Mendel University in Brno
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Energy-Economy Nexus: a meta-analysis

Diploma thesis

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Vote of thanks

I would like to thank the supervisor of my diploma thesis, Ing. Vladimír Hajko, Ph.D., for his experience, professional mentoring and valuable advice, which contributed to the elaboration of this diploma thesis.

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Abstract

Kocianová, A. Energy-economy nexus: a meta-analysis. Diploma thesis. Brno: Mendel University in Brno, 2016.

The aim of the thesis is to identify whether there is a consensus in the field of Energy-Economy Nexus literature. The used econometric methods serve to conduct the systematic review of empirical literature to investigate the presence of a significant evidence for any form of (Granger) causality and the prevailing type of the causality, with regard to the influence of multiple study characteristics, such as the geographic area, sample size, length of the study period, etc. Partial goal of the thesis is to review the factual relevance of the empirical literature for the policy makers. Notably whether the "influential" papers (as indicated by the number of citations) are also reflected, for example in the EU, US or OECD policy documents.

Keywords

Meta-analysis, energy-economy nexus, causal relationship, binary logit model, multinomial logit model, energy policy.

Abstrakt

Kocianová A. Vzťah medzi spotrebou energie a ekonomickým rastom: meta-analýza. Diplomová práca. Brno: Mendelova univerzita v Brne, 2016.

Cieľom tejto práce je identifikovať či existuje konsenzus v oblasti literatúry zaoberajúcej sa vzťahom medzi spotrebou energie a ekonomickým rastom. Použité ekonometrické metódy slúžia na spracovanie systematického prehľadu empirickej literatúry, ktorý je ďalej použitý k preskúmaniu prítomnosti významných dôkazov akejkoľvek formy (Grangerovej) kauzality a prevládajúci typ kauzality s ohľadom na vplyv niekoľkých študijných charakteristík, ako napríklad geografická oblasť, veľkosť vzorky, dĺžka študovaného obdobia, atď. Čiastkovým cieľom práce je preskúmať vecnú dôležitosť empirickej literatúry pre tvorcov politík. Najmä či sú „vplyvné" štúdie (ako je naznačené počtom citácií) spomenuté napriklad v politických dokumentoch EU, USA alebo OECD.

Kľúčové slová

Meta-analýza, kauzálny vzťah, vzťah medzi spotrebou energie a ekonomickým rastom, binomiálny logit model, multinomiálny logit model, energetická politika.

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1 Introduction and Aim

1.1 Introduction

Energy is an essential input to the economy and the bond between the use of energy and the level of economic activity and economic growth is very strong. Current energy services are an engine that drives economic as well as social and environmental development. Without securing minimum accessibility to the energy sources for a vast majority of its population, no country has successfully developed beyond the subsistence economy. Therefore, economic growth is related to the consumption of energy and is influenced by its availability.

The comprehensive relation between the economic process and energy use has attracted attention for a long time. Issues like the energy resources´ scarecity, energy theory of value, degrowth and a-growth approaches are closely related to the relationship between the development and energy (Kalimeris, Richardson, Bithas, 2014).

The topic of the causal relationship between energy consumption and GDP growth has been well-studied in the energy economics literature. There are many studies which have focused on different countries, time periods, variables and different econometric methodologies have been used to analyse the relationship. The empirical outcomes of these studies varied and sometimes were in conflict. (Ozturk, 2010).

Meta-analysis is a statistic technique focused on the aggregation of results obtained in independent studies, particularly in cases where the results of various studies provide results either ambiguous or directly contradictory. The method is popular especially in the area of medical research and areas which allow controlled experiments. However, it should be emphasized that a typical embodiment of a controlled experiment, for example, type focused on the clinical investigation of the effect of drug administration, permits and often directly requires that these studies are models designed in a very similar way.

