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Abstract. This paper serves as a brief introduction to the complex relationship between energy consumption and economic growth and between energy consumption and greenhouse emissions. We provide a critical overview of recent literature dealing with energy, carbon emissions and economic growth. We focus mainly on econometric literature examining causal effects between energy consumption and economic growth and on literature adding carbon emissions into the investigation of this topic.

Key words: Economic growth, energy consumption, oil consumption, natural gas consumption, renewable energies, biomass

JEL classification: Q28, O40, Q42, Q43

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Introduction

It is undeniable that energy is fundamental in an economy, as energy enter in most forms of transformation and productions. Moreover, as we can see from history, there has been always high repercussion and restriction to global economic growth due to shortage or any disturbance in energetic sector. As reported by Hamilton, J. D. (2011), we can list the main historical events as the OPEC oil embargo of 1973-1974, the Iranian revolution of 1978-1979, the Iran-Iraq War initiated in 1980, the first Persian Gulf War in 1990-1991and the second in 2003 or the Venezuelan unrest in 2003, which affected the oil supply and prices. Not to forget that the European Union is mainly depending in energy importation reaching 53% of its energy consumption in 2013, and the raise of concern for the supply delivery of gas from Russian via Ukraine.

The European Union since 2005, as reported by the IEA (International Energy Agency) started two major reforms in the energy and the climate policy, one is about the progressive liberalism of the internal electricity and climate policy and the second is the ambitious climate and energy market package. The main policy targets are stated as following; competitiveness, security, and sustainability with more concern on the security of the supply security since the Ukrainian Crisis. According to the official EU website, their policy target in 2020, are a reduction by 20% of the greenhouse emissions compared to the 90's, reaching 20% of energy share for the renewable energies and 20% of energy efficiency improvement. The greenhouse emissions decreased by 19.2% in 2012, and the renewable energies share increased to 14.1%.

These reasons are why the energy consumption's growth is the concern of many economists and policymakers as for its importance for policy implications. However, most of the literature, consider energy as an intermediate product of labour and capital. As standard economic, consider both of them as the main input in the production process, the scarcity of energy could make us interpret it as a primary input and not as an intermediate.

The rise of interest to the relationship between income and energy consumption began just after the developed countries proposed significant energy conservation programs in 1970s. Kraft and Kraft (1978) were one of the first pioneers in studying the causality relationship, which was allowed by using method and technique from Sims (1972) and

Granger (1969). They concluded from their studies a unidirectional causality from Gross National Product to energy consumption. This finding was confirmed and contradicted by several works, in addition the results seems not to conclusive for different countries or event for different laps of time in the same country. Malick (2010) proved that the growth of coal consumption is the main cause of the economic growth in India. In the other hand Shaari et al. (2012) has shown a unidirectional relationship between gas and economic growth. Shahbaz Shabbir (2011) has shown for the electric consumption, for the economic growth, and for the population, that they are Granger-causes each other in addition, the financial development Granger-cause electricity consumption in the case of Portugal. Moreover, in the spirit of different countries for different periods while studying a possible causal relationship between oil consumption and the economic growth in small European countries, Živković and Vlahinić-Dizdarević (2011) split the European countries by using small-developed countries for 1980–2007 and transition countries for 1993-2007. They concluded by the possibility of division of the small countries into two groups, one where the causality running from real GDP to oil consumption , this group is represented by of most of developed countries and a number of transition countries. Moreover, the second group where the causality is running in the opposite way from oil consumption to Gross Domestic Product. Even with all these divergences and different conclusion, the debate and the discussions about a possible causal relationship remain a focus and a centre of interest of many researchers. It leaded to include more variable to make the research more effective for a policy, by including employment or CO_2 emissions to have for example a weight for a representation of an environmental policy.

Literature review

In this section, we will review the methods and main finding from different relevant literature related to the topic.

