire to combine energy development with economic growth. This dynamic continued until 2001, but it was stopped in 2002 due to the post-election crisis in the country. The post-election crisis period 2003-2008 coincides with continued economic growth until the end of 2008(Waltisperger & Mesle, 2005). At the same time, there was an increase in energy consumption, which apparently accompanied economic growth. The internal socio-political crisis of 2009 resulted in a significant decline in economic growth and also a drop in energy consumption, this drop affected the economic activities.

Based on the events that have already happened in the history of energy and the economy of Madagascar, it is important to analyze these areas retrospectively to see what turned out wrong and to anticipate a better future because it is already clear that there is a relationship between these variables. Therefore, adequate policies are needed to achieve sustainable and durable growth. This Master thesis will provide a new perspective for the environmental relationship and the economy of Madagascar through the causality analysis between energy, growth and CO_2 emission. Apart from that, it is important to note that the relevance of this master is a tool for decision makers in the environmental and sustainable development field.

1.7.Scop of study

Since this master's thesis is about the study of energy, economy and environment of Madagascar through econometrics and the variables to be analyzed are delimited on GDP, CO_2 emissions, energy consumption and population. In order to have certainty in the analysis of this master thesis and to ensure that the results that will be obtained are not biased, it is therefore necessary to have data for a minimum of 30 years, which means that data from ministries and international organizations since 1986 until 2016 will be used for this analysis.

CHAPTER TWO

LITERATURE REVIEW

2.1.Historical review and theoretical debates between energy and economic development

Human society has gone through centuries of change from one civilization to another. During these changes, innovations have happened following the trajectory of human intellectual development. Many periods have marked the history of energy, but those which have changed the perception of the place of the energy sector in the development of countries are the industrial revolution and the oil crisis of the seventies.

2.1.1. The Industrial Revolution

By definition, the industrial revolution designates a process of transformation of the production method, in other words, the transformation from a society dominated by crafts and agriculture to a society dominated by the development of production techniques on an industrial scale. Until now, the world has experienced two industrial revolutions. These revolutions are both characterized by a high consumption of energy(Amiron et al., 2019).

The first industrial revolution took place between the end of the 18th century and the first half of the 19th century. This first stage is marked by the introduction of the machine in the production process with the invention of the steam engine by James Watt which later became the name of the unit of measurement of power. This period was marked by the predominance of coal and wood as energy resources. At that time, some authors like Stanley Jevons highlighted a question about the risks of exhausting the coal stock and the impact of deforestation on the environment. The second revolution is also based on the use of coal but other new sources of energy such as oil and petroleum products were used. This period is marked by the development of heavy industries such as metallurgy and chemical(Sato Duarte et al., 2018).

2.1.2. Petroleum crises of the 1970s

After years of unprecedented growth known as the "Glorious Thirty", the Western economy was faced with the petroleum problem. Since 1950, the price of petroleum has been on a downward trend of 40% compared to industrial products. In response to this price decline, the Organization of Petroleum Exporting Countries (OPEC) grouped together the leading producer countries located in the Middle East(Kersten, 2014). The objective was not to set off the embargo of petroleum products to Western countries in which are the first consumers of petroleum. In addition, this reaction was in agreement with the demands of the Third World for a revision of the price fixing mechanism and the local processing of raw materials. In November 1973, the level of petroleum production dropped by 25%, while a few months later, the price was almost quadruple the current price. A few years later, a second petroleum crisis reappeared, but the consequences only got graver. After these two crises, global changes were introduced and the perception of the place of petroleum was revised. Energy programs have been relaunched, headed by the IEA (International Energy Agency). This agency is working to counterbalance OPEC and to ensure the long-term objectives for the security of petroleum supply(Van de Graaf, 2013).

2.2.Kyoto protocol

The Kyoto Protocol is an international treaty whose objective is to reduce greenhouse gas emissions. It was signed in 1997 and is an extension of the United Nations Framework Convention on Climate Change (UNFCCC) adopted in 1992 at the Earth Summit in Rio de Janeiro (Brazil). The initial objective of the Kyoto Protocol was to achieve a reduction in anthropogenic greenhouse gas emissions of at least 5% (in committed countries) compared to 1990 levels during the 2008-2012 commitment period. A second commitment period was set at the Doha Summit in December 2012. It runs from 1 January 2013 to 31 December 2020(Dessai, 2003).

The Protocol was signed on 11 December 1997 at the third annual Conference of the Parties ("COP3") in Kyoto, Japan. To enter into force, it had to be ratified by 55 developed countries generating at least 55% of the world's greenhouse gas emissions in 1990. It entered into force on February 16, 2005. Currently, 196 "Parties" (195 States and the European Union) have deposited their instruments of ratification, accession, approval or acceptance, with the notable exception of the United States. The protocol was signed under President Clinton but has not been ratified by the US Senate.

2.3. Environmental challenges

Many scientists agree that average temperatures could rise by 1.4 to 5.8°C by 2100 compared to 1990 (for the COP21, the pre-industrial era is taken as the reference period). The consequences of such an increase could be considerable: desertification, floods, spread of diseases, disappearance of animal species, etc. Global warming is therefore considered by many as the environmental challenge of the 21st century. The Kyoto Protocol illustrates the importance that the world's countries attach to the environment and to the relationship between humanity and the natural balance of the planet(Ai & Leigh, 2017).

2.4. Economic challenges

The implementation of the CO2 emission permit market raises many economic questions about the financial implications for the signatory countries of the Kyoto Protocol. How will companies integrate the CO2 constraint in their financial accounts and in their development forecasts? What financial compensation will be associated with the commitment of developing countries to participate in the collective effort to reduce greenhouse gas emissions?

Moreover, the Kyoto Protocol redraws the North-South divide. It exempts developing and emerging countries from crucial climate responsibilities, without any financial compensation. Developing countries have a rapidly growing population and energy consumption. Industrialized countries, which are considered historically responsible for anthropogenic greenhouse gas emissions, are encouraged to finance "clean projects" in developing countries if they fail to meet their national targets(Li et al., 2021).

2.5.The major debates on the place of energy in the economy

2.5.1. Evolution of the place of energy in economic theory

The place of energy in economic debates is well confirmed, although it was still mentioned in an implicit way. During the second half of the 18th century, the "physiocratic" current succeeded mercantilism, which noted that in other countries, energy resources were the source of all riches (Ribeiro & Cantarino, 2016). The physiocrats stipulate that nature is a gift and it must serve the economy otherwise its utility is not founded. After the physiocrats, the "classical" school of thought marked the advent of modern economics. The origins of this stream are to be found in the United Kingdom and in France. Beyond the theory of value, what really marked this movement was that the question of production was also an object of concern. This school of thought considers natural resources to be free and unlimited. Some authors have tried to introduce the concept of energy in the use of machines in order to increase productivity(Salvatore, 2009). However, Malthus' population principle and David Ricardo's theory of differential rents attempt to grasp the principle of land scarcity. This notion of scarcity explains in fact Malthus' thesis that the level of population tends to grow at a geometric rate while the trend of production is in arithmetical progression, and this in parallel with Ricardo's theory which explains that progressively there is a cultivation of land then its production will decrease and tend towards a stationary state. However, the most significant aspect of this school of thought is its appearance in parallel with the industrial revolution, which really marked the hegemony of the use of coal to operate machinery. After the classical school of thought, neoclassical theories appeared with the introduction of the productive system of the factor capital, labor and land. This approach gradually discarded the role of natural resources in economic thought and evoked the notion of scarcity. For neoclassicals, the main objective of economics is the optimal allocation of resources. Nevertheless, other neoclassical authors are convinced of the importance of natural resources and their place in the economy. For example, Stanley, Jevons (1865) highlighted the possibility of the depletion of the coal stock. This depletion led to the decline of the United Kingdom, which was then in full industrial expansion.

2.5.2. The new energy controversies

The 1970s were marked by the rise of environmental concerns. It was at this time that the economic analysis of energy began to develop. The growth experienced during the thirty glorious years was not without effects on the environment and on the depletion of natural resources(Godard & Beaumais, 1993). Consequently, the emergence of energy crises was important; as a result, debates and contestations started. On the other side, there are the optimists who believe in the power of the market in its role of regulation and allocation of resources, as well as in the capacity of innovation and technological ingenuity of humans to overcome these obstacles. Furthermore, there is the class of pessimists who are realistic about the limit of substitutability of natural resources by other factors of production and support the idea of the complementarity of factors. The fundamental question that requires the best solution is: how to grow in the long term with limited resources?.

The week or utilitarian approach is the approach that supports the neoclassical thesis on the maximization of well-being. To achieve this, it is necessary to take into account the factors of production that include labor, capital and natural resources which are referred by natural capital. In this vision, for economic growth to be sustainable, the factors of production must not decrease over time. Therefore, if one of the factors decreases, there is no need to fear because this gap can be filled by the other factors. The weak approach thus supports the thesis of perfect substitutability of factors of production. It recognizes the trend towards the disappearance of natural resources, but the complication posed by this finitude is rejected. According to this approach, nature can only be useful for satisfying needs and must not constitute an obstacle to the sustainability of growth. Its disappearance will be compensated by the development of innovation and the power of technology. Barnett. H.J and Morse. C (1963) and Barnett. H.J (1979) confirm that scarcity does not present a threat to the economy because the market plays a role on the internalization of external effects.

The strong approach: A group of international economists and experts known as the "Club of Rome" questioned the effects of economic growth on the depletion of natural resources. In 1972, this group published a report called "Stop Growth". In this report, the neoclassical thesis stipulating the substitutability of different forms of capital was criticized. The difficulty is related to the specificity of natural capital which includes energy resources and that makes it a non-substitutable capital. According to these specificities, we find first of all that its function as a support for the life of animal and plant species which in no case can be substituted; and secondly, the fact that this type of capital is self-produced, namely that it does not need the intervention of other forms of capital. The Club of Rome rather opted for the complementarity of the different forms of capital. As a result, the notion of de-growth with the emergence of deep ecology has been evoked. This thesis stipulates that the productive capacity of nature must not decrease over time. In this perspective, economic growth must remain at zero, which results in a stationary state. Recognizing that the thesis evoked by the Club of Rome on degrowth is unrealistic, another approach appears to try to reconcile the two approaches. The objective is to highlight the interdependence between the environment and development and to try to bring them together. After the Stockholm conference in 1972, the notion of sustainable development was launched in the Brundtland Report in 1987.

2.6. Place of the energy sector in economic growth

2.6.1. Energy transition in developing countries

By definition, the energy transition is a concept that aims to qualify the transition from one energy system to another. It implies the transition from a development model based on the use of polluting energies to a new model based on more promising and environmentally friendly alternatives(Kim, 2019). It is the only alternative in the face of climate change, the upward trend in energy demand and the fact that resources are becoming increasingly scarce. The 1972 Rio Conference, which led to the Framework Convention on Climate Change, set the objective of stabilizing greenhouse gas emissions and proposed the introduction of a carbon-energy tax. The economic development of developed countries based on non-renewable energy has led to the deterioration of natural resources and environmental degradation. The option for renewable energy is indeed the way out for these countries if they want to see their economic growth sustainable. As for developing countries, even at a low level of development, the effects on the environment are also significant. The use of renewable energies is a relevant choice and should be the subject of a national policy. However, renewable energies face various obstacles, notably financial obstacles due to the high cost of implementation, technological obstacles and institutional obstacles. As a result, the "clean development" mechanism has been mentioned. Through cleaner but lower cost technologies, emerging industries can overcome the difficulties posed by unsustainable energy sources and move towards clean energy. To this day, the energy transition remains a major challenge for developing countries. Indeed, long-term policies should include key issues such as energy security, which must take into account the supply and availability of energy resources. energy at a fair price.

2.6.2. Contribution of the energy sector to economic growth

Since the work of Kraft and Kraft (1978), many studies are recorded in the literature using various methodologies for different time periods. For example, Charles Jumbe (2004) examined the cointegration and causality between electricity consumption and nominal Gross Domestic Product (GDP) and agricultural GDP. He used Malawi's data for non-agricultural GDP for the period 1970-1999 and concluded that there is a long-run equilibrium relationship between electricity consumption and nominal GDP and non-agricultural GDP but not with agricultural GDP(Polyakova et al., 2019). He used the error correction model and Granger causality to examine the causality between these three variables. He found that there is a bi-directional causality between electricity consumption andGDP while a unidirectional causality from non-agricultural GDP to electricity consumption.In the same context, many studies have been recorded concerning the causal relationship between energy consumption and economic growth in Turkey. Indeed, using a Vector error Correction Model (VECM), Soytas and Sari (2003) found a unidirectional causality from energy consumption to GDP per capita in France and a causality from GDP to energy consumption in Italy and Japan. However, using the unit root tests in the presence of breaks proposed by Zivot and Andrews (1992) and Perron (1997), Altinay and Karagol (2004) deduced that a false causality would exist between the series if the data are integrated of order one. Studying the period of 1950- 2000, they proved that the energy consumption and GDP series in Turkey are stationary in trend with a structural break and they found no evidence of causality between energy consumption and GDP in Turkey. However, using annual data during the period 1970-2003, Lise and Van Montfort (2007) recently found that in Turkey, energy consumption and GDP are cointegrated and the direction of causality shifts from GDP to energy consumption. Again, for the case of Turkey, in a very recent study, Jobert and Karanfil (2007) using the annual time series for the period 1960-2003 discuss that in the long run income and energy consumption are neutral with respect to aggregate and industrial levels. Their study also indicates strong evidence of instantaneous causality, which means that contemporaneous values of energy consumption and income are correlated. Karanfil (2008), for the period from 1970 to 2005 and for Turkey, concluded that there is a cointegration relationship between energy consumption and economic growth. But when he took into account the non-registered economy, he found that they are not cointegrated. In a large number of studies contradictory results about the direction of the relationship have been found for different countries for different time periods, for example in India the direction of causality is from energy to income (Asafu-Adjaye, 2000; Masih and Masih, 1996). However, Paul and Bhattacharya (2004) found bi-directional causality for the same country. On the other hand, empirical studies for some industrialised countries give varying estimates; for example, Kraft and Kraft (1978) found a causal relationship from income to energy consumption in the case of the US for the period 1947-1974. However, Stern (2000), using a VAR model, specified that the direction of causality is from energy consumption to income in the US. For the same country, Dergiades and Tsoulfidis (2008) examined the determinants of residual electricity demand. The econometric specification assumes that residual demand depends on the price of electricity, per capita income, weather conditions, the price of substitutes and the reserve of homes. Thus, they tested the stability of the demand function via the cointegration technique within an ARDL and concluded the existence of a single long-run relationship between the variables considered. Concerning energy prices and cointegration theory, Panagiotidis and Rutledge (2007) deduced that gas prices and oil prices (UK) are cointegrated using Johansen's methodology and Breitung's procedure (2002) over the period 1996-2003. However, using Johansen's method they concluded that the prices are cointegrated over the whole period. They also used the VECM specification to model short-term adjustments(Jian et al., 2019). They used impulse response functions to study the response of gas prices to an oil price shock and the results showed a negative and rapid response. In China, Wang Yu, Guo Ju'e, Xi Youmin (2008) used Engel and Granger's two-step cointegration test on annual data covering the period from 1980 to 2005 and investigated the effect of shocks to variables on each other via impulse response functions. The particularity of this study is that the energyeconomic growth relationship was studied in two equations, one explaining economic growth in terms of energy consumption and the other in terms of energy production. Some recent studies have also used the dynamic panel data approach to study the relationship between energy and income in developed and developing countries. For example, using panel data for 40 countries (22 developed and 18 developing), Lee and Chang (2007) found that there is a unidirectional causality running from GDP to energy consumption in developing countries and a bidirectional causality in developed countries. The same authors studied the same relationship but this time testing its stability via unit root tests and cointegration tests in the presence of structural change (Zivot and Andrews test and Hansen test). Narayan and Smyth (2007) examined the relationship between capital formation, energy consumption and real GDP in the panel cointegration framework and Granger causality. To test for the existence of long-run equilibrium relationships between the variables, they used the Pedroni (1999) and Westerlund (2006) tests. However, the Pedroni (1999) test led to the absence of cointegration, once they took into account structural changes, they deduced that there is a cointegrating relationship. Thus, in the long run capital formation and energy consumption cause real GDP in Granger's sense of the term and have had a positive effect on real GDP in the G7 countries. In 2009, several authors continued to study the relationship between energy consumption and economic growth using econometric methods, namely Idrissa M. Ouédraogo studied this relationship for the case of Boukina Fasso using cointegration and the Granger causality test on monthly data from 1960 to 2003. In the same year, Mounir Balloumi applied the same technique in the Tunisian context. He deduced that energy consumption causes economic growth. Thus, research on the relationship between energy consumption and economic growth is sensitive to the period considered, the country and the methodology used. In this context, our work aims to contribute to the existing debate on the relationship between energy consumption and economic growth by taking into consideration the breaks and shocks recorded via the theory of cointegration developed by Engle and Newbold in 1974. It is at this level that we can show our contribution by combining economic theory with new econometric methods using the method of cointegration with structural changes.