The aim of a meta-analysis in the energy-economy nexus is not to make some policy recommendations on the efficient and sustainable way to use the energy consumption while, at the same time, enabling the growth. This is performed in the individual studies. In a meta-analysis, the synthesis of the trends in a sample of studies is provided. It enables a more detailed overview of studies by examining different hypotheses (Menegaki, 2014).

Current work elaborates a meta-analysis to investigate the possible existence (non-existence) and direction of the causal relationship between energy use and GDP growth as well as to identify important factors influencing the prevailing type of some hypothesis. The meta-analysis is carried out by employing two methodologies, namely binary logit model and multinomial logit model. The sample consists of 104 top-cited studies on causality between GDP and energy consumption published over the period 2000-2015.

I chose this topic because it is a very up to date issue that has been present on the world scene for several years. We are all aware of natural resources´ scarcity and impacts of energy consumption on the environment. Countries are trying to reduce the carbon emissions and consequently the consumption of energy from non-renewable sources but they want to do so without endangering their economic growth. There are different types of relations or directions of the causal relationship between these two variables and it is interesting to study and find out what they are and whether they influence the energy policy making of countries.

1.2 Aim

The aim of the thesis is to identify whether there is a consensus in the field of Energy-Economy Nexus literature. The used econometric methods serve to conduct the systematic review of empirical literature to investigate the presence of a significant evidence for any form of (Granger) causality and the prevailing type of the causality, with regard to the influence of multiple study characteristics, such as the country area, sample size, length of the study in question etc.

Partial goal of the thesis is to review the factual relevance of the empirical literature for the policy makers. Notably whether the "influential" papers (as indicated by the number of citations) are also reflected, for example in the EU, US or OECD policy documents.

2 Meta-analysis and energy-economy nexus

The topic of energy-economy nexus has gained attention mainly due to the increasing energy costs, international efforts to cut greenhouse gas emissions and the very basic issue of allocating scarce resources in the economy. Results of empirical researches are key for the development and implementation of environmental and energy policies. An important issue is the size of the impact of reducing energy consumption on the reduction of GDP growth or income which are naturally unfavourable by individual countries. Therefore, the current work also studies the relevance of the top-cited papers in this field for the policy makers, especially in EU, US or OECD.

2.1 Meta-analysis

In the past, most researchers elaborated summaries of empirical studies in a narrative manner. Number of studies reviewing the same topics was collected, individual studies were narratively described and based on their interpretation, research outcomes were summarized. However, such research synthesis has been subjected to criticism. Critics of this traditional method warned that its process and results are inaccurate. As Cooper (2016) states, the main disadvantages were poor standards of evidence, lack of systematic procedures, limited search for studies, lack of measures evaluating the descriptions´ reliability, or the use of post hoc criteria.

Systematic reviews and meta-analysis started to be adopted by researchers in the mid 1980s and took root in 1990s. These kinds of reviews use explicit criteria which later determine what will be or will not be included in the analysis. Due to the subjectivity of setting the rules, systematic review cannot be considered completely objective. Anyhow, clear definition of all decisions makes the mechanisms transparent. Meta-analysis, or statistical synthesis of data, is the principal part of the most systematic reviews (Borenstein, Hedges, Higgins, Rothstein, 2011).

'Meta-analysis is valuable not only because it is widely used, more importantly, meta-analysis is widely used because it represents a powerful approach to synthesizing the existing empirical literature and contributing to the progression of science' (Card, 2012, p. 9).

2.2 Energy-economy nexus

Energy is an essential input in all production and many consumption activities. It is the main source of economic growth, industrialization as well as urbanization. Conversely, economic growth, industrialization and urbanization can raise use of more energy, especially, commercial energy (Paul, Bhattacharya, 2004).

Economic development is closely related to energy consumption because higher economic development is awaited with the higher energy consumption. Nevertheless, higher level of economic development can also bring more efficient use of energy which could possibly lead to the reduction in energy consumption. This means that better economic performance can work as an engine for energy efficiency (Ang, 2008).