Stern (2010) is a compilation of different approaches and models explaining effect of energy on economic growth. Bringing together the mainstream, the resource economics, and the ecological economics models of economic growth and discussing theories, which analyse and potentially justify the economic growth in the long run, passing through periods and laps of time covering industrial revolution to our days.
Some models including energies from mainstream models are listed. One of these models is a simple Solow model, where energy and capital are poorly substituted, showing that energy is scarcity can constraint and restrict the economic growth while abundant energy effects is not anymore a constrain and the model explains better the economic growth, taken as a possible explanation to the industrial revolution economic shift. Stern (2010) acknowledged than when using vector auto regression(VAR) model and that capital and different production input are incorporated, that time series analysis shows that energy and GDP cointegrate and that there is Granger causality between energy and GDP. In addition, he pointed on that energy used per unit of economic output has declined in multiple countries and that could be as a result to a technological change and a shift in quality of fuels to higher quality fuels.

In further studies, Shaari, Hussain and Ismail (2012) while studying for the case of Malaysia, used annual data from 1980 to 2010, to find relationship between energy and GDP growth. They started by doing a stationary test using the Augmented Dickey Fuller test which show that the variable are stationary allowing Johansen cointegration, which was used to analyze the data in order to determine the long run relationship between all variables. The findings were that energy consumptions are related to economic growth without catching the direction of the relationship. In order to catch the direction, Granger causality model was used to examine the direction of causality relationships by measuring the causal effect of Gross Domestic Product. Their finding showed that there is no causality effect between both oil and coal consumption and economic growth. However there is causality from GDP growth to the electricity consumption, in addition and more surprising is the unidirectional relationship existing between gas and economic growth, this relationship seems to have a negative impact to the economy. Additionally Shaari et al (2012) concluded by saying that it would be absurd to decrease the gas consumption as it would have mostly a negative impact.

Apergis and Payne (2010) took the case of South America while studying the relation between energy consumption and economic growth using Gross Domestic Product to measure that directly and real gross fixed capital formations indirectly. He used an annual data from 1980 to 2005, for Venezuela, Argentina, Bolivia, Chile, Ecuador, Brazil, Paraguay, Uruguay, and Peru. To do that he used a panel cointegration test and Error Correction Model. He was able to prove a positive Granger causality running from energy consumption to economic growth, both directly and indirectly (Gross Domestic Product and real gross fixed capital formation in the short run and long run.

Shahbaz, Tang, and Shahbaz Shabbir (2011) is a paper dealing with the possible relationship between electricity consumption, economic growth, financial development, population, and foreign trade. Like Shaari et al(2012) they started with an ADF test which proved the variable are stationary, then a cointegration test to determine the long run relationship between all variables and showed that they cointegrate, in addition they used as well the Granger causality model to examine the direction of causality relationships between the variables . As well they used an annual data but for Portugal from 1970 to 2009. The finding was that for all the variables expect the financial development Granger cause each other's, and that there is a causal effect running from financial development to electricity consumption. Shahbaz et al. (2011) affirm from these finding that even if the energy seems to be an important source, using a conservation policy of that one could lead to a deterioration of the Portuguese economy.

To check the variables whether they are or not stationary, Mallick (2009) used in addition to the ADF an DF(Dickey Fuller) test and Phillips Perron (PP) test and proved that they are stationary in order to be able to use the bivariate Granger causality tests.
The test other here was realised for India with an annual data from 1970 to 2004. The main finding from Granger causality tests accentuated more that there is a Granger causality effect running from economic growth to crude oil and electricity consumption while it is from growth of coal consumption to economic growth. That means in other words that the main component that leads to economic growth is in that study, the coal consumption. The result from Granger causality tests seems to be contradicted by an additional test of dynamic causality relationship

between growth of energy consumption demand and growth rate of GDP through variance decomposition analysis of vector autoregression (VAR) which suggested in contrast to the Granger causality tests that there is a bi-directional influence between electricity consumption and economic. The author conclusion from that is "on the basis of application of two econometric to OLS , the study with little more conviction could suggest for reducing oil and natural gas consumption for achieving higher rate of economic growth in the economy."