2.7.Environmental degradation and its effects on the economy related to energy activities

The question of the environment caused by human activities was raised in the 1960s following an awareness of the harmful effects of the growth of Western countries during the thirty glorious years. The exploitation, production and consumption of energy are in fact a large part of the degradation of the environment. Since then, the reading of the environment and the economy has become interdependent.

2.8. Environmental impacts of energy resource exploitation

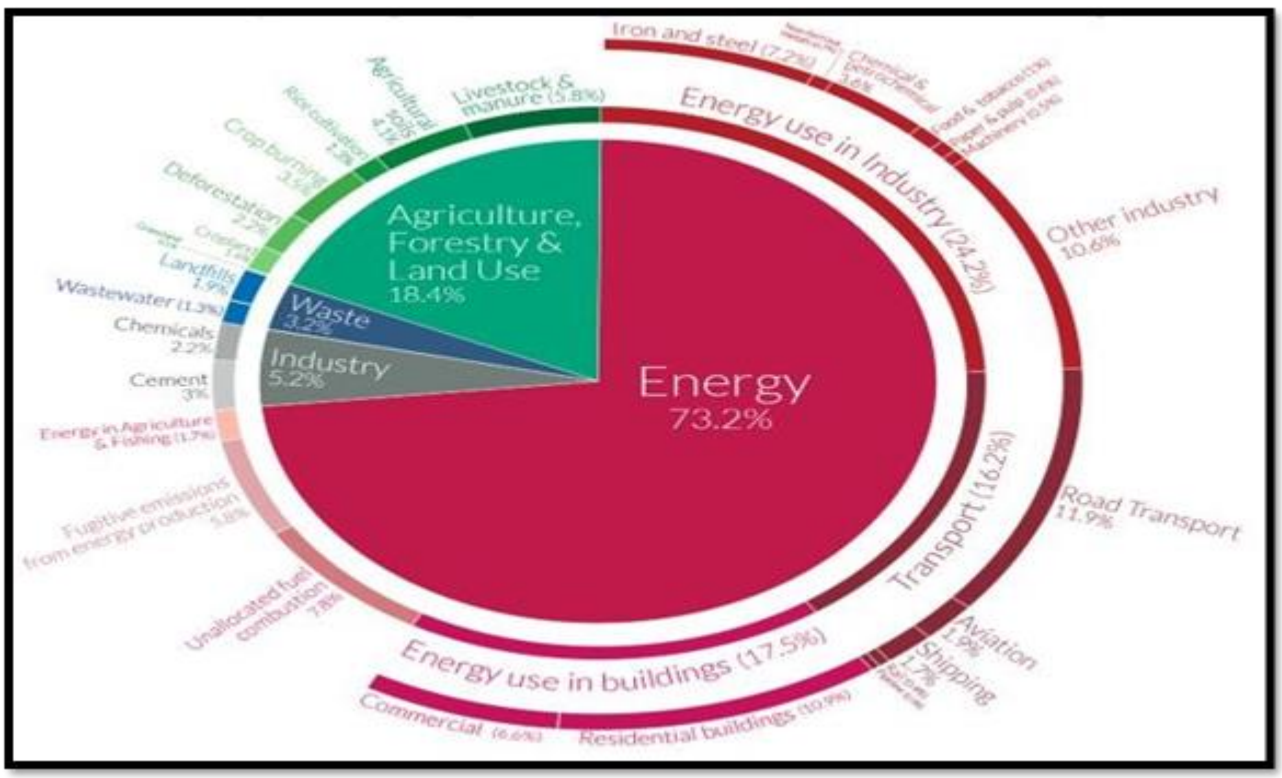
2.8.1. Deforestation

Deforestation is defined as the loss of forest cover. Conversion to agricultural land, mining, the supply of energy resources such as wood and coal and oil drilling, and fires are all primary drivers of deforestation. A large proportion, 31%, of the world's land surface is occupied by forests. According to figures from the Food and Agricultural Organization (FAO), every year from 2000 to 2010, about 13 million hectares of forest are lost. In the 1990s, the figure was 16 million. In many developing countries such as Madagascar, biomass is the primary source of energy because it is cheaper than other sources, but its overexploitation leads to severe deforestation. For more than 2 billion poor people in the world, wood-based fuels are the main source of energy. In Africa, for example, more than 90% of the wood harvested is used to meet energy needs(Vieilledent et al., 2018).

2.8.2. Climate change

According to the Intergovernmental Panel on Climate Change (IPCC), climate change is defined as: "a change in the state of the climate, which may be identified (for instence, using statistical tests) by changes in the mean and/or variability of its properties, and which persists over an extended period of time, typically decades or more. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in atmospheric composition or land use. The United Nations Framework Convention on Climate Change (UNFCCC) gave another definition and stated climate change "as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods"(Ortega & Klauth, 2017). In relation to these definitions, climate change is defined as an undesirable modification of the climate due to natural or human-induced phenomena. It is manifested by the deterioration of the ozone layer which will subsequently increase the global temperature as a result of high emissions of harmful gases consisting mainly of CO2, known as greenhouse gases. The IEA scenario in 2030 has estimated a 62% increase in energy-related carbon dioxide emissions. The following graph illustrates the share of the sectors in the emission of greenhouse gases in 2007.

Figure 2: Global greenhouse gas emissions by sector in 2007



Source: Climate watch, the world resource institute, 2020

This figure illustrates the significant share of energy in greenhouse gas emissions. Indeed, it constitutes 73.2% of the emissions.

2.9. Problems related to environmental degradation

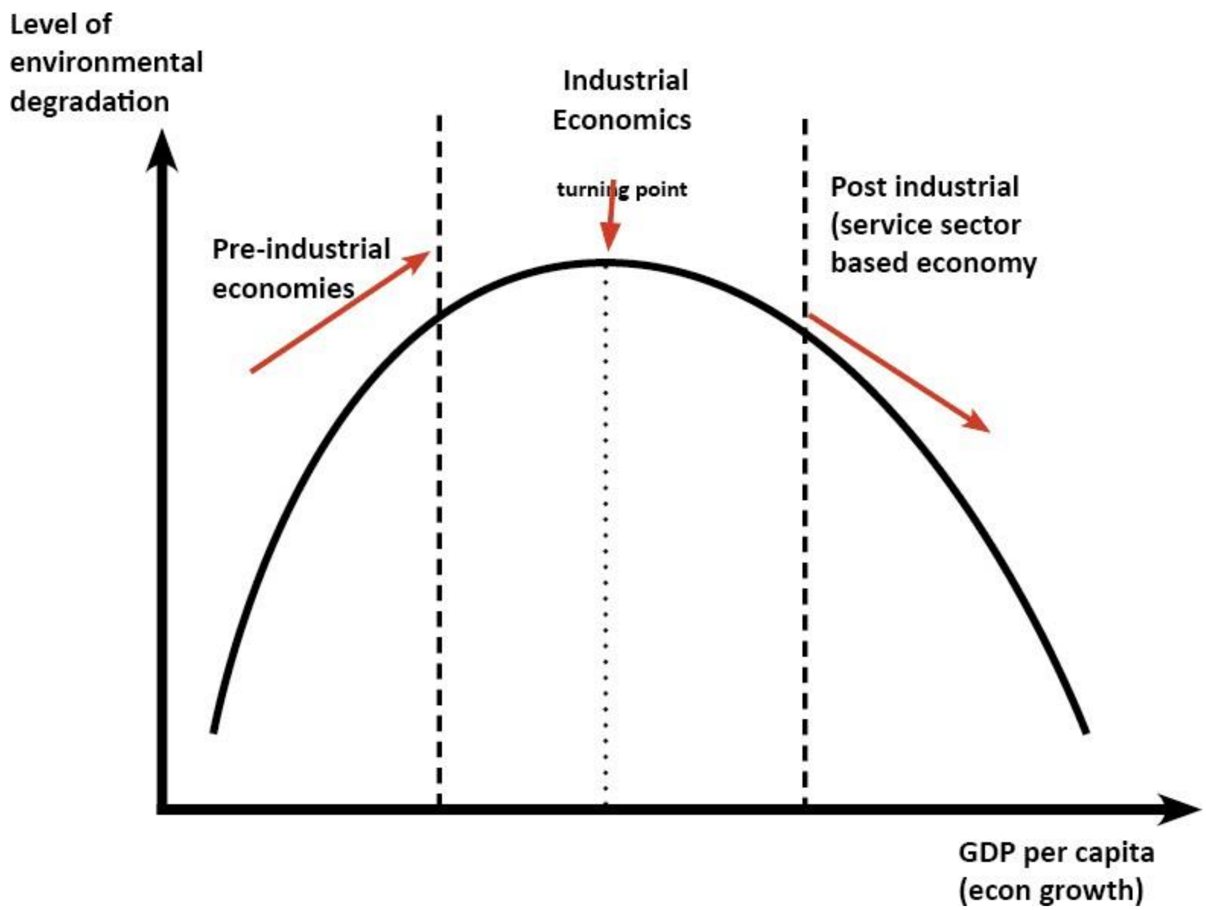
The risks associated with environmental degradation, particularly climate change, are weighing on the global economy and human societies. In 2006, an economist, not a meteorologist, at the request of the British government, published a report by Nicholas Stern on the economic consequences of global warming. It is an attempt to integrate together the assessment of the damage caused by global warming and the costs of response strategies. This study shows that the problem of climate change is a major issue for the economy. In fact, this report proposed major impacts such as melting polar ice which will subsequently lead to sea level rise, reduced harvests especially in countries experiencing the greatest temperature increase, increased mortality rates due to malnutrition and health problems related to climate change, and population displacement manifested by high rates of migration. 5.5 trillion over the next ten years, and it is predicted that this cost could reach 5% of gross world product if nothing is done to reduce the current rate of increase in greenhouse gas emissions. The geographical distribution of this cost attracts particular attention, as most of the emissions are attributed to developed countries, while developing countries suffer more. The costs of climate change in India and South East Asia on the one hand and the Middle East and Africa on the other are respectively 3.5% and 2.7% of GDP with an average temperature increase of 4.3°C in 2100(Wang et al., 2018).

Volume 2 of the IPCC's Fifth Assessment Report published in March 2014, entitled "Climate Change 2014: Impacts, Adaptation and Vulnerability", presents the impacts of global warming and the future risks from climate change. According to the report, the negative effects are becoming increasingly apparent and are being felt on a global scale. The IPCC reports these effects on several key points, including the impacts on drinking water resources due to the disruption of the precipitation cycle and climate disruption, the impacts on biodiversity marked by the disruption of the natural environment of species, the impacts on food production including a drop in the level of production, the effects on health which can be seen in a sharp increase in the mortality rate linked largely to the development of diseases favorable to the climate profile, the advent of extreme events such as floods and heat waves and finally the socio-economic effects which can be explained by the widening of the inequality gap. As a result, the risks of natural hazards are high because the level of vulnerability does not allow for a response. A World Bank report has also in short, the negative impacts of energy use, especially traditional energy sources such as coal and oil, lead to a disruption of the ecosystem in general and of human activities in particular.

2.10. Kuznets environmental curve

From an economic point of view, the relationship between economic growth and environmental quality is a major debate and a vast literature has been devoted to the study of this relationship (Kotroni et al., 2020).This debate was based mainly on discussions and purely theoretical work until the early 1990s. At that time, the availability of data on the state of the environment prompted empirical investigation of the relationship between economic growth and environmental quality. Moreover, empirical studies (see, among others, Shafik and Bandyopadhyay, 1992; Grossman and Krueger, 1993; Panayotou, 1993) revealed a very important result: a bell-shaped relationship exists between various pollution indices and the level of per capita income! The name " curve environmental of Kuznets " (henceforth CEK) was given to this relationship. The CEK hypothesis postulates an inverted U-shaped relationship between environmental degradation and economic growth. This curve indicates that during the first phase of economic growth (increasing income), environmental degradation increases; but from a certain level of income (turning point), an improvement in the state of the environment occurs.

Figure 3: Kuznets environmental curve



Source: https://www.economicshelp.org

Several forms of the CEK have been proven in addition to the inverted U-form, namely U-, N-, inverted N-forms, etc., depending on the environmental indicator, the database, the model to be estimated, etc. Thus, the econometric specification of the CEK remains one of the most important tasks and requires more in-depth studies. Thus, the econometric specification of the CEK remains one of the most important tasks and requires more in-depth studies. Moreover, several models have been proposed in the CEK literature. At the risk of being incomplete, we mention the Weibull function, the Gamma function; the regime-switching model, the kernel regression, etc. But the polynomial specification presented in linear, semi-log-linear or log-linear form remains the most often used (Shafik, 1994; Panayotou, 1995; Vincent, 1997; Bhattarai and Hamming, 2000; Zarzoso and Morancho, 2004; Dijkgraf and Vollebergh, 2005; Richmond and Kaufmann, 2006; Culas, 2007; Brajer et al.) It is on this specification that this work focuses attention.

2.11. Kaya identity

The ECK has been criticised by Dinda (2004) since according to this curve emissions are a share of GDP, and therefore it assumes that there is a unidirectional causal relationship from GDP to emissions, whereas the reverse may exist. However, this curve does not highlight the other factors influencing the level of emissions other than economic growth. For this reason, the Kaya identity proposes a decomposition of CO2 emissions according to different economic, demographic, industrial and political parameters. The most common form is that based on the following

Theoretical specification:

$$\boldsymbol{CO_2 = P * \frac{GDP}{P} * \frac{E}{GDP} * \frac{CO_2}{E}}$$

$\frac{GDP}{P}$ Growth domestic per capita, $\frac{E}{GDP}$: Energy Intensity, $\frac{CO_2}{E}$: Carbon intensity, P: population. According to that identity, CO2 emissions are a function of population, income (GDP per capita), energy intensity (energy units/GDP), and the energy dirt index (CO2 emissions per energy unit). This equation states that population, economic growth and technology (in other words, energy and CO2 intensities) are the determinants of greenhouse gas emissions. Alternatively, any increase or decrease in the amount of CO2 emissions must be matched by an equivalent change in at least one of the decomposition factors. The combined effect of these factors on the environment can be detailed in the following.