Even if the economic theories do not solely specify a relationship between energy consumption and economic growth, empirical studies of this relationship have been subjected to intense research in energy economics literature for the past two decades (Altinay, Karagol, 2005).

It was not until the energy crisis in 1970 and the unprecedented high levels of energy prices when the calls for the implementation of energy conservation polices have started. Most of the industrialized countries succeeded in cutting their energy requirements. At the end of the decade, there has been a large interest in empirical research on the temporal causality between energy consumption and economic growth with no convincing results or persuasive explanations (Hondroyiannis, Lolos, Papapetrou, 2002). The investigation studies of the causal relationship between energy consumption and economic growth have started since the seminal work of Kraft and Kraft (1978). Many studies focus on aggregated level of consumption. In disaggregated level, it is especially electricity consumption that is the centre of interest because it is not only related to economic wealth but also an indicator of socioeconomic development (Altinay, Karagol, 2005).

The newly developed statistical techniques (e.g. Sims) aimed at investigating whether economic growth takes precedence over energy consumption, or vice versa, energy consumption can boost economic growth, facilitated the research efforts. The recent improvement of econometric techniques stimulated the empirical research on the energy-economy debate which still brings the elusive results (Hondroyiannis, Lolos, Papapetrou, 2002).

The results seem to be different on both the existence of causality and the direction of causality and its impact on energy policy. The significance of policy implications can depend on the kind of a causal relationship that exists. According to Ozturk (2010) the reasons behind conflicting and ambiguous results might be different data set, different countries´ characteristics and alternative econometric methodologies. Different actual causality in different countries may be the result of different indigenous energy supplies, political arrangements, political and economic histories, cultures, institutional arrangements or energy policies. In developing countries, the investigation of the relationship between energy consumption and official GDP may not result in a reliable outcome because the GDP in these countries is measured uncorrectly, mainly due to unrecorded economic activities.

The relationship between energy consumption and economic growth may be categorized into four directions, each of which has important implications for energy policy.

2.2.1 Neutrality hypothesis (E≠GDP)

The neutrality hypothesis is supported by the non-existence of causal relationship between energy consumption and real GDP. It considers energy consumption to be a small part of overall output and therefore have little or no influence on real GDP. Energy conservation policies would not adversely impact real GDP (Apergis, Payne, 2009).

2.2.2 Conservation hypothesis (GDP→E)

The conservation hypothesis represents a unidirectional causality running from economic growth to energy consumption. This hypothesis implies that GDP growth causes energy consumption. It suggests that an economy that functions in such a causal relationship is less energy dependent; consequently, any conservation policies concerning energy consumption will have little or no adverse effect on economic growth (Ozturk, 2010).

Yet, a growing economy constrained by political, infrastructural or resource mismanagement could generate inefficiencies and the reduction in demand, including energy consumption. In such case, energy consumption would be adversely affected by a rise in economic growth (Squalli, 2007).

2.2.3 Growth hypothesis (E→GDP)

The growth hypothesis represents a unidirectional causality running from energy consumption to economic growth. It implies that energy consumption causes economic growth and the economy is energy dependent. The conservation policies reducing energy consumption may adversely impact real GDP (Apergis, Payne, 2009).

Contrary, some explanations might be given if there is a negative impact on GDP resulting from the increase in energy consumption. For example, the situation in which a growing economy requires a decreasing amount of energy consumption due to the shifts in production toward less energy intensive service sectors. Furthermore, the negative impact could be also referred to excessive energy consumption in unproductive economic sectors, an inefficient supply of energy, or capacity constraints (Squalli, 2007).

2.2.4 Feedback hypothesis (E↔GDP)

The feedback hypothesis represents bi-directional causality flows between GDP and energy consumption. Both energy consumption and GDP growth trigger each other (Kalimeris, Richardson, Bithas, 2014). They are interrelated and can serve as complements to each other. An energy policy focusing on improvements in energy consumption efficiency might not have an adverse impact on real GDP (Apergis, Payne, 2009).