Stern and Enflo (2013) in this study, there is an analysis of the relation between energy and economic growth, for a long period of 150 years. Starting from 1850 in order to catch the transition period from one of the poorer countries in Europe at the mid of the 19th century to one of the richest today. As it was an industrialization period, they checked if the switch in energies quality and the increases of energy consumption affected the economic growth. The Unit Root Test was used in this literature as well, which is a fundamental to proceed to the cointegration and Granger cause test, for that PP test was used. The period of 150 years is split into three time series. As model, they used multivariate models. All their finding point to that energy consumption fuels the economy and accelerates the growth rate. However the range of the sample periods and the as we know that thing change other time specially other 150 years, Stern et all noticed that the relation between energy consumption and economic growth could have changed, in addition they stressed Energy prices have big role in this process in our days.

To discuss other methods, Rafiq and Alam (2010) used three different models to support his research; the first model is a Fully Modified OLS, which allow suppressing encountered problem from endogenity and serial correlation usually encountered in by a standard OLS. The second one is a parametric dynamic OLS, which was used for the same purpose. The third model is ARDL, which avoids the inherent limitations in testing for Unit Roots prior to testing for cointegration. These models where used to check the determinants of renewable energy consumption in six major emerging economies. which are according to Rafiq et al.(2010) are Brazil, China, India, Indonesia, Philippines and Turkey who use more and more renewable energy as fuel for their economies, they applied these models to annual data from 1980 to 2006 performed on panel data and time series analyses. they concluded that the long-run elasticity seem to be pretty consistent and that excepting for Philippines and Turkey, renewable energy consumption is significantly determined by income and pollutant emissions while for these two, the renewable energy consumption seems to be driven by income. In addition, they found

that for the short-run, Brazil and China have bi-directional causalities between renewable energy and income from one side and in the other hand between renewable energy and pollutant emissions.

Csereklyei, Rubio Varas, and Stern (2014) is an investigation of historical pattern and stylized facts, which where enlisted and in addition it is a study giving more evidences about fact from the relationship between energy intensity , energy per capita, energy per capital with the GDP per capita. To do that they used a large sample of 99 countries covering time period from 1971 to 2010 and for some countries as United States or England they started the analysis from the 19th century. This study does not just analyse the cross sectional relationship it also seek after the convergence of these ratios to a kind of a steady state. The main finding of this paper is that for the data from 1971 to 2010 there is a stable cross sectional relation between the energy per capita and the GDP per capita. Moreover, for the long-run historical data, the authors stated, "there is a convergence in energy intensity towards the current distribution, per capita energy use has tended to raise, energy quality to increases."

Kubiszewski, Cleveland, and Endres (2010), this paper is a meta-analysis covering multiple literatures, dealing with Energy return on investment for wind turbine. The authors examine 119 turbines from 50 analyses from 1977 to 2007. In addition, they recreate the ratio (EROI) to do that the authors used three different types of net energy analysis techniques, the first one is the process analysis, the second input–output analysis and the third one as a combination of the two previous one. According to the results they found that the EROI from wind in a favourable position relatively to fossil fuels, nuclear, and solar power.

Most of literature had no conclusive results while trying to estimate a possible substitute between energies. Papageorgiou, Saam and Schulte (2013), found and concluded a possible substitution between clean and dirty energies. They used a panel of cross-country sectoral data, which was built by European Commission, which include 35 industries combined to Purchasing Power Parities for 30 countries, to Electricity Information Statistics, and to the Annual Energy Outlook from 1995 to 2009. They specified a production function of Constant Elasticity of Substitution using specification from electric sector and non-energy sector in order to estimate a special case of the CES parameter: the elasticity of substitution

between clean and dirty energy inputs. The finding was an evidence of elasticity exceeding one which concord with clean energies could substitute the dirty ones.