2.11.1. Effect of population growth on the environment

Population size and growth are the main factors causing CO2 emissions. The causal pattern induced by this relationship is that, firstly, a large population could imply an additional demand for energy for industry and transport, resulting in significant emissions. Secondly, an increase in population contributes to greenhouse gas emissions through its effect on deforestation. An increase in population causes more deforestation, changes in land use and more consumption of wood for fuel. Thus, the larger the population, the higher the CO2 emissions, which contribute to the greenhouse effect (Birdsall, 1992). Shi (2003) has shown that a 1% increase in population leads to a 1.28% increase in emissions on average. Dyson (2005) estimates that the growth of the world's population (estimated at 9 billion in 2050) will lead to a 27% increase in CO2 emissions, which scientists believe is the direct cause of global warming, following a previous increase of 400% between 1950 and 2000.

2.11.2. Effect of economic development

Several studies have demonstrated the correlation between economic development and CO2 emissions(Radmehr et al., 2021). Economic development is accompanied by an increase in the consumption of fossil fuels, with increasing amounts of coal, oil and natural gas being consumed by factories and power plants, motor vehicles and households. The resulting carbon dioxide emissions have become the main source of greenhouse gases. International experience shows that in most countries air quality deteriorates in the early stages of industrialisation and urbanisation. But once countries experience income growth, their priorities change: they realise the value of their natural resources (clean air, clean water, fertile arable land, abundant forests) and adopt and enforce laws to protect them.

2.11.3. Effect of technology on the environment

Most studies show that climate change policy will have a positive impact on employment, for example in the field of renewable energy or advanced technologies(Pei et al., 2020). The development of technological solutions leading to low levels of consumption and very significantly reduced levels of pollutants (low carbon intensity) is leading to the emergence of advanced technologies, notably using new modes of combustion (cogeneration, LED lamps, electric cars, etc.). The three factors, population, standard of living and technology, are correlated in equation (E1) with another equation which will be used as a basis for estimating their effects on GHG emissions in Madagascar. As this equation is not estimable, we associate it with an additive stochastic form defined by: $Ln(\boldsymbol{CO_2}) = \boldsymbol{LnP} + \boldsymbol{Ln}(\frac{\boldsymbol{GDP}}{\boldsymbol{P}}) + \boldsymbol{Ln}(\frac{\boldsymbol{E}}{\boldsymbol{GDP}}) + \boldsymbol{Ln}(\frac{\boldsymbol{CO_2}}{\boldsymbol{E}})$

2.13.Summary of literature review

The call for cointegration tests on panel data, established on a double dimension of analysis (individual and temporary) compared to the study of temporal data, thus allowing a preponderant analysis to study macroeconomic relationships. The unit panel root tests are varied for each and are of comparable importance to the other. In fact, there has been a twofold evolution of these tests since the seminal work of Levin and Lin (1992): a shift towards heterogeneous modelling with the work of Im, Pesaran and Shin (1997).

The Kuznets curve (derived from Simon Kuznets' work on economic development in the 1950s) describes an inverted U-shaped relationship between the level of development of a country and income inequality. In 1991, Grossman and Krueger proposed to carry this idea to the environmental field, but it was not until 1993 that the expression Curve Environmental of Kuznets (CEK) appeared with the article by Panayotou (1993). The CEK implies that in the early stages of economic development, agents care little for the environment. When the level of income allows basic needs to be met, a threshold (the turning point) is reached where concern for the environment increases and the trend is reversed. Beyond this threshold, economic growth is accompanied by an improvement in environmental conditions, including a reduction in pollution. There is thus an inverse U-shaped relationship between pollution and economic development.

The Kaya identity was developed by the Japanese energy economist Yoichi Kaya. It is the subject of his book Environment, Energy and the Economy: Sustainability Strategies co-authored with Keiichi Yokobori at the Conference on Global Environment, Energy and Economic Development (1993: Tokyo, Japan). It is a more coherent mathematical variation of Paul R. Ehrlich & John Holdrende's formula I = PAT that describes the environmental impact factors.

I: Impact of environment, P: Population ,A: Affluence, T: Technology

CHAPTER THREE

METHODOLOGY

3.1.Introduction

This chapter aims to present the overall view of the energy sector in Madagascar as a field of study for this Master thesis and also the presentation of panel data econometrics as a method of analysis during this Master thesis. For this purpose, it is important to highlight the advantages, disadvantages and specifications of the models using panel data as well as the estimation methods. As stated in the objective of this Master thesis, we will verify whether the hypothesis of the Kuznets environmental curve is true or not for the case of Madagascar. At the end of this methodology, we will present the necessary steps to verify the Kuznets hypothesis.

3.2.Overview of the energy sector in Madagascar as a field of study

The average energy consumption per capita in Madagascar is among the lowest in the world, at 0.315 toe/year (tones oil equivalent). This compares to 0.407 toe/year in Mozambique, 2.655 toe/year in South Africa and 3.840 toe/year in France. The energy market in Madagascar is dominated by domestic consumption: wood energy meets household needs for cooking energy, estimated at 140,000 TJ/year (Tera joules), while paraffin and electricity meet lighting needs of about 8,000 TJ/year. The low level of energy consumption in the productive sector reflects the current relatively low dynamism of the Malagasy economy(Nematchoua, 2021). More than 90% of Madagascar's energy supply is made up of wood energy, while petroleum products and renewable energies account for only 7% and 1% respectively, in order to meet fuel demand and electricity production. A summary of the state of energy in Madagascar can be found below:

- Wood energy (firewood and charcoal) is mainly used as cooking fuel by households; the use of improved cooking stoves remains marginal.
- The petroleum products consumed are entirely imported. The petroleum product most used by the economic sector accounts for over half (54%). Paraffin is used by about 80% of households.

- Among the renewable energies, hydroelectric power is the most exploited, but represents only a very small share of the primary energy used.

3.3.Econometric methods

The econometric approach aims at establishing a relationship between energy consumption (global or sectoral) and some macroeconomic indicators (GDP, income, VA, energy prices...). These relationships and indicators can be chosen from two perspectives: the first is the representation of phenomena according to a certain theory and the second is the translation of purely statistical relationships into mathematical form. Among the best-known models, we can mention some examples:

- KLEM models: where energy is considered a factor of production along with capital (K), lab our (L) and raw materials (M). This is because energy is never consumed for its own sake, but as a means to operate equipment that can satisfy a need.
- LES (linear expenditure system) models: where the structure of household consumption by product is linked to the evolution of relative product prices and income: $QE(t) = f(P_i/P_j, Y)$
- LOGIT" models: of market sharing according to the different competing energy products:

$$\log\left(S_{it}/S_{jt}\right) = \propto_i + \propto_2 \log\left(P_{it}/P_{jt}\right) + \propto_2 \log\left(S_{it-1}/S_{jt-1}\right.$$

With $\sum_{i=1}^{4} S_i = 1$

Where:

S_i: the market share of energy i in total energy demand.

P_i: the price of energy i.

I: represents gas, electricity and fuel oil.

j: represents coal.

- The Nordhaus model: This is a classic model representative of a whole family of economic models. Its representation is of the form: $E = CY^{\alpha}P^{\beta}$

Where:

E: energy consumed.

C: constant.

Y: income.

P: energy price.

α Income elasticity.

β Price elasticity.

- Linden's model: This model has the merit of linking energy demand directly to demographic factors. It was developed in the United States and is presented as follows: $E = CP^{\alpha}T^{\beta}A^{\gamma}$

With:

E: energy consumed.

P: energy price.

T: total population.

A: Active population.

- The Champlon model: The adapted econometric model is a dynamic model with four explanatory variables:

$E = CP^{\alpha}A^{\beta}I^{\gamma}E_{-1}^{\mu}$

With:

P: relative energy price index.

I: Industrial production index.

A: Active population.

E_{-1}^{μ} Delayed energy population.

Whatever the approach adopted, the econometric method can only reproduce past developments in the future, or more precisely the links between economic variables and energy demand. Thus, the disadvantage of these methods is that they adopt a restrictive vision since they retain a limited number of explanatory variables which are essentially quantitative variables. In addition, they are very rigid since the relationships on which they are based are constructed once and for all from past statistical series and cannot be modified following an important change. They are also static since they assume the existence of stable relationships between the variables they incorporate. In fact, econometric models are unsuitable for the apprehension of the medium and long term where structural changes mark their presence, hence the need to look for other methods that can overcome these limits. Before 1973, forecasting methods were purely econometric, but the oil crisis led to the development of new "technico-economic" methods. Their main characteristic is to integrate the uncertainty of the future in the energy and economic field by means of scenarios.

3.4. Panel data econometrics

In econometrics, time series are most frequently used as data, such as the number of births recorded each year in Madagascar between 1990 and 2020; the alternative is to record data for a specific period, such as the number of births recorded in 1990 for each of the regions of Madagascar. Panel data, also known as cross-sectional data, have the two dimensions mentioned previously and report the values of the variables collected for a panel of individuals for a series of periods(Burlig et al., 2020).

There has been a great deal of interest and revival in panel data econometrics over the last twenty years, which has led to a dramatic increase in academic work based on panel data. To illustrate this, figures provided by Hsiao (2007) show that in 1986 only 29 empirical studies listed in the Social Science Citation Index matched the keywords "panel data", less than a decade later 733 empirical studies matched the same keywords. How do we explain this?

There are two main causes, firstly the information sources of statistical organizations are more frequently formed by individuals observed repeatedly, so multi-pass surveys make it possible to compose panels. Subsequently, technological advances and the development of computer programmers have helped in the application of econometric methods. Advances in economic theory aim to improve the representation of the dynamics of agents' behavior and to take into account their heterogeneity. Thanks to the characteristic of double dimensions, panel data are very suitable for the estimation of these models. A new trend is the shift to macroeconomic problems, for example., ISLAM (1995), caselli, esquivel and lefort (1996), nerlove (1999) for work on growth and macdonald (1996) and oh (1996) on exchange rates and others. In econometrics, panel data analysis is the most dynamic and innovative field because the development of estimation techniques and theoretical results are favored by panel data. In practice, panel data allow the study of questions that cannot be addressed in cross-section or time series.

3.5. Definition and terminology

The word Panel comes from the Latin pan meaning (All, totality).

- In the humanities, a panel is a group of people/companies interviewed regularly on their opinions, attitudes or behavior. The collection of this information can be done automatically or on a declarative basis.
- In econometrics, panels are very interesting because they are repeated observations in time on the same subjects. This repetition makes us better understand the differences between individuals and the evolution over time of the phenomena studied.
- Panel data: repeated observations over time for the same set of individuals. "Individual": any type of entity (a household, a company, a country, etc.). Synonyms: individual data, longitudinal data, panel data, data grouped; longitudinal date, cross - sections over time, pooled cross - section time - series data.
- Short (long) panel: when the number of periods is small (large).
- panel cylinder (non-cylindrical): all individuals are (not) followed for the same number of periods.
- rotating panel: for each period, a certain number of individuals.
- A balanced panel: contains the same number of observations for each individual.
- An omnibus panel is a sample of people on whom information is collected for different studies and analyses.
- A cohort is a set of individuals who have experienced the same event at the same period (e.g., women who had their last child in 1988).
- Homogeneous (vs. heterogeneous) panel when there is no significant difference between the individuals.
- Static (dynamic) panel when there is no significant difference between the t-periods.
- A pseudo-panel is a collection of information carried out at different moments in time on different samples but randomly drawn from the same population.
- Attrition is the fact that some individuals 'leave' the panel without being replaced. Examples: Macro-economic data statements (GDP, interest rates, Chrome....) on different sectors for several years.

Table 1: representation of data panel

	Farmers i = 1	Tourism i = 2	. . . .	Industries i = n
1990 t = 1	$X1_{,1}$	$X1_{,2}$		$X1_{,n}$
1991 t = 2	$X2_{,1}$	$X2_{,2}$		$X2_{,n}$
. . . .				
N t = m	$Xm_{,1}$	$Xm_{,2}$		$Xm_{,n}$

- The data are indicated by a double index:

i: Individual, i = 1, ... n or n individuals

t = the period, t = 1, ... m knows m periods

In this example X_{ti} represent the GDP or energy consumed in a given period by a given sector.

For this purpose, we can say that the representation of the panel data model is as follows: Let Y_{ti} be endogenous variables or explanatory variables and X_{ti} be exogenous variables or explanatory variables.

$Y_{i,t} = \alpha_i + \beta_i X_{i,t} + \varepsilon_{i,t}$ with $\alpha_i \in R$, $\beta_i = (\beta_1, \beta_2, \ldots., \beta_k)$ is a vector of dimension (K; 1).

3.6. Advantages and disadvantages of panel data

3.6.1. The advantages of panel data

- Taking into account unobserved heterogeneity:

A very important feature of panel data is its dual dimension which is and time and allows the study of both the dynamics and the heterogeneity of the agents' behavior (Verlove and Bolestra 1995). It should be noted that the two dimensions can be any, time is not necessarily part of it, for example it is possible to have observations by individuals grouped in hamlets, or by companies grouped in industrial branches. There are two kinds of heterogeneity: unobserved heterogeneity and observed heterogeneity, which is controllable by explanatory variables. The first one is more problematic, let's take the example of an individual's productivity: it depends on his or her observed level of education and some unobservable personal characteristics (address; preferences....). Not considering unobserved heterogeneity in Ordinary Least Squares (OLS) estimation makes the estimator biased and this heterogeneity is uncontrollable for snapshot or time series analysis. Correctly modelling behavioral heterogeneity for model estimation, the use of panel data has the advantage of making it easier to compare the results of the in order to take into account temporal and/or individual disparities in behavior, we focus on individual heterogeneity because temporal heterogeneity is less marked and can be demonstrated more easily by a priori reflection.

- The decomposition of total variability

The use of the double dimension results in increased accuracy in the interpretation of this is because, on the one hand, individuals differ from each other: inter-individual variability, and on the other hand, the situation specific to each individual changes over time: intra-individual variability, which is divided into inter-temporal variability (variations common to all individuals and intra-individual-temporal variability specific to each individual) Thus, the total variability is broken down into three elements: Total variability = inter-individual variability + inter-temporal variability + intra-individual variability - Temporal.

- Inter-individual variability is based on the calculation of averages per individual, it identifies the relative position of an individual compared to an average individual. It is captured by an operator called "between - group".
- Inter-temporal variability is based on the calculation of period averages, it identifies the variability of the elements common to all individuals, this variability is calculated by using the "between time" operation.
- Intra-individual variability is based on the difference between the individual's situation at time and its average situation over the periods, its situation in relation to the individuals and its position relative to the total sample average, the resulting component represents an element that changes over time specific to the individual, this variability is calculated using the intra-individual-temporal or double -Within operator, the becomes intra-individual (Within) when the temporal dimension is neglected.
- It is possible to illustrate this decomposition with this example: Let's have a panel of data wilayas of Algeria (individual) over time. Savings can be explained by several variables (salary; demographic and other variables) the panel dimension allows for three variabilities;

thus, inter-individual variability captures the structural differences between the wilayas that are invariable over time (culture, tradition, (e.g., ethnicity, religion, natural endowment, etc.), inter-temporal variability captures changes in macro-economic reforms to Algeria as a whole (central reforms, legislative framework....). Intra-individual variability -temporal captures savings behavior specific to each wilaya (local government decisions, idiosyncratic shocks (nature) ....).