The interdependence of energy consumption and economic growth might imply that conservation policies limiting the growth of energy consumption can have a negative influence on economic growth. Contrariwise, any possible influence on economic growth may be negatively transferred back to energy consumption (Wolde-Rufael, 2014).

During the years, many purely narrative surveys and few meta-analyses have been constructed to study the energy and GDP causal relationship. Among the newest examples of meta-analyses are works of Kalimeris, Richardson, Bithas (2014) and Menegaki (2014).

Kalimeris et al. in their work called *A meta-analysis investigation of the direction of the energy-GDP causal relationship: implications for the growth-de-growth dialogue* studied the existence of macro direction of causality between energy use and economic growth not influenced by study-specific features and events. The study consists of 158 observations during the period 1978-2011. The results were used to examine the direction of the mentioned causal relationship. The outcomes do not support the existence of robust macro direction and failed to define general factors influencing the direction. Similarly, it does not support the neutrality hypothesis of this causal relationship. This documents the contradictory results in the energy-economy nexus debate. They concluded that the direction of the causal relationship is the result of very specific conditions related to individual case studies. Therefore, policy implications based on the direction of causality relationship ought to be formulated carefully regarding that they might be sensitive to different factors. However, they argue that the outcome of their work cannot question that growth needs energy and efficiency gains reached through technological improvements did not reduced this strong link.

Menegaki in her study *On energy consumption and GDPstudies; A meta-analysis of the last two decades* elaborates a meta-analysis of 51 papers on the relationship between energy consumption and GDP growth published in last two decades. The goal of the work was to systematize factors causing the differences among the papers´ outcomes. The results showed evidence that the energy consumption elasticity depends on the used econometric analysis type, number of countries in dataset, electricity as a part of the overall energy consumption and the presence of variables like the price level or capital in the cointegration equation. The study follows that the omitted variable problem should not be ignored and suggests additional research in developing countries, application of more advanced econometric methods as well as inclusion of more variables in multivariate framework aiming to reduce omitted variable bias.

2.3 Empirical Studies

This subchapter describes the studies used for the empirical part of the thesis and a short description of contradictory results for severel individual countries found in the literature. The selection of the studies was described in the previous chapter. The final number of studies used is 104.

The overview of analysed studies is available in appendix A. It includes names of authors, year of publication, journal title, the country of the first author, length of study years, the type of causality found or geographical area analysed in the concrete study. As it was mentioned above the papers are limited by the year of publication therefore the papers in the table are dated since the year 2000. The newest study in the sample is from the year 2015. The chosen sample of studies includes both studies that analysed data of individual countries and panel data, respectively 71 and 33 studies.

There are many different authors from different countries analyzing various geographic areas. As it was outlined before, the outcomes of studies vary as well and it is difficult to reach the consensus among them. This can be demonstrated on many cases.

Considering the studies focusing solely on the USA, Gross (2012) concluded, in his bivariate model, that at the aggregate level there is a bidirectional causal relationship between energy consumption and economic growth. On the other hand, Soytas, Sari, Edwing (2007) found no causality between the two variables in a multivariate model. Even more confusion brings the analysis of Cleveland, Kaufmann, Stern (2000) which resulted in unidirectional relationship from economic growth to energy consumption in case of multivariate framework, and no causality in case of bivariate model. Even though, these results differ from each other there is one common characteristic in case of the USA, and that is that none of the studies (including studies not solely focused on the USA) proved a unidirectional causality running from energy consumption to GDP growth.