As most of literature found a causal relationship between energies and income, and as Papageorgiou, Saam and Schulte (2013) showed that the dirty and clean energies are substitutable. The expectation is that there is a causal relationship between renewable energies and economic growth. However Menegaki, A. N. (2011) showed in his studies while studying a multivariate panel data from 1997 to 2007 for European countries, that there is no clear evidences of causality relationship between the renewable energies and the Gross Domestic Product.

Menegaki (2011) used as most literature of this type, a Unit Root Test, in addition, he used a random effect model for cointegration and Engle and Granger (1987) two-step procedure. He included as variable the final energy consumption, the greenhouse gas emissions and the employment. The author claimed a neutrality of renewable energies on the economy and said that it is probably due to the lack of its use across Europe.

Apergis and Payne (2012) used similar data set as Menegaki, A. N. (2011). This work was for 80 countries from 1990 to 2007, and they checked the relationship between renewable, non-renewable energies consumption and economic growth. They also used a Unit Root Test by doing the Fisher ADF and the Fisher pp. For the cointegration, they used the Pedroni (1999, 2004) and the Fully Modified OLS (FULLY MODIFIED OLS) technique to determine the long-run equilibrium relationship between the variables. As well, they included in addition the capital and the labour. Their finding pointed to the importance of both renewable and non-renewable energies as the long-run relationship exists between all the variables. They also found out and as it is one of my centre of interest a possible substitutability between the two kinds of energies, as there is negative bidirectional causality between them.

Hoogwijk and Graus (2008) is a report redacted for third Ministers Meeting in the Gleneagles Dialogue on Climate Change. It is a compilation of literature and expert research, which gives an objective view on the long term (2050) about the potential of the renewable energies in order to incite the deployment of resources and the investment into the development of renewable energies, especially in large energy economies. In addition, they

include the cost of distribution. The main conclusion of the exposition after taking into account the cost and the possible outcome was that solar power (CSP and PV) is by far the largest renewable energy sources with the largest global potential especially for North Africa, followed by wind and ocean energy.

Zhang, Xing-Ping, and Xiao-Mei Cheng (2009) is a paper studying the relationship between energy consumption, carbon emission, and economic growth for the case of China. The authors used annual data from 1960 to 2007, to check the existence of any relationship between the variables, and if found, the direction of such relationship. The authors applied a multivariate model of economic growth, energy use, carbon emissions, capital, and urban population. While most of the literature used an Error Correction Model or standard Granger causality to find the causal relationship, they used the TY procedure (augmented VAR approach proposed by Toda and Yamamoto) and generalized impulse response to find out the Granger causality in the long run. Mainly because according to the authors, it seems to have a higher power of testing larger samples. The main results coming from the empirical tests, suggests evidences supporting that economic growth is not affected by neither energies consumption nor carbon emissions. These evidences are that there are no Granger causalities in the long run between economic growth and carbon emissions and the causality between economic growth and energy consumption is running from the GDP. The test shows also a unidirectional Granger causality running from energy consumption to carbon emissions in the long run. The authors concluded from there that China could decline the use of some fossil energies, specially coal which represent a high proportion. The change to more clean energies would lead to a decline of the carbon emissions without effecting the economic growth. The evidence, which support the benefits of changing the form of energies, is that there is a Granger causality running from energy consumption to carbon emissions.

Soytas, Ugur, and Ramazan Sari(2009) in a similar way as the previous paper, this paper is examining the relationship between energy consumption, gross fixed capital formation, labour, carbon emission, and economic growth, but for the case of Turkey. The authors used annual data from 1960 to 2000 to check the long run Granger causality. The authors used as well the TY procedure (augmented VAR approach proposed by Toda and Yamamoto) and generalized impulse response to check the causality. The results imply that there is no causality in the long run between income and energy consumption, neither between income and carbon emissions, and that all the variables impact on the labour

innovation. In addition, it sees that there is a unidirectional Granger causality running form carbon emissions to energy consumption. The authors concluded from there that reducing the emissions would not harm the economic growth in Turkey.