- Increasing the sample size:

- Panel data have a major advantage in terms of the amount of data, using the large number of data increases the degree of freedom and decreases the collinearity between explanatory variables, which improves estimates and econometric tests.
- The repetitive study of cross-sectional observations allows panel data to be to be more in tune with the search for and dynamics of change, the periods unemployment rates, labor turnover and labor mobility are best studied with panel data.
- Panel data provides an opportunity to study more complex patterns of for example, economies of scale and technical progress are better served by panel data than in cross-sectional studies or in the pure time series.
- With data on several thousand units, panel data can minimize the bias that may result from aggregating individuals into firms in a given in sum, panel data enriches the empirical analysis of directions that may not be possible using instantaneous cuts or time series, which is not to say that there are no drawbacks related to panel data.

3.6.2. the disadvantages of panel data

Two difficulties are often encountered in practice:
Selection bias and the incomplete panel. A panel is said to be complete if all the observations are filled in. Conversely, when observations are not filled in, the panel is said to be non-cylindrical, that means, to eliminate observations so that each individual has the same number of observations; in doing so, the researcher risks creating a cylindrical bias similar in these effects to selection bias in that the elimination of observations may be linked to an underlying economic mechanism. It is, however, relatively easy to test for a possible cylindrical bias by a Hausman-type specification that compares the model on the cylindrical and non-cylindrical sample the use of a non-cylindrical

sample can lead to problems of heteroscedasticity and/or autocorrelation of random deviations, it is then necessary to resort to adjustments of estimation methods taking into account the non-cylindrical nature of the samples. Most econometric software is capable of handling non-cylindrical panels, so these are no longer a major problem for most standard estimators. Time-consuming work in setting up samples and difficulties in locating points aberrant.

3.7.Presentation of the model

Total energy demand modelling can be applied either to the economy as a whole or at sectoral level, such as the residential sector, transport and industry, and then to obtain the total consumption by addition. This is the This first approach is preferred. Our modelling proceeds on two levels: on the at the first level, the total energy consumption by the above three sectors measured in kilo tons of oil is expressed as an endogenous variable. At the second level, the other variables used to represent the different aspects such as: GDP, CO2 emission, energy intensity, dirt index, etc. are presented as exogenous variables. More formally, the integrated pattern of total energy demand by these three sectors can be expressed as follows:

$$\mathbf{Log\ EC_{it}} = \boldsymbol{\alpha_i} + \boldsymbol{\beta_1}\mathbf{Log\ GDPi_{,t}} + \boldsymbol{\beta_2}\mathbf{LogEIi_{,t}} + \boldsymbol{\beta_3}\mathbf{Log}\boldsymbol{CO_{2_{i,t}}} + \boldsymbol{\beta_4}\mathbf{LogIDi_{,t}} + \boldsymbol{\varepsilon_{i,t}}$$

The assumption is made that the total energy consumption by these three sectors is a function of the GDP, total carbon dioxide (CO2) emissions and the dirt index and cannot incorporate the population because sometimes the population in the industrial sector is also in the residential sector at the same time so in order to have unbiased results it is important not to incorporate the population as an endogenous variable. The model is presented as a linear relationship between the different variables expressed in Log. Thus, we define:

ENRit: as the total energy consumption by sector (i) in year t

GDPit: As GDP (Gross Domestic Product) by sector (i) in year t

CO2it: As total carbon dioxide (CO2) emissions from energy consumption by sector (i) in year t

$EIi_{,t}$: as energy intensity per sector (i) in year t

$IDi_{,t:}$ as a dirt index per sector (i) in year t

3.7.1. Unit root tests in panels

Unit root tests in time series inspired by Unit root tests on panel data, including Phillips-Perron (PP). Levin and Lin (1992; 1993) were the first to propose a unit root test on panel data. Various tests have subsequently been proposed in the literature (Levin and Lin, 1993; Quah, 1994; Im, Pesaran and Shin, 1997, IPS). In this exercise, we will present four-unit root tests. The first two are first generation tests in which independence between individuals is assumed and the second two will be second generation tests that allow for dependence between individuals.

3.7.2. Non-stationarity tests

In general, root tests on panel data are based on regression following:

$\Delta y_{it} = a_i + \rho_i y_{it-1} + \varepsilon_{it}$

Where $i = 1, ..., N$ denotes the individual, $t = 1, ..., T$ et $\varepsilon it \sim iid$ $(0, \sigma_i^2)$. The null hypothesis tested is the unit root hypothesis, it means $\rho_i = 0$ $\forall i$.

The different tests are then distinguished by the degree of heterogeneity inserted under the alternative. The first unit root tests on panel data are due to Quah (1992, 1994) and Levin and Lin (1992, 1993). The tests proposed by Quah are correct when N et T tend to infinity at the same rate, do not take into account the possibility of heterogeneous dynamics between individuals, and also, the existence of individual specific effects and the presence of auto correlation in the residual series. A more general test proposed by Levin and Lin (1992, 1993) which allows for the presence of individual specific effects and heterogeneity between individuals. This test also proposes that N et T tend to infinity, but T increase more rapidly so that $N/T \rightarrow 0$. Under the alternative hypothesis, the alternative and autoregressive coefficients are assumed to be homogeneous across individuals, that means $\rho_i = \rho < 0 \forall i$. As this assumption is highly restrictive, an alternative test procedure proposed by Im, Pesaran and Shin (2003) based on the mean of the unit root test statistics allowing for the presence of residual serial correlation and heterogeneous dynamics.

3.7.3. Second generation tests

In this context we choose to present only the tests of Choi (2002) and Pesaran (2003).

Choi (2002) suggests an approach to test the unit root hypothesis by transforming the observed series yit to eliminate potential deterministic trends and correlations inter-individual. The test proposed by Pesaran is very simple, in order to identify possible dependencies between individuals. Indeed, the unit root test proposed by Pesaran differs from other authors, notably Choi (2002) who carried out a unit root test on transformed variables. Pesaran chooses to test the possible presence of a unit root directly on the raw series y_{it} by augmenting the DF or ADF model with individual means y_{it-1} and first differences Δy_{it}. This model thus becomes an augmented CADF (Cross Sectionally Augmented Dickey-Fuller) model. However, this test no longer follows standard asymptotic distributions.

3.8.Cointegration

The theory of cointegration made its debut in the mid-1980s, in 1974 by Engle and Newbold. Indeed, it was developed by Engle and Granger (1987) to deal with the links between the non-stationary components of several time series. The basic idea is that these components can be in some sense neutralized by one or more linear combinations of the series in question to give rise to one or more stationary series(Hatemi-J, 2020).

If X_t and Y_t are two series I (d) then in general the linear combination $Z_t = X_t$ –a Y_t is also I (d). However, it is possible that Zt does not follow I (d) but I (d - b) where b > 0, in which case X_t and Y_t are said to be cointegrated and the vector (1, -a) is the cointegration vector. Graphically, X_t and Yt can have a divergent evolution (they are both non-stationary) in the short run but they will evolve together in the long run. There is therefore a stable long-term relationship between X_t and Y_t. This relationship is called the cointegration relationship or the long-run relationship is given by X_t = a Y_t (Z_t = 0). In the long run, the series X_t and Y_t have similar trend movements which, by linear combination, will compensate each other to obtain a stationary series. If the series are cointegrated, the trajectory of Z_t will remain in the vicinity of its mean which is finite. Thus, Z_t measures the extent of the imbalance in the relationship between X_t and Y_t, which Granger (1986) describes as the "equilibrium error". On the other hand, if the series are not cointegrated, they would diverge with unit probability, their difference being non-stationary. Hence there is not necessarily a value of a which gives a $Z_t \sim I(0)$. The most studied case corresponds to d = b =1 which was mentioned by Engel and Granger (1987). Thus two non-stationary series, it means, we can say to be cointegrated if there is a stationary linear combination, which is $Z_t \sim I(0)$ if

$Z_t = X_t - a Y_t$, with X_t and Y_t evolving in a similar way and if a = 1 their difference will be

$Z_t \sim I(0)$. To study the existence of cointegrating relationships, two testing approaches are often used, the two-step method (Engle and Granger (1987)) and the maximum likelihood method (Johansen (1988, 1991)).

3.9.Panel cointegration tests

As in the case of time series, the problem of spurious regression arises in the case of in the context of panel data, several authors have proposed a multitude of tests to deal with this problem, allowing the estimation of a long-term relationship between various variables. Certainly, it must be said that the use of cointegration techniques to test for the presence of long-run relationships between integrated variables has enjoyed increasing popularity in the empirical literature, and this acceleration in popularity among researchers is due to the performance of the tests. We recommend presenting here only the Pedroni test which is based on the null hypothesis of no cointegration(Örsal, 2008).

3.10. CAUSALITY

The search for the direction of causality between variables is as important as the demonstration of a link between them. There are several definitions of causality, and we will limit ourselves to one of them: causality in the sense of Granger (1969)(Friston et al., 2014).

3.10.1. Definition of causality

The question is whether or not the variable X causes the variable Y. The variable Y is said to cause the variable X in the Granger sense if and only if the knowledge of Y's past improves the prediction of X at any horizon. Otherwise:

- Y causes X at date t if and only if:

$E(X_t/X_{t-1}, Y_{t-1}) \neq E(X_t/X_{t-1})$

with $X_{t-1} = \{X_{t-1}, X_{t-2}, \dots\} = \{X_{t-i}, i \geq 1\}$
$Y_{t-1} = \{Y_{t-1}, Y_{t-2}, \dots\} = \{Y_{t-i}, i \geq 1\}$

- Y causes X instantaneously at date t if and only if:

$E(X_t/X_{t-1}, Y_t) \neq E(X_t/X_{t-1}, Y_{t-1})$
Avec $Y_t = \{Y_t, Y_{t-1}, \dots\} = \{Y_{t-i} i \geq 0\}$

It follows from the properties of theoretical linear regression that a forecast of a variable based on more information is necessarily better. Thus, we always have: $V_\varepsilon(X_t/X_{t-1}, Y_{t-1}) \leq V_\varepsilon(X_t/X_{t-1})$ With V_ε is the variance-covariance matrix of the forecast error. So, we can present the condition of non-causality. Indeed, Y does not cause X to the
date t if: $V_\varepsilon(X_t/X_{t-1}, Y_{t-1}) = V_\varepsilon(X_t/X_{t-1})$

3.10.2. Measures of causality

Causality measures can be defined

- Measure of causality from Y to X: $C_{Y\to X} = \log \left[\frac{\det V_\varepsilon(X_t/X_{t-1})}{\det V_\varepsilon(X_t/X_{t-1}, Y_{t-1})}\right]$

If Y does not cause X, then $C_{Y\to X} = 0$ sinon $C_{Y\to X} > 0$

3.10.3. Granger Panel Causality

Panel data cointegration is a method for verifying the existence or absence of a panel data. the absence of the long-term relationship between the variables. It does not specify the direction of causality. Where a co-integration relationship exists between variables, it should be modelled in a Engle and Granger (1987) dynamic error correction model(Lopez & Weber, 2017). The main aim of each study is to establish causal links between the endogenous variable and the set of exogenous variables, the Granger causality tests will be based on the regressions following:

$$(\mathbf{1-L})\begin{pmatrix}\mathbf{EC_{it}}\\ \mathbf{GDP_{it}}\\ \mathbf{EI_{it}}\\ \mathbf{CO_{2_{it}}}\\ \mathbf{IS_{it}}\end{pmatrix}=\begin{pmatrix}\mathbf{a_iEC}\\ \mathbf{a_iGDP}\\ \mathbf{a_iEI}\\ \mathbf{a_iCO_2}\\ \mathbf{a_iIS}\end{pmatrix}+\sum_{\mathbf{i=1}}^{\mathbf{P}}(\mathbf{1-L})\begin{pmatrix}\boldsymbol{\varphi}_{\mathbf{11ip}} & \boldsymbol{\varphi}_{\mathbf{12ip}}\\ \boldsymbol{\varphi}_{\mathbf{21p}} & \boldsymbol{\varphi}_{\mathbf{22p}}\end{pmatrix}\begin{pmatrix}\mathbf{EC_{it-p}}\\ \mathbf{GDP_{it-p}}\\ \mathbf{EI_{it-p}}\\ \mathbf{CO_{2_{it-p}}}\\ \mathbf{IS_{it-p}}\end{pmatrix}+\begin{pmatrix}\boldsymbol{\beta}\mathbf{EC_i}\\ \boldsymbol{\beta}\mathbf{GDP_i}\\ \boldsymbol{\beta}\mathbf{EI_i}\\ \boldsymbol{\beta}\mathbf{CO_{2_i}}\\ \boldsymbol{\beta}\mathbf{IS_i}\end{pmatrix}\mathbf{ECT_{t-1}}+\begin{pmatrix}\boldsymbol{\varepsilon}_{\mathbf{1t}}\\ \boldsymbol{\varepsilon}_{\mathbf{2t}}\end{pmatrix}$$

p is the Lag (the delay length), 1-L is the first difference operator and ECTt-1 mean the offset error correction term from the Cointegration relationship. The error correction model distinguishes between the long-term and short-term relationship in Granger causality. Short-term dynamics are captured by the various coefficients of the lagged terms. The statistical significance of the coefficients of each variable is used to test for long-term Granger causality while the significance of the coefficients of ECTt-1 provides information on short-term causality. It is also desirable to check whether the two sources of causality are jointly significant.

3.11. Principle of verification of the Kuznets curve hypothesis for Madagascar

The objective here is to show which of the three sectors follows the inverse Kuznets curve, it means the demonstration will be done only with the use of panel data. According to the literature review, CEK is essentially an empirical phenomenon. The basic specification for examining the evolution of environmental degradation in terms of economic growth is presented by a two or three stage polynomial function. For this purpose, we will examine the direct relationship between the evolution of CO2 emissions and the GDP of its three sectors. For this purpose, three models will be presented: the linear model, the semi-log-linear model and the log-linear model(Stern, 2004).

They are presented as follows:

$$\boldsymbol{CO_{2_{it}} = \gamma_i + \gamma_1 PIB_{it} + \gamma_2 PIB_{it}^2 + \varepsilon_{it}}$$

$$\boldsymbol{CO_{2_{it}} = \delta_i + \delta_1 LogPIB_{it} + \delta_2 (LogPIB_{it})^2 + \mu_{it}}$$

$$\boldsymbol{LogCO_{2_{it}} = \theta_i + \theta_1 LogPIB_{it} + \theta_2 (LogPIB_{it})^2 + \vartheta_{it}}$$

With:

CO2 represents CO2 emissions by sector.

GDP represents income per sector.

γ_i , δ_i and θ_i represent the individual effects.

$\varepsilon_{it}, \mu_{it}\ et\ \vartheta_{it}$ are white noise error terms. i = 1, ..., N (N: number of sectors) and t = 1, ..., T (T: number of years).

3.12. Kaya Identity

The Kaya identity is one of the commonly used methods to analyze CO2 trends. It is an accounting decomposition of emissions into several factors: population, GDP per capita, energy intensity of GDP and CO2 intensity of energy. We will study the evolution of Madagascar's CO2 emissions in the light of these elements, which we will present in turn(Hwang et al., 2020). As seen in the introduction, the equation of this KAYA identity is the following:

$$\boldsymbol{CO_2 = P * \frac{GDP}{P} * \frac{E}{GDP} * \frac{CO_2}{E}}$$

The objective here is to estimate Madagascar's CO2 emissions by 2030 based on the use of this identity. When this is done, we compare the international convention held at COP21 in Paris that limits Madagascar's CO2 emissions until 2030. The purpose of this assessment is to establish a clear policy for Madagascar to achieve this goal.

3.13. Data resources

As the study will be conducted in one country, the data to be used in this thesis comes from national and international institutions, including the "Institut National de la Statistique de Madagascar" and the Ministry of Energy and Mineral Resources Hydrocarbons of Madagascar as well as data from the World Bank and the International Energy Agency.

3.14. Summary of literature review

The methodology used in this thesis is the following: first the unit root test to check if the model is stationary or not. The reason why this stationarity test should be done is to see if the variance accumulates with each increase in time or not? The reason why the stationarity test should be done is to see if the variance accumulates with each increase in time or not, because when this variance increases then it is difficult to find the direction of the trend so it is complicated to make the forecast, that's why the stationary test should be done. Once finished that, cointegration analysis was done to examine the long-term relationship of the variables, then causality test was also done to examine the direction of the inter-variables in the combined sectors.

CHAPTER FOUR

DATA ANALYSIS

This first table shows the number of all observations in the panel data to be analyzed and all the means for each variable and also shows the standard deviation and the minimum and maximum of each variable.

Table 2: Descriptive statistics

Variable		Mean	Std. Dev.	Min	Max	Observations	
EC	overall	1339.685	660.486	156.59	3245	N =	99
	between		533.4877	874.3568	1921.937	n =	3
	within		494.5364	526.9587	2662.749	T =	33
GDP	overall	1884.404	1766.004	248.0314	7378.735	N =	99
	between		1453.962	839.328	3544.865	n =	3
	within		1301.942	-737.2932	5718.274	T =	33
EI	overall	.1832907	.1104042	.0074753	.5572188	N =	99
	between		.0396663	.1442473	.223552	n =	3
	within		.1054961	-.0327859	.5584367	T =	33
CO2	overall	232.5498	121.7264	101.09	630.35	N =	99
	between		15.59837	215.0756	245.0682	n =	3
	within		121.0515	88.57161	617.8316	T =	33
ID	overall	.130533	.0194468	.0857032	.1801	N =	99
	between		.0099782	.1190112	.1363369	n =	3
	within		.0176388	.0879949	.1742961	T =	33

Sourse: author from Stata 16

Table 3: Correlation of variables

	EC	GDP	EI	CO2	ID
EC	1.0000				
GDP	0.8536	1.0000			
	0.0000				
EI	0.4140	0.2959	1.0000		
	0.0000	0.0029			
CO2	0.4454	0.4622	-0.0145	1.0000	
	0.0000	0.0000	0.8865		
ID	0.0277	0.0388	-0.0469	0.6133	1.0000
	0.7857	0.7030	0.6448	0.0000	

Sourse: author from Stata 16

This result shows the correlation between all these variables but does not indicate which variable in which sector correlates with which. This is a small limitation of this method. According to the table below, each variable has a positive and negative correlation. If the number is positive, both variables have a positive correlation, but if it is negative, then there is a negative correlation. Moreover, it is also checked if the value is close to 1 and positive, then we can say that there is a strong positive correlation between the variables but if it is less than 0.5 then there is a weak positive correlation and the opposite in case of negative values.

As shown in this table, there is a strong correlation between gross domestic product and energy consumption as the correlation level is higher than 85%. Also, the pollution index and CO2 emissions have a high level as it is more than 61%. Except for those that have a positive correlation, all their relationships are weak. We also find that there is a negative correlation between CO2 emissions and energy intensity and also between dirt index and energy intensity; that is, if one of them goes up, the other goes down, but the levels of correlation found are very low. Here, what was said in the introduction proves that if a country wants to increase its economic growth, it must also increase its energy consumption.

In the analysis of the relationship in the long run-in panel data, the choice of the appropriate technique is a very important theoretical and empirical issue. Cointegration is the most appropriate technique to study the long-run relationship between our variables. The empirical strategy used in this paper can be divided into three main steps. First, unit root tests (IPS and LLC) are undertaken. Secondly, co-integration tests are used. Finally, the panel Granger causality test will be undertaken.

4.1.Unit root tests

To study the stationarity of the series used, we used IM Pesaranshin's unit root tests and Levin Lin and Chu.

The assumptions made here are both H0 and Ha

Ho: all panels have unit roots, that means non-stationary

Ha: all panels are fixed

Table 4: The IM Pesaran shin unit root test.

```
Im-Pesaran-Shin unit-root test for lnEI

Ho: All panels contain unit roots           Number of panels  =      3
Ha: Some panels are stationary              Number of periods =     33

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Not included

ADF regressions: No lags included
```

	Statistic	p-value	Fixed-N exact critical values 1%	5%	10%
t-bar	-1.8414		-2.430	-2.160	-2.020
t-tilde-bar	-1.7289				
Z-t-tilde-bar	-0.6179	0.2683			

Im-Pesaran-Shin unit-root test for **lnEC**

Ho: All panels contain unit roots
Ha: Some panels are stationary

Number of panels = 3
Number of periods = 33

AR parameter: **Panel-specific**
Panel means: **Included**
Time trend: **Not included**

Asymptotics: **T,N -> Infinity sequentially**

ADF regressions: **No lags included**

	Statistic	p-value	Fixed-N exact critical values 1%	5%	10%
t-bar	-0.5005		-2.430	-2.160	-2.020
t-tilde-bar	-0.4715				
Z-t-tilde-bar	2.1308	0.9834			

Im-Pesaran-Shin unit-root test for **lnGDP**

Ho: All panels contain unit roots
Ha: Some panels are stationary

Number of panels = 3
Number of periods = 33

AR parameter: **Panel-specific**
Panel means: **Included**
Time trend: **Not included**

Asymptotics: **T,N -> Infinity sequentially**

ADF regressions: **No lags included**

	Statistic	p-value	Fixed-N exact critical values 1%	5%	10%
t-bar	-0.7055		-2.430	-2.160	-2.020
t-tilde-bar	-0.7066				
Z-t-tilde-bar	1.6167	0.9470			

Im-Pesaran-Shin unit-root test for **lnID**

Ho: All panels contain unit roots
Ha: Some panels are stationary

Number of panels = 3
Number of periods = 33

AR parameter: **Panel-specific**
Panel means: **Included**
Time trend: **Not included**

Asymptotics: **T,N -> Infinity sequentially**

ADF regressions: **No lags included**

	Statistic	p-value	Fixed-N exact critical values 1%	5%	10%
t-bar	-2.6754		-2.430	-2.160	-2.020
t-tilde-bar	-2.4256				
Z-t-tilde-bar	-2.1410	0.0161			

```
Im-Pesaran-Shin unit-root test for lnCO2
----------------------------------------
Ho: All panels contain unit roots           Number of panels  =      3
Ha: Some panels are stationary              Number of periods =     33

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                   sequentially
Time trend:   Not included

ADF regressions: No lags included
------------------------------------------------------------------------------
                                              Fixed-N exact critical values
                    Statistic      p-value          1%        5%       10%
------------------------------------------------------------------------------
 t-bar               -0.0432                     -2.430    -2.160    -2.020
 t-tilde-bar         -0.0439
 Z-t-tilde-bar        3.0654        0.9989
------------------------------------------------------------------------------
```

Source: Author from Stata 16

Interpretation

As can be seen in these tables, each test includes five variables (energy consumption, domestic product growth, CO2 emissions, energy intensity and dirt index). Here, all sectors are combined in the form of panel data analysis to see whether the five variables in the three sectors are stationary or not.

From the analysis performed with STATA 16 software, we have produced tables that contain several numbers in which the p-value is the most important for each of them. The decision rule that is followed here is that if the p-value is greater than 5% then we accept Ho and we reject Ha, but if the p-value is less than 5% then we reject Ho and we accept Ha.

According to the Im-Pesaran-Shin test that all these tables show, we can see that all the p-values are higher than 5% except for the LnID variable, that means in the long term all the variables are not stationary so a first distinction must be made in order to convert them into stationary.

To confirm the above result, another test must be performed and it is the Levin-Lin-Chu test.

The decision rules are the same as above:

Ho: all panels have unit roots, that means non-stationary

Ha: all panels are fixed

Table 5: The Levin-Lin-chu unit root test

```
Levin-Lin-Chu unit-root test for lnEC

Ho: Panels contain unit roots              Number of panels  =      3
Ha: Panels are stationary                  Number of periods =     33

AR parameter: Common                       Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 10.00 lags average (chosen by LLC)

                    Statistic      p-value

 Unadjusted t         0.5368
 Adjusted t*          1.5412         0.9384
```

```
Levin-Lin-Chu unit-root test for lnGDP

Ho: Panels contain unit roots              Number of panels  =      3
Ha: Panels are stationary                  Number of periods =     33

AR parameter: Common                       Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 10.00 lags average (chosen by LLC)

                    Statistic      p-value

 Unadjusted t        -1.3603
 Adjusted t*         -0.8655         0.1934
```

```
Levin-Lin-Chu unit-root test for lnEI

Ho: Panels contain unit roots              Number of panels  =      3
Ha: Panels are stationary                  Number of periods =     33

AR parameter: Common                       Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 10.00 lags average (chosen by LLC)

                    Statistic      p-value

 Unadjusted t        -2.6548
 Adjusted t*          0.0458         0.5182
```

```
Levin-Lin-Chu unit-root test for lnCO2
--------------------------------------
Ho: Panels contain unit roots           Number of panels  =      3
Ha: Panels are stationary               Number of periods =     33

AR parameter: Common                    Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 10.00 lags average (chosen by LLC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 Unadjusted t         0.7402
 Adjusted t*          2.1525        0.9843
------------------------------------------------------------------------------
```

```
Im-Pesaran-Shin unit-root test for D.lnEI
-----------------------------------------
Ho: All panels contain unit roots           Number of panels  =      3
Ha: Some panels are stationary              Number of periods =     32

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                     sequentially
Time trend:   Not included

ADF regressions: No lags included
------------------------------------------------------------------------------
                                                Fixed-N exact critical values
                    Statistic      p-value          1%       5%       10%
------------------------------------------------------------------------------
 t-bar               -6.6739                     -2.430   -2.160   -2.020
 t-tilde-bar         -4.2467
 Z-t-tilde-bar       -6.1351        0.0000
------------------------------------------------------------------------------
```

```
Levin-Lin-Chu unit-root test for lnID
-------------------------------------
Ho: Panels contain unit roots           Number of panels  =      3
Ha: Panels are stationary               Number of periods =     33

AR parameter: Common                    Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 10.00 lags average (chosen by LLC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 Unadjusted t        -4.4821
 Adjusted t*         -2.5773        0.0050
------------------------------------------------------------------------------
```

Source: Auther from Stata 16

All the results obtained in this other test confirm what the first test said because all the variables except LnID are not stationary and so we have to make a first difference to make all these variables stationary.

4.2.unit root test for variables in firts difference

In order to make all variables stationary, we will do a first difference and if the p-value is less than 5% then Ho will be rejected, that means the variable is stationary.

The following tables show the results obtained using the Im-Pesaran-Shin method.

Table 6: The Im-Pesaran-Shin unit root test

```
Im-Pesaran-Shin unit-root test for D.lnCO2
------------------------------------------
Ho: All panels contain unit roots           Number of panels  =      3
Ha: Some panels are stationary              Number of periods =     32

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                     sequentially
Time trend:   Not included

ADF regressions: No lags included
------------------------------------------------------------------------------
                                              Fixed-N exact critical values
                  Statistic      p-value          1%        5%       10%
------------------------------------------------------------------------------
 t-bar             -7.0126                     -2.430    -2.160    -2.020
 t-tilde-bar       -4.3205
 Z-t-tilde-bar     -6.2966        0.0000
------------------------------------------------------------------------------
```

```
Im-Pesaran-Shin unit-root test for D.lnGDP
------------------------------------------
Ho: All panels contain unit roots           Number of panels  =      3
Ha: Some panels are stationary              Number of periods =     32

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                     sequentially
Time trend:   Not included

ADF regressions: No lags included
------------------------------------------------------------------------------
                                              Fixed-N exact critical values
                  Statistic      p-value          1%        5%       10%
------------------------------------------------------------------------------
 t-bar             -6.2978                     -2.430    -2.160    -2.020
 t-tilde-bar       -4.1525
 Z-t-tilde-bar     -5.9289        0.0000
------------------------------------------------------------------------------
```

```
Im-Pesaran-Shin unit-root test for D.lnID

Ho: All panels contain unit roots           Number of panels  =      3
Ha: Some panels are stationary              Number of periods =     32

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                    sequentially
Time trend:   Not included

ADF regressions: No lags included
-------------------------------------------------------------------------
                                            Fixed-N exact critical values
                    Statistic     p-value        1%       5%       10%
-------------------------------------------------------------------------
 t-bar               -6.9262                  -2.430   -2.160   -2.020
 t-tilde-bar         -4.2650
 Z-t-tilde-bar       -6.1751       0.0000
-------------------------------------------------------------------------
```

```
Im-Pesaran-Shin unit-root test for D.lnEC

Ho: All panels contain unit roots           Number of panels  =      3
Ha: Some panels are stationary              Number of periods =     32

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                    sequentially
Time trend:   Not included

ADF regressions: No lags included
-------------------------------------------------------------------------
                                            Fixed-N exact critical values
                    Statistic     p-value        1%       5%       10%
-------------------------------------------------------------------------
 t-bar               -6.3452                  -2.430   -2.160   -2.020
 t-tilde-bar         -4.1630
 Z-t-tilde-bar       -5.9518       0.0000
-------------------------------------------------------------------------
```

Source: Author from Stata 16

As can be seen from these tables, the p-value of all variables is less than 5% when the first difference is taken and therefore all these variables are now stationary.

4.3.Another test

In order to ensure that all these variables are stationary after the first difference, we need to use another test. We use the Levin-Lin-Chu test.

Table 7: The Levin-Lin-Chu unit root test

```
Levin-Lin-Chu unit-root test for D.lnGDP

Ho: Panels contain unit roots              Number of panels  =      3
Ha: Panels are stationary                  Number of periods =     32

AR parameter: Common                       Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 10.00 lags average (chosen by LLC)

                    Statistic      p-value

 Unadjusted t         -7.6517
 Adjusted t*          -4.9044       0.0000
```

```
Levin-Lin-Chu unit-root test for D.lnEI

Ho: Panels contain unit roots              Number of panels  =      3
Ha: Panels are stationary                  Number of periods =     32

AR parameter: Common                       Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 10.00 lags average (chosen by LLC)

                    Statistic      p-value

 Unadjusted t         -6.7597
 Adjusted t*          -3.4222       0.0003
```

```
Levin-Lin-Chu unit-root test for D.lnEC

Ho: Panels contain unit roots              Number of panels  =      3
Ha: Panels are stationary                  Number of periods =     32

AR parameter: Common                       Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 10.00 lags average (chosen by LLC)

                    Statistic      p-value

 Unadjusted t         -7.2450
 Adjusted t*          -3.6557       0.0001
```

```
Levin-Lin-Chu unit-root test for D.lnCO2
------------------------------------------------
Ho: Panels contain unit roots                 Number of panels  =      3
Ha: Panels are stationary                     Number of periods =     32

AR parameter: Common                          Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 10.00 lags average (chosen by LLC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 Unadjusted t        -8.4262
 Adjusted t*         -5.2104        0.0000
------------------------------------------------------------------------------
```

```
Levin-Lin-Chu unit-root test for D.lnID
------------------------------------------------
Ho: Panels contain unit roots                 Number of panels  =      3
Ha: Panels are stationary                     Number of periods =     32

AR parameter: Common                          Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 10.00 lags average (chosen by LLC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 Unadjusted t        -9.5352
 Adjusted t*         -6.6920        0.0000
------------------------------------------------------------------------------
```

Source: Author from Stata 16

As can be seen from these results, the Levin-Lin-Chu test confirms the results of the Im-Pesaran-Shin test performed above and it can be said that all these variables are stationary when tested in first difference.