Fei, Li, et al (2011) is a paper dealing with the causality effect between the economic growth and energy consumption for China in the long run. The data take into account 30 provinces from China according to the availability with an annual data from 1960 to 2000. Additionally a cross sectional data was created in order to investigate two different groups of provinces, the east of China, and the west of China. Like most of the literature, the author checked the stationarity and the cointegration of the variables via panel Unit Root and Panel Cointegration. To check the causality, he used a panel based DOLS (Dynamic OLS) as it is taking into account the co-movement. The main result coming from the test shows a positive cointegrated relationship between the economic growth and the energy consumption in the long run. The relationship seems to be bidirectional, an increase of the GDP per capita lead to increase of the energy consumption and vice versa. While taking into account the two groups, it seems that the positive relationship between the variables holds for the separated groups as for both. As its increase by 1%, lead to an increase of energy consumption by 0.48% in east China, and by 0.45% for west China. The authors showed also that from this increase is resulting an increase of the carbon emissions by 0.41% for east China and 0.43% for west China. The main conclusion of the authors is that it seems obvious that China is energy dependent, however the carbon emissions is becoming a concern due to the pollutions and the climate change. He also added that it start to be urgent to promote rapidly the nuclear and the renewable energies.

Chang (2010) is a multivariate co-integration Granger causality study to evaluate the causal effect between economic growth, dioxide emissions, crude oil consumption, natural gas consumption, coal consumption, and electricity consumption in China. The data used, is an annual data from 1981 to 2006. In order to do so, the author used as several other literatures studying this question, Unit Root Test for the stationarity, a cointegration test for the interaction between the variables an Error Correction Model to check the causality effect. The main results seems to show a bidirectional causality running from economic growth to the dioxide emissions, crude oil consumption, and coal consumption, in addition a unidirectional causality running from electricity consumption to economic growth. According to Chang (2010), all the variables seem to be highly interacting, and it would be harming the

economic growth to pursue an energy conservation policy, where the energy consumption is decreased in order to decrease the dioxide emissions and save some of its consumption. However, the author admitted that this study is limited due to the excluding to all other form of energies except the fossil ones.

Conclusions and policies

This review paper aims to examine the relationship between energy consumption and economic growth and between energy consumptions and greenhouse emissions. As the renewable energies seems to impact positively on both environment and economies, a development of policies focusing more on its consumption in order to decrease the greenhouse emissions and substitute some of the fossil energies consumption, with as example some subventions to investment on the renewable energies should be considered. Some economies are already making plans dealing with this problem.We can talk about national actions plans from the European commission, several nationals plans distinctive for each country were made, because each of the EU members have different potential linked to renewable energies and resources, in addition due to the difficulty to put together one policy as the energy supplies are not that connected among the EU members. A new policy of Energy Union is undertaken by the EU, which could lead to a more effective energy policies, as "Energy Union will also help Europe speak with a single voice on global energy matters." (EU official web). More policies going in this direction could lead not just to the economic growth but also of the employment. Not to forget the fact that, the fossil energies even if there is still plenty of it, are exhaustible material, and one day there will be needed for an alternative. While the renewable energies are unlimited and as pointed by Hoogwijk and Graus (2008) with high potential. The so-called "2020 Climate and Energy Package" implemented by the two reforms in 2008, seems to go in this direction.

Even if it seems that a decrease in the greenhouse emissions would lead to a decrease in economic growth, the fact is that the energies could substitutes each others from the one with high emissions to cleaner one, and not to forget that the technology factors which are not included in this model. Here the technology factor could be measured by the energy efficiency and energy intensity; this is why it would be interesting to see them taken into account in further research. Moreover, as the main factor limiting the renewable energies increase seems to be the investment, it would be interesting to see a possible analyse linking the renewable energies production, to its investment and capital, and its impact on economies.

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