4.5.cointegration relationships between the variables

To check the cointegration of all these variables in the combined sectors, we will use two different tests.

Table 8: Test of KAO

```
Kao test for cointegration

Ho: No cointegration                        Number of panels       =      3
Ha: All panels are cointegrated             Number of periods      =     31

Cointegrating vector: Same
Panel means:          Included              Kernel:             Bartlett
Time trend:           Not included          Lags:               2.67 (Newey-West)
AR parameter:         Same                  Augmented lags:     1
```

	Statistic	p-value
Modified Dickey-Fuller t	-1.6693	0.0475
Dickey-Fuller t	-0.6686	0.2519
Augmented Dickey-Fuller t	0.2965	0.3834
Unadjusted modified Dickey-Fuller t	-2.5733	0.0050
Unadjusted Dickey-Fuller t	-1.0083	0.1567

Source: Author, from Stata 16

Here, the decision rule is the same as the first one; therefore, only the p-value is considered and if it is less than 5%, then Ho is rejected, it means the variable is cointegrating. The KAO test consists of 5 tests and also has five p-values. According to this result, two p-values are less than 5% in modified Dickey_Fuller and unadjusted modified Dickey-Fuller and the rest are greater than 5%. The question here is whether there is cointegration between the variables because the p-values are both higher and lower by 5%?

To know if there is a co-integration or not, we just have to count the number of p-values lower than 5% and then count also the number of p-values higher than 5%. Here we have three p-values above 5% and two below 5% so the Ho hypothesis is accepted, that is, there is no cointegration between the variables in these sectors according to KAO.

As done above, a single test will not be enough to make a decision, but we will have to use another test so that the result is not biased, so here the Pedroni test will be used again.

Table 9: Test of Pedroni

```
Pedroni test for cointegration
------------------------------
Ho: No cointegration                      Number of panels       =      3
Ha: All panels are cointegrated           Number of periods      =     32

Cointegrating vector: Panel specific
Panel means:          Included            Kernel:           Bartlett
Time trend:           Included            Lags:             3.00 (Newey-West)
AR parameter:         Same                Augmented lags:   1
------------------------------------------------------------------------------
                                          Statistic         p-value
------------------------------------------------------------------------------
 Modified variance ratio                   -1.9791          0.0239
 Modified Phillips-Perron t                 1.1952          0.1160
 Phillips-Perron t                          0.4087          0.3414
 Augmented Dickey-Fuller t                  0.2518          0.4006
------------------------------------------------------------------------------
```

Source:Author, from Stata 16

The method here is the same as the KAO test, that is to say that the p-values lower and higher than 5% are calculated so we see that only one is lower than 5% and the rest are higher so this test confirms that there is no cointegration between these variables.

4.6.Panel ganger causality test between all of those variables

The next step is made to test the causality between these variables using the Granger Causality panel test. This paper focuses on the relationship between CE, GDP, CO2, EI and ID. A Granger causality analysis is performed to determine if there is potential predictability power from one indicator to the other. The results of the Granger Causality Panel Test for all individuals are summarized in the following table.

Table 10: Panel ganger causality test

Variables	EC	GDP	CO2	EI	ID
EC	---	-0.1038 (0.9173)	1.0722 (0.2836)	-0.9051 (0.3654)	-0.7147 (0.4748)
GDP	3.1957 (0.0014)	---	-0.9885 (0.3229)	0.2416 (0.8091)	0.0003 (0.9998)
CO2	5.0605 (0.0000)	3.9036 (0.0001)	---	-0.1661 (0.8680)	1.4116 (0.1581)
EI	-0.1885 (0.8505)	0.1034 (0.9176)	0.1182 (0.9059)	---	-0.0398 (0.9682)
ID	2.4975 (0.0125)	3.5455 (0.0004)	4.6447 (0.0000)	-0.1395 (0.8891)	---

Source: Author, from Stata 16

Our study aims to illustrate the interactive relationships between all the variables GDP, CO2, EI, ID and between EC, but this does not prevent the study of all possible relationships. From the results of the Granger Causality Panel tests presented in the table above, we can deduce the direction of the causal relationships that may appear between the variables at the critical threshold (probability of error) of 5%. The results indicate the existence of a unidirectional causality to be reported from CO2 to EC. With respect to the other causal relationships between all variables, there is no causal relationship.

4.7.Kuznets curve hypothesis for Madagascar

In a first subsection, we will present for each group of countries the estimation results under the three specifications. In a second subsection, the results of the non-nested hypothesis tests will be presented. Before proceeding to the analysis of the estimation results, we present some descriptive statistics for this group.

Table 11: Descriptive statistics for CO2/p and GDP/p

	CO2/P	***GDP/P***
Mean	1.031255484	397.3578985
Median	0.998435206	361.769284
Standard Deviation	0.186273813	101.3025691
Minimum	0.668053594	269.5607
Maximum	1.369971544	541.0660586
Confidence Level(95.0%)	0.078656533	42.77632334

Source: Author, from R

The income is a preliminary indicator of an inverse U-shaped curve for Madagascar. According to the data analysis, the average per capita income is $ 397.35. The average per capita CO2 emission is 1.03 metric tons.

Table 12: Results of relative estimates for this $\boldsymbol{CO_{2_{it}} = \gamma_i + \gamma_1 PIB_{it} + \gamma_2 PIB_{it}^2 + \varepsilon_{it}}$

Coefficients				
	Estimate	**Std. Error**	**T value**	**Pr(>|t|)**
Intercept	-1.898e+00	1.727e+00	-1.099	0.2805
GDP/P	1.588e-02	8.713e-03	1.823	0.0783
(GDP/P)^2	-2.108e-05	1.035e-05	-2.037	0.0505

Source: Author, from R

Table 12: Results of relative estimates for this $\boldsymbol{CO_{2_{it}} = \delta_i + \delta_1 LogPIB_{it} + \delta_2 (LogPIB_{it})^2 + \mu_{it}}$

Coefficients				
	Estimate	**Std. Error**	**T value**	**Pr(>|t|)**
Intercept	5.0257	1.6653	3.018	0.00505
GDP/P	-1.6184	0.6336	-2.554	0.01577
(GDP/P)^2	-	-	-2.037	-

Source: Author, from R

Table 13: Results of relative estimates for this $LogCO_{2_{it}} = \theta_i + \theta_1 LogPIB_{it} + \theta_2 (LogPIB_{it})^2 + \vartheta_{it}$

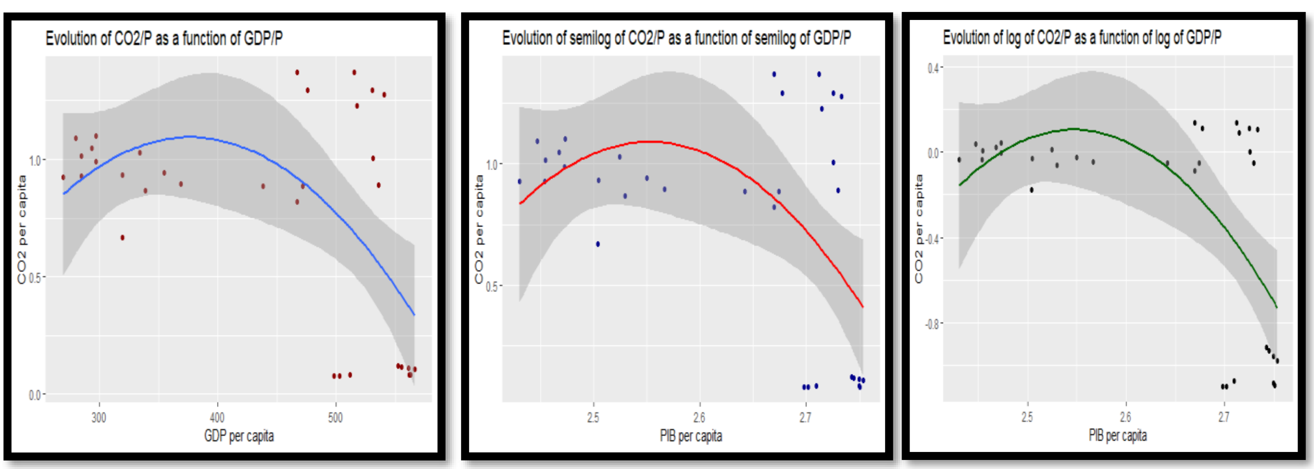
Coefficients				
	Estimate	**Std. Error**	**T value**	**Pr(>|t|)**
Intercept	5.2499	1.6404	3.200	0.00316
GDP/P	-2.1040	0.6241	-3.371	0.00202
$(GDP/P)^2$	-	-	-	-

Source:Author, from R

The estimation results are shown in the three tables above. The first finding is that all three models fit the data well with reference to the F-test for overall significance and the R^2. As far as specific effects are concerned, the F-test rejects the hypothesis of the absence of these effects, which confirms the use of the panel data methodology.

If we want to verify the CEK hypothesis for Madagascar we must have the sign of the linear term GDP is always positive and significant as well as the sign of the quadratic term GDP2 must be negative and significant. According to the above estimations, we find that all the signs of the GDP term are positive and the signs of the quadratic GDP2 are all negative that's why we obtain the inverse U curve below. Therefore, we can say that the necessary condition for the CEK hypothesis is verified for Madagascar. We can say that the increase of CO2 emission levels is a function of the growth of per capita income for Madagascar.

Figure 4: Madagascar's inverted U-curve



Source: Author, from R

These three figures show that there is a relationship between per capita CO2 emissions and per capita GDP for Madagascar because if the per capita income is still low then CO2 emissions are high. An example that justifies this is the use of charcoal in daily life; because people with low per capita income cannot consume electricity for cooking or daily needs and have to use mass wood. As we know that the use of this type of energy degrades the environment and increases the CO2 emissions considerably. We can say that the Kuznets Theory is true for Madagascar.

4.8.Kaya identity analysis of Madagascar

Table 14: Forecast of CO2 emission by KAYA identity

YEARS	P	GDP	GDP/P	TOE	TOE/GDP	CO2 emission	CO2/TOE
1994	13.1	352.22	26.956	12.5195	0.03554	121	9.66496
1995	13.5	383.81	28.482	15.5987	0.04064	137	8.78276
1996	13.9	493.19	35.474	14.7848	0.02998	131	8.86044
1997	14.3	426.30	29.712	16.6927	0.03916	142	8.50671
1998	14.8	440.20	29.725	19.7358	0.04483	163	8.2591
1999	15.3	427.79	27.992	19.8345	0.04636	167	8.41969
2000	15.8	462.92	29.361	18.2636	0.03945	165	9.03438
2001	16.3	543.83	33.444	16.769	0.03083	167	9.95885
2002	16.8	535.17	31.922	12.5364	0.02343	112	8.93396
2003	17.3	637.25	36.880	17.4017	0.02731	155	8.90718
2004	17.8	506.47	28.449	17.7342	0.03502	165	9.30406
2005	18.3	585.93	31.954	18.4969	0.03157	171	9.24477
2006	18.9	639.57	33.875	17.8519	0.02791	164	9.18669
2007	19.4	852.46	43.866	17.6166	0.02067	172	9.7635
2008	20.0	1072.51	53.635	18.2601	0.01703	178	9.74802
2009	20.6	961.69	46.754	19.1736	0.01994	169	8.81419
2010	21.2	998.27	47.196	21.2614	0.0213	187	8.79527
2011	21.7	1155.18	53.127	24.8683	0.02153	219	8.80637
2012	22.3	1157.90	51.815	31.0682	0.02683	274	8.8193
2013	23.0	1242.36	54.107	33.2377	0.02675	293	8.8153
2014	23.6	1252.30	53.086	34.5996	0.02763	305	8.81514
2015	24.23408	1132.3	46.723	70.202	0.062	332	4.72921
2016	24.89437	1184.86	47.596	71.091	0.06	322	4.52941
2017	25.57051	1317.63	51.529	75.346	0.05718	350	4.64524

Once all the parameters of KAYA have been predicted, then the results below are obtained by 2030 with the CO_2 emission.

year	P	GDP/P	TOE/GDP	CO2/TOE	KAYA
2030	32.1716	70.35068	0.037982	5.566982	478.5568

When all KAYA's parameters have been taken and the forecasts for 2030 have been made, we obtain 478.5568 million tons of CO_2 emissions. Then this amount should be Madagascar's CO_2 emissions by 2030, but according to COP 21, it should be reduced to 220 million tons of CO_2 emissions for Madagascar by 2030.

CO_2 emissions are the main cause of global warming and each country must take responsibility. So, KAYA identity is a way for each country to look at the sector that actually emits this CO_2. KAYA identity is composed of 4 parameters: population, GDP per capita, energy intensity and carbon intensity an according to that table above, it was found that Madagascar had a problem in how to use energy in production and needed to use technology to reduce the energy used in production in order to reach energy efficiency.

4.9.Summary of data analysis

In order to establish a pragmatic policy for a country then it is necessary to always rely on scientific analysis. The industrial, transport and residential sectors have been analyzed here in order to establish an adequate energy policy for Madagascar. Energy consumption, GDP, CO_2 emissions, dirt index and energy intensity were the variables used for all studies. Panel data analysis was carried out as it included both individuals and time. The analysis was done to examine the correlation between the variables in order to establish a strategy for the correlated variables. It was also examined which of these variables had a long-term relationship using cointegration analysis. The last step of the analysis in this master thesis is the causality test of all the variables. This in turn helps the decision maker when setting a development policy based on the variables that have unidirectional or bidirectional causality. At the end of these analyses, the Kuznets hypothesis testing for the Madagascar case was also carried out and finally the KAYA analysis identical to the Madagascar case.

CHAPTER FIVE

DISCUSSION OF THE FINDINGS

5.1.Introduction

This chapter is divided into two parts, the first of which will be the economic interpretation of all the above results and the second will be a global view of Madagascar's current energy policy.

Economic interpretation of the results obtained.

5.2.Discussion of the findings

From the first results of the correlation table of all the variables, we see that they are all correlated. The most important for us here is the relationship between GDP and EC, because the objective is to increase energy consumption in order to increase GDP without increasing CO2 emissions. According to the results, there is a very strong correlation between GDP and EC for Madagascar, which means that if Madagascar wants to increase its production, it must increase its energy consumption at the same time. As mentioned in the introduction, it was found that during the glorious thirty years there was a huge increase in energy consumption worldwide and even now we still see that energy is also a factor of production. In other words, the energy consumption of these three sectors must be increased in order to increase the share of GDP for Madagascar.

According to the results obtained in the cointegration analysis, the long-run relationship of the variables in these sectors exists but not all of them. If we want to see exactly which of these variables has a long run relationship and in which sector the HSIAO test must be performed so that we can determine if the model is heterogeneous. After testing this model and if it is heterogeneous then we can separate into three time series models; therefore, we can examine individually the long-term relationship between these variables and each sector. On the other hand, this master's thesis focuses on the panel data model and just focused on whether or not there is a long-run relationship between the data of these sectors and it was found that two results said yes (the long-run relationship exists) and three said no (the long-run relationship does not exist). We can say that this is the limit of this Master thesis.

As for the causality between the variables, they are all unidirectional. Here are the variables that have unidirectional causality that we found after the data analysis: GDP to EC, there is also CO_2 to EC and CO_2 to GDP and finally we found that there is also ID to (EC, GDP and CO_2). Economically speaking, when there is a policy on these variables on the left then there is a negative or positive externality to these variables on the right. It is not necessarily the policy that can influence them but it can also be the different natural hazards, for example a very destructive cyclone in Madagascar could reduce the GDP and this will lead to a reduction in energy consumption.

Concerning Kuznets' inverse U-curve, we can see that the three images on the Madagascar case follow his hypothesis. His hypothesis is that when CO_2 emissions per capita are high then GDP per capita is low. He also said that CO_2 emissions per capita always increase until the optimal level of GDP per capita is reached and then the level of CO_2 emissions per capita will decrease. More precisely, according to him, the higher the CO_2 emission the higher the GDP will increase until the optimal level is reached and after that the CO_2 emission per capita will decrease and the GDP per capita will continue to increase. If Madagascar wants to reduce its CO_2 emissions, it must increase its per capita income. Currently, the Malagasy government has adopted a new policy of limiting the population by using family planning, we can say that the government wants to increase the GDP per capita by reducing the fecundity rate of Malagasy women.

Regarding the estimate of CO_2 emission by KAY identity, it has been found to be higher than that set by COP21. In order to reduce this CO_2 emission and achieve what was announced in COP21, the state must resort to the sector that emits the most CO_2 and then implement a pragmatic CO_2 reduction policy for that sector. According to the analysis conducted in this thesis, it is found that there is a strong positive correlation between energy consumption and GDP in the industrial, transport and residential sectors; for this reason, the State must have an energy policy to achieve energy efficiency.

In relation to the above interpretations, Madagascar's current energy policy needs to be reviewed in order to recommend adequate policies to develop these three sectors.

5.3.Current energy policy of Madagascar

5.3.1. Biomass

The NPE supports efforts to protect forest resources and reforest 35,000 to 40,000 ha per year in order to secure wood energy supplies. The Ministry in charge of Energy will work closely with the Ministry in charge of the Environment and Forests to ensure that regulations are respected and reinforced. Investment in forestry production will be encouraged. These investments include reforestation for wood energy production, and watershed protection to sustain hydroelectric schemes. The territorial delimitation of wood-energy exploitation areas will be established, along with the setting up of a monitoring system and the professionalization of the sector. For biomass other than wood energy, an ambitious national strategy will be defined and administrative procedures simplified.

The improvement of techniques and energy efficiency in the fields of wood exploitation and processing will aim at better valorizing the raw material "wood" by reducing losses related to exploitation and carbonization. The replacement of carbonization wheels by high efficiency equipment will allow charcoal makers to significantly improve their production yields without major additional investments. An increase in efficiency of 12 to 20% is expected and will correspond to a 67% increase in carbonization productivity. This improvement will make it possible to considerably reduce the production area to obtain the same quantity of charcoal.

At the national level, the effective application of the improved technique of producing "green" charcoal from 100% charcoal millstones with a yield of more than 20% for legally and sustainably extracted forest resources (50% of the needs) will increase the market value of the order of 43 million USD over the period 2015-2030, and will create natural forest conservation benefits estimated at 73 million USD over the same period.

The optimization of carbonization will require the involvement of communities in the management of forest resources. Information on the benefits and techniques of efficient carbonization will be disseminated (both to professionals and consumers), training provided, regulations updated, means of enforcement allocated and access to finance facilitated.

Incentive and restrictive taxation will be promoted, complemented by climate financing. Local authorities will be made responsible, both in terms of taxation and enforcement of regulations. Information on forest biomass will be disseminated to producers, investors and consumers, and training will be provided. A reforestation financing program will be designed with the support of the international community. The most suitable agricultural biomass options will be identified and promoted. Forest and land information management will be improved. Biomass other than wood, agrofuel plantations (jatropha, sugarcane, others) will be developed considering the best use of the soil and the needs for agricultural products.

5.3.2. Domestic energy

Household adoption of fuel-efficient stoves (or gas stoves, briquettes and agrofuels) will reduce energy consumption by more than 40,000 TJ in 2030 and reduce health risks and costs nationwide.
An incentive information system on the techniques, opportunities and impacts of wood energy efficient stoves could attract operators and craftsmen and encourage them to invest in the production of these stoves. This activity will constitute a stable source of income in the face of the economic situation.

For modernization, continued formalization of the wood energy marketing chain is essential. The marketing centres should operate as small and medium-sized enterprises, subject to standardised financial management rules and promotion of alternative energy. The development of commercial spaces in rural and urban areas for the sale of wood fuels (firewood and charcoal) will aim to contribute to a more equitable distribution of the economic value added generated by the sector among the actors, and allow reinvestment in the sub-sector. These commercial spaces will make it possible to present labelled and certified products on the market, and will facilitate the diversification of product ranges.

Agro-fuel stoves will be promoted to reduce wood consumption. To this end, information campaigns on the advantages in terms of efficiency, reduction of time needed for fuel supply as well as improved sanitary conditions will be undertaken. Incentives for the production and sale of energy-efficient cookstoves will be adopted and access to finance facilitated through the microfinance system. Agricultural biomass resources such as rice husk and sugarcane as well as organic waste to produce heat, electricity and fuel can be used for power generation and cooking in urban and rural areas and should be further investigated.

The wood/biomass resource is also used in industrial processes. Information will have to be collected in order to specify the potential. It is necessary to revise and complete the legislative and regulatory framework of the biomass sub-sector, covering the entire production chain: forest management, plantations, exploitation, transformation, manufacture of fireplaces, transport, marketing, use, and monitoring and control. Law 97-017 on forestry policy and Decree 82-312 on charcoal production will be revised in this context to give preference to legal actors and combat illegal logging.

5.3.3. Electricity

Achieving the objective of access to electricity or a modern form of lighting by 70% of the population would imply an electricity production of 7,900 GWh by 2030, compared to the 1,500 GWh currently produced.

Increasing access to electricity and lighting can be achieved economically through a combination of systems: extension and interconnection of networks, mini-grids.

(i) Thus, of the three (3) interconnected networks of Antananarivo (RIA), Toamasina (RIT) and Fianarantsoa (RIF) currently in existence, they could be connected to each other or to other networks: RIAautonomous: RIA to be connected to the RIT and RIF to the autonomous networks of Ambositra, Mananjary and Manakara, then to the RIA via Antsirabe

(ii) New regional interconnected networks, which can supply rural, urban and peri-urban centres, will be envisaged for the regions, following the development of their respective potential hydroelectric sites, that means in the regions of SAVA, DIANA, Boeny, Betsiboka, Sofia, AlaotraMangoro.

(iii) For isolated centres, electrification could be achieved by means of mini-grids based on production plants using hydroelectric, biomass, wind, solar and diesel technologies (in case of absence or insufficiency of local renewable sources).

The networks will be extended through the development of the potential capacities of the hydroelectric sites, the optimal and rational exploitation of their energy efficiency, through an improvement of the "business" space in order to promote public-private partnerships and a consequent allocation of public investments for the energy sector.

i. According to Law 98-032, the concessionaires of interconnected networks and transmission networks are selected through a call for tenders by the concessioning authority. The operator holding a transmission concession in an interconnected system is the sole buyer in its system. The suppliers of the generation capacities are selected through tenders launched by the Concessionaire of the network or the Concession Authority according to an indicative plan elaborated by the BRO; the tariffs will be determined in order to cover the costs, respecting equity, and promoting solidarity between the different categories of consumers. Particular attention will be paid to the transition to new tariffs that take into account the consumers' capacity to pay (see the tariff study of the PAGOSE project, with the World Bank).

ii. For the promotion of private participation in large-scale hydroelectricity development, this policy refers to Law 98-032 regarding competitive bidding processes. The rules that apply will be defined to ensure transparency and fairness in the decision-making process, with possible guarantees. For the development of other renewable energy sources, measures such as feed-in tariffs and purchase obligations may be considered.

iii. The Government will ensure that regulatory and fiscal barriers to market development are removed.

5.3.4. Concerning JIRAMA:

i. The recovery and rehabilitation plan for JIRAMA, in all its aspects, financial, technical and in the use of financial and human resources, will make it possible to reduce technical, non-technical and financial losses. This plan will consist of restoring the proper functioning of the thermal power plants running on diesel in the various operating centres in order to put an end to load shedding and to build more facilities to increase production so that electricity connections can be resumed. This plan will be completed by a tariff study.

ii. JIRAMA's role should be as defined by Law 98-032. Similarly, future concessions for generation, transmission and distribution will be based on the results of studies.

Concessions will be based on transparent contractual (financial and service) relationships.

iii. JIRAMA will benefit from a legal and financial reinforcement, as well as additional means to fight fraud.

iv. JIRAMA's concessions and authorisations have been renewed in accordance with the regulatory framework while clearly defining the perimeters.

The prioritization of the implementation of generation, transmission and distribution systems will be based on the principle of economic efficiency complemented by equity and solidarity between regions and different segments of the population.

The fight against theft or fraud in the production, transport and distribution sector will take the form of communication actions, institutional changes as well as the implementation by the country's high authorities of the relevant regulations.

The participation of local communities will be encouraged in the development of renewable energy sources, whose potential will be accurately assessed and regularly updated. A competitive market approach will support the use of individual equipment (solar lamps, Solar Home Systems). For SSDs and solar lamps, the Government will undertake a communication effort with public and private stakeholders, establish quality standards, encourage replication of successful models, and set appropriate pricing rules. Financing will be facilitated for households.

The potential hydroelectric sites in the different regions will be developed to increase the access of the populations to the electricity service in order to improve their standard of living. Electrical energy in sufficient quantity and quality would constitute opportunities that can be offered to economic agents, in terms of transformation of local products, mechanization and industrialization in the regions themselves.

Sites exist for the economically viable exploitation of wind energy, particularly in the North (Antsiranana) and South East (Taolagnaro) regions. The solar potential is particularly important in the western and southern regions of the country. The exploitation of solar energy will make it possible to generate inexpensive electricity, in particular through urban self-production and off-grid installations in rural areas, thanks to the new technologies of electrical production and lighting, the prices of which will decrease.

5.3.5. Hydrocarbons

The actions envisaged will be harmonised with those developed in the 2014 National Mining and Petroleum Policy. The use of locally produced hydrocarbons, particularly heavy oil, for electricity generation will reduce the import bill and increase local skills. Studies should identify the types of hydrocarbons with the best potential for power generation. The introduction of management measures and more efficient consumption equipment for petroleum products in 60% of Malagasy businesses and industries will make it possible to save nearly 1000 TJ per year by 2030. Standards and controls for the import of hydrocarbons will have to be approved, and safety standards regularly updated and applied.

5.3.6. Renewable energy

The energy potentials and policy guidelines for renewable electricity generation and biomass are described in the sub-sectoral sections of the NPE. A comprehensive national mapping of hydropower resources with an investment plan will facilitate the optimal exploitation of hydropower resources. Similar studies will be required to identify the best sites for biomass resources (including solid and organic waste), solar and wind sites while taking into account environmental factors. Ocean and geothermal energy resources will also represent a potential to be explored, and studies will have to be conducted on innovative energies through funding available for climate mitigation technologies. 58. A general regulatory framework for renewable energies will be put in place with emphasis on :

i. diversification of resources ;
ii. production, transport, storage and distribution ;
iii. Procurement procedures, institutions responsible for their management and pricing ;
iv. decommissioning of facilities and waste management ;
v. instruments, accompanying measures and means of promotion, such as support for research, the use of hybrid systems and the provision of appropriate financial instruments to the sector.

5.3.7. Energy Efficiency

The economic gain will amount to USD 265 million per year in 2030 (other than the health benefit which is difficult to quantify), of which USD 232 million will come from electrical measures and USD 33 million from thermal measures. The economic benefit is measured by the significant reduction in consumption through energy efficiency, which has a direct financial impact.

The promotion of energy efficiency will be achieved through programming of energy efficiency solutions, energy efficiency regulations in new constructions, and support to consumers, industries, businesses and administrations for the acquisition of energy efficient equipment. The investment needed for households, businesses, and industries over the period 2015-2030 is estimated to be around USD 1.2 billion, of which USD 1.16 billion is for electricity efficiency and USD 32 million for thermal (and non-electric) efficiency.

5.3.8. Rural Electrification

Rural electrification covers all the rural or peri-urban areas of the Republic of Madagascar where no installations are installed. The rural electrification programme is implemented by ADER according to clear and transparent rules in compliance with the legal and regulatory framework in force. As such, it selects and implements projects on the basis of regional master plans that prioritize locally available renewable energy resources, including hydroelectricity, biomass, solar and wind power, in order to provide electricity to local development hubs (households, productive and commercial activities to be developed). ADER is working on the electrification of rural and peri-urban areas, either by extending the networks or in decentralized mode with mini-grids by promoting the development of regional interconnections, in partnership with JIRAMA and private operators. ADER will provide technical and financial support to these operators in the sector.

In addition, ADER will carry out studies with a view to the gradual replacement of existing thermal power plants by renewable energy in the regions concerned,

The participation of local communities will be encouraged in the identification of locally available renewable energy sources, which will be accurately assessed and regularly updated. In addition, the use of individual equipment such as solar lamps and solar home systems (SSD) will be encouraged and will be based on the dynamics of competitive markets. For SSDs and solar lamps, the

Government will undertake a communication effort with public and private stakeholders. Quality standards will be established. Replication of successful models will be encouraged. ADER would monitor and evaluate established systems and provide management assistance. A more coordinated approach to financing as outlined in the NPE will allow for an increase from 4.7% of the rural population having access to electricity in 2015 to 8 times or more by 2030, through institutional strengthening of ADER, improved regional energy planning and promotion of private sector and project implementation.

5.3.9. Capacity and knowledge building

For the Ministry in charge of Energy and related agencies, it is estimated that new posts will be created for the period 2015-2017 to ensure the implementation of the policy in the first years. This capacity will increase in line with the Government's resource mobilization effort and the growing number of projects.

A framework for the implementation of the NEP will be created, including the strengthening of human and technical capacities of institutions, the creation of specific procedures for decision-making and monitoring, and the identification of technical assistance needs. School, university and vocational training curricula will be reviewed and reformed to include the acquisition of specific energy-related skills (production, consumption, energy management). An increasing number of specialized teachers and trainers will be trained. Increased regional and international cooperation will enable Madagascar to participate in programmes of excellence in the field of energy studies, to benefit from capacity building and knowledge in the energy sector. Research centres and laboratories will be supported and will work in synergy with the institutions and the various operational entities,

5.3.10. Prioritization of actions

The actions related to the implementation of the NPE will have to be prioritized, as some are urgent and do not require preliminary work, while others are underway at the time of the policy's development or condition the implementation of the policy in its entirety. This prioritization does not necessarily reflect the chronology of the implementation of interventions. Rather, it is a matter of identifying priority actions, the monitoring and implementation of which will require particular attention.

5.3.11. Summary of discussion of the findings

The results were clearly defined in the discussion on the variables that can stimulate growth that the Malagasy government should consider in the energy policy. It was indicated that energy consumption should be increased in order to increase production in the three sectors considered in this master thesis. Even the government will increase the energy consumption so it must put in place a strict policy in order to achieve the objectives set by the COP21 on the reduction of CO2 emissions. An analysis of Kuznats curve and KAYA identity shows that there should be no environmental degradation for Madagascar if the energy consumption will increase because the GDP per capita will increase and the CO2 emissions per capita will decrease as mentioned in Kuznets hypothesis. According to the analysis that has been done with the KAYA identity, obviously the state must implement strategies to achieve energy efficiency in order to increase productivity.

CHAPTER SIX

GENERAL CONCLUSION AND POLICY RECOMMENDATION

6.1.General conclusion

Energy is as vital to countries as food or access to water is to human beings. Population growth throughout the world is contributing to a veritable explosion in energy needs. However, the observation of energy production and consumption on a global scale shows strong inequalities between the different continents. The difference in the level of development between countries is found in the energy intensity. In developed countries, this intensity is higher, while in developing countries it is still low. Energy security also remains a major problem for poor countries. This energy security is based on two obstacles: the ability to obtain energy resources and the availability of at least one form of exploitable resources to stimulate development. This second statement in fact sums up the high external dependence on oil supplies for some countries. However, foreign dependence does not necessarily mean that a country is energy insecure. China, for example, is a country dependent on others for some types of energy, and even though it is currently the world's largest consumer of energy, China's economic growth is still in a better position.

Until the awareness of the environmental degradation in the sixties, the most used energy sources are still fossil energy, coal and wood. These different sources are used mainly in the processing and power generation industries, in transportation, in the household and in several fields. The role they have played in economic growth explains the current position of developed countries. From the first industrial revolution to the present, these types of energy remain the most dominant. According to the International Energy Agency, fossil fuels will continue to dominate in 2030. Energy is the driving force behind the economic and social development of any country and for poor countries it presents opportunities to be exploited. The main question of this study was which sector should really implement the energy policy in order to increase the GDP of Madagascar. In an attempt to answer this question, we conducted an investigation on three sectors over a period from 1985 to 2017.

Using the Logarithm model, the implementation of unit root test, cointegration test and causality test in panel data found that there is no long run equilibrium relationship between energy consumption, economic growth, CO_2 emission, energy intensity and index of dirty in the industrial, transport and residential sectors. On the other hand, we find that the cointegration test says that even if there is no long-term relationship, two out of five tests say that the relationship between these variables in these three sectors exists. On the other hand, a correlation analysis was carried out and it was found that there is a strong correlation between energy consumption and GDP and also includes a unidirectional causality in order to implement an adequate energy policy for these sectors to be able to increase the GDP per sector.

On the other hand, Kuznets' inverted U curve is verified for the case of Madagascar because if we increase energy consumption to boost GDP then this will not affect CO_2 emissions. The reason is that the GDP per capita of the Malagasy will increase and this will increase the purchasing power to buy electricity for example to use for daily cooking instead of using charcoal. When the CO_2 emissions will decrease, it is clear that the emissions fixed by the COP21 will be reached by 2030, that is to say the Malagasy State can converge the result of the forecast of CO_2 emission by the KAYA identity in 2030 towards the quantity fixed by the COP21. Of course, the use of this energy must be associated with technology to maintain energy efficiency and reduce the rate of CO_2 emission per energy consumed.

6.2.Policy Recommendation

The lack of consideration of the basic needs of the populations is one of the causes of failure of the policies of a country will put because it does not take the opinion of the local populations and does not involve them in the implementation of the project. Since the objective here is to increase again the growth rate of Madagascar then I recommend this adequate energy policy according to all the studies made above.

i) Before making a policy, we have to take the opinion of the households and if possible make a kind of survey to let them know the project and the goal we want to achieve. We use a mixed method for the realization of this policy, that is to say, a top-down and bottom-up method.

ii) Once this mixed method has been achieved, the key sectors that can be worked on to achieve the objective are then identified. The objective of this Master's thesis is to argue for an increase in energy consumption in order to stimulate Madagascar's economic growth without increasing CO2 emissions; the industrial, transport and residential sectors are therefore the key sectors chosen as they are the sectors with the highest energy consumption rate and GDP share.

iii) Since the key sectors have been identified, all the variables to reach these targets have been well identified as well: energy intensity and dirt index are combined with energy consumption, GDP and CO2 emissions.

iv) According to the above analysis, Madagascar needs to increase its energy consumption if it wants to increase its GDP because there is a strong positive correlation and causality between these variables. For this, the Malagasy State must encourage the private sectors for the production of renewable energy and increase the production capacity of the national company.

v) As it is necessary to increase energy consumption, it is possible that Madagascar's CO2 emissions increase, but Kuznets' inverse U-curve indicates that when Madagascar's GDP per capita increases, its CO2 emissions per capita decrease. The Malagasy government must increase this GDP if it wants to reach the COP21 target on the amount of emissions Madagascar should produce, of course energy must be used well to achieve energy efficiency.

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APPENDIX

1. Stata Do file

```
*CHANGE WORK DIRECTORY WHEN YOU USE THIS*
cd "E:\Master thesis\final data\stata"

*IMPORT DATASET*
import excel "base_safidy.xlsx", sheet("Feuil1") firstrow

*CONVERT VARIABLE "IND" TO NUMERIC*
encode ind , gen(ind_num)

*GENERATE LOG VARIABLES*
foreach x in EC GDP EI CO2 ID{gen ln`x'= ln(`x')}

*DECLARING PANEL DATA*
*Please use "ind_num" instead of "ind" in the xtset command below*
xtset ind_num year
**Panel is strongly balanced**

*VISUALIZING PANEL DATA*
*Graph of EC GDP EI CO2 (together)*
zahjxtline EC GDP EI CO2 ID

*Graph of EC GDP EI CO2 (isolated)*
*Graph of EC*
xtline EC
*Graph of GDP*
xtline GDP
*Graph of EI*
xtline EI
*Graph of CO2*
```

```
xtline CO2
*Graph of ID*
xtline ID

*SCATTERPLOT*
*NUAGE DE POINT*
twoway scatter EC GDP, msize(tiny) name(Sp1, replace)
twoway scatter EC EI, msize(tiny) name(Sp2, replace)
twoway scatter EC CO2, msize(tiny) name(Sp3, replace)
twoway scatter EC ID, msize(tiny) name(Sp4, replace)
graph combine Sp1 Sp2 Sp3 Sp4

*DESCRIBE DATA*
xtsum EC GDP EI CO2 ID

*CORRELATION MATRIX*
pwcorr EC GDP EI CO2 ID , sig
*2nd method
* Visualisation de la matrice 2
*ssc install corrtable
*corrtable EC GDP EI CO2 ID
*corrtable EC GDP EI CO2 ID,  ///
*flag1(r(rho) > 0) howflag1(plotregion(color(blue * 0.1))) ///
*flag2(r(rho) < 0) howflag2(plotregion(color(pink*0.1))) half rsize(2 + 6 * abs(r(rho)))



*CROSS SECTIONAL DEPENDANCE TEST*
*UNIT ROOT TEST FOR VARIABLES IN LEVEL*
```

```
*IM-PESARAN-SHIN TEST*
foreach y in lnEC lnGDP lnEI lnCO2 lnID{xtunitroot ips `y'}

*LEVIN-LIN AND CHU
foreach y in lnEC lnGDP lnEI lnCO2 lnID{xtunitroot llc `y'}

*UNIT ROOT TEST FOR VARIABLES IN FIRTS DIFFERENCE*
*IM-PESARAN-SHIN TEST*
foreach y in lnEC lnGDP lnEI lnCO2 lnID{xtunitroot ips d.`y'}

*LEVIN-LIN AND CHU*
foreach y in lnEC  lnGDP lnEI lnCO2 lnID{xtunitroot llc d.`y'}

*VARIABLES ARE STATIONNARY IN FIRST DIFFERENCE*
*NOW WE MUST CHECK IF THERE IS ONE OR MORE COINTEGRATION RELATIONSHIP AMONG VARIABLES*
*COINTEGRATION TEST*
*KAO TEST Ho : no cointegration*
xtcointtest kao lnEC  lnGDP lnEI lnCO2 lnID

*PEDRONI TEST Ho: no cointegration*
xtcointtest pedroni lnEC  lnGDP lnEI lnCO2 lnID , trend ar(same)

*WESTERLUND TEST Ho : no cointegration*
xtcointtest westerlund lnEC  lnGDP lnEI lnCO2 lnID ,allpanels

*HSIAO'S SPECIFICATION TEST*
* VARIABLES:  EC GDP EI CO2 ID*
* MODEL 1: Constant slope and intercept*

reg EC GDP EI CO2 ID
scalar RSS1=e(rss)
```

```
di RSS1
scalar  N= 3
scalar  T= 24
scalar  K = 5

*STORE & DISPLAY   RESIDUAL SUM SQUARE (RSS1)
* MODEL 2 : FIXED EFFECT MODEL
xtreg EC GDP EI CO2 ID, fe robust
*STORE & DISPLAY RESIDUAL SUM SQUARE (RSS2)*
scalar RSS2 = e(rss)
di RSS2
* MODEL 3 : HETEROGEN MODEL*
local RSS3 = 0
foreach y in industries residentiel transport{qui reg EC GDP EI CO2 ID if ind == "`y'"scalar RSS3
= `RSS3' + e(rss)}
*STORE & DISPLAY & RESIDUAL SUM SQUARE (RSS3)
di `RSS3'

*HSIAO TEST*
*Step 1 : Ho: bi=b and ai=a*
scalar F1=((RSS1-RSS3)/((N-1)*(K+1)))/(RSS3/(N*T-N*(K+1)))
scalar pva1=Ftail((N-1)*(K+1),(N*T-N*(K+1)),F1)
display pva1
*We reject the null hypothesis if the pvalue < 5%*
*Here we reject Ho*

*Step 2: Ho:bi=b
scalar F2=((RSS2-RSS3)/((N-1)*K))/(RSS3/(N*T-N*(K+1)))
scalar pva2=Ftail((N-1)*K,(N*T-N*(K+1)),F2)
display pva2
*We reject the null hypothesis if the pvalue < 5%*
*Here we reject Ho*
```

```
*Step 3: Ho: ai=a*

scalar F3=((RSS1-RSS2)/(N-1))/(RSS2/(N*(T-1)-K))
scalar pva3=Ftail((N-1),(N*(T-1)-K),F3)
display pva3

**********************************************************************************
***PANEL GANGER CAUSALITY TEST BETWEEN LNEC AND Lngdp****
xtgcause lnEC lnGDP
***PANEL GANGER CAUSALITY TEST BETWEEN LNEC AND LnEI****
xtgcause lnEC lnEI
***PANEL GANGER CAUSALITY TEST BETWEEN LNEC AND LnCO2****
xtgcause lnEC lnCO2
***PANEL GANGER CAUSALITY TEST BETWEEN LNEC AND LnID****
xtgcause lnEC lnID

***PANEL GANGER CAUSALITY TEST BETWEEN Lngdp AND LNEC ****
xtgcause lnGDP lnEC
***PANEL GANGER CAUSALITY TEST BETWEEN Lngdp AND LNEI ****
xtgcause lnGDP lnEI
***PANEL GANGER CAUSALITY TEST BETWEEN Lngdp AND LNCO2 **
xtgcause lnGDP lnCO2
***PANEL GANGER CAUSALITY TEST BETWEEN Lngdp AND LNCID **
xtgcause lnGDP lnID

***PANEL GANGER CAUSALITY TEST BETWEEN LnEI AND LNEC **
xtgcause lnEI lnEC
***PANEL GANGER CAUSALITY TEST BETWEEN LnEI AND LNGDP **
xtgcause lnEI lnGDP
***PANEL GANGER CAUSALITY TEST BETWEEN LnEI AND LNCO2**
xtgcause lnEI lnCO2
***PANEL GANGER CAUSALITY TEST BETWEEN LnEI AND LNID **
```

```
xtgcause lnEI lnID

***PANEL GANGER CAUSALITY TEST BETWEEN LnCO2 AND LNEC **
xtgcause lnCO2 lnEC
***PANEL GANGER CAUSALITY TEST BETWEEN LnCO2 AND LNGDP **
xtgcause lnCO2 lnGDP
***PANEL GANGER CAUSALITY TEST BETWEEN LnCO2 AND LNEI **
xtgcause lnCO2 lnEI
***PANEL GANGER CAUSALITY TEST BETWEEN LnCO2 AND LNID **
xtgcause lnCO2 lnID

***PANEL GANGER CAUSALITY TEST BETWEEN LnID AND LNEC**
xtgcause lnID lnEC
***PANEL GANGER CAUSALITY TEST BETWEEN LnID AND LNGDP **
xtgcause lnID lnGDP
***PANEL GANGER CAUSALITY TEST BETWEEN LnID AND LNCO2 **
xtgcause lnID lnCO2
***PANEL GANGER CAUSALITY TEST BETWEEN LnID AND LNEI **
xtgcause lnID lnEI
```

2. R Do file

```
#Installing and loading packages-
library(readxl)
library("ggplot2")

#Setting working directory-
setwd("E:/Master thesis/final data/R")



#Import dataset-
library(readxl)
par_tete <- read_excel("kuznets.xlsx", sheet = "par_tete")
```

```
semilog <- read_excel("kuznets.xlsx", sheet = "semilog")
log <- read_excel("kuznets.xlsx", sheet = "log")

#visualization-
View(par_tete)
View(semilog)
view(log)

#List of variables-
##for "par_tete"-
names(par_tete)
##for "semilog"-
names(semilog)
##for "log"-
names(log)

#scatterplot & smoothing-
##Computing model coefficients-
###Data = par_tete
model1 <- lm(CO2per_capita~GDP_per_capita + GDP_per_capita2 , data = par_tete)
summary(model1)
##Visualization-
ggplot(par_tete,aes(GDP_per_capita,CO2per_capita))+ geom_point(color = "darkred") +
geom_smooth(method = "lm", formula = y ~ poly(x,2),size =1) + ggtitle("Evolution of CO2/P as a
function of GDP/P") + labs(y ="CO2 per capita", x= "GDP per capita") theme_light()

###Data = semilog
model2 <- lm(CO2per_capita~GDP_per_capita + GDP_per_capita2 , data = semilog)
summary(model2)
##Visualization-
ggplot(semilog,aes(GDP_per_capita,CO2per_capita))+
  geom_point(color = "darkblue") + geom_smooth(method = "lm", formula = y ~ poly(x,2),size
```

=1,color = "red") + ggtitle("Evolution of semilog of CO2/P as a function of semilog of GDP/P") + labs(y ="CO2 per capita", x= "PIB per capita") theme_light()

```
###Data = ilog
model3 <- lm(CO2per_capita~GDP_per_capita + GDP_per_capita2 , data = log)
summary(model3)
##Visualization-
ggplot(log,aes(GDP_per_capita,CO2per_capita))+ geom_point() + geom_smooth(method = "lm", formula = y ~ poly(x,2),size =1,color = "darkgreen") + ggtitle("Evolution of log of CO2/P as a function of log of GDP/P") + labs(y ="CO2 per capita", x= "PIB per capita")
theme_light()
```