Another example can be studies including China, most of which are focusing solely on China. In their study Bloch, Rafiq, Salim (2012) developed two multivariate models. The first one, covering shorter time period and including production control variables, concluded that there is a unidirectional causal relationship running from energy consumption to economic growth. The same result is supported by the multivariate model of Shahbaz, Kahn, Tahir (2013) as well. The second one, covering longer time period and emissions as one of the variables, found bidirectional causal relationship. In the later study from Bloch, Rafiq, Salim (2015), however, the bidirectional causality was proven in both cases. The same direction of a causal relationship was also concluded in the bivariate analysis of Zhang, Xu (2012). On the contrary, multivariate analysis by Soytas, Sari (2006) brought the result of no causal relationship between the two variables. Another contrasting outcome is delivered by Naser (2014) whose multivariate model found a unidirectional causality running from economic growth to energy consumption. As it can be seen from the paragraph there are all four causality directions concluded in different studies of China.

In case of Germany, again, all four types of the causality direction were found. Using a bivariate model, Soytas, Sari (2005) found a unidirectional causality running from energy consumption to economic growth. Study of Tugcu, Ozturk, Aslan (2012) with a mulitvariate model concluded a unidirectional causality running from economic growth to energy consumption in case of renewables and no causal relationship in case of the fossil fuels consumption. No causality also resulted from the multivariate model by Lee, Chien (2010) and bivariate model by Balcilar, Ozdemir, Arslanturk (2010). Lee, Chiu (2014), on the contrary, concluded a bidirectional causality in their multivariate analysis.

Last but not least, is the example of Nigeria. Nigeria was present in 7 studies (considering the analysis at the aggregate level) altering the first three hypotheses. However no bidirectional causality was found. Akinlo (2008), Esso(2010), and Abalaba, Dada (2013) discovered no causal energy-GDP relationship. A unidirectional causality running from energy consumption to economic growth is supported by Squalli (2007), Wolde-Rufael (2005), Onafowora, Owoye (2014) and Ighodaro (2010) in case of electricity and gas. Conservation hypothesis or causality running from economic growth to energy consumption resulted in the analysis of Ighodaro (2010) in case of crude oil.

Many other examples could, of course, be mentioned to demonstrate the difficulty to find the consensus among studies. The four mentioned above were selected to provide an insight into the dichotomy of the results.

2.4 Relevance of the Empirical Studies

Following subchapter elaborates the partial goal of the work which is to review the factual relevance of the empirical literature for the policy makers. Notably whether the "influential" papers (as indicated by the number of citations) are also reflected, for example, in the EU, US or OECD policy documents. Policy documents are usually available online, on the websites of relevant institutions. EU´s papers can be easily find via European Commission web pages. EU regularly publishes its communications and policies on individual matters as well as different guidelines, brochures and other type of documentations which are avialable for free. Information about the US energy policies is available directly on the webpages www.whitehouse.gov/energy. It is more difficult to find published documentation or brochures that would be available without payment. OECD papers are also easily accessible. One can find published declarations, guides or materials prepared for OECD´s meetings online.

2.4.1 Policy Documents of the European Union

The necessity of energy makes it a strategic sector. The current standard of living demands huge amounts of energy which consequently cause pollution. According to the European Commission (2014), energy related emissions in 2011 represented 80% of the European Union´s greenhouse gas emissions. Moreover, EU is the world´s largest importer of energy and depends on other countries. This dependency influences the economy in a massive way, especially by increasing the energy costs. The rising amount of evidence of climate change and growing dependence on energy emphasized the European Union´s determination to become a low-energy economy and reduce the impacts of pollution as much as possible.

Nowadays, European Union is considered to be the most active group with respect to the negotiations for the environmental protection and presses to adopt strict measures (Dritsaki, 2014).

2020 Strategy

In 2007, the European Council adopted the first set of measures for climate and energy for 2020. On 10 November 2010, the European Commission has adopted the Communication Energy 2020 – A strategy for competitive, sustainable and secure energy. The EU set itself three main goals to be reached by 2020:

- reduction of greenhouse gas emissions by at least 20%
- increase of the renewable energy´s share to at least 20%
- 20% improvement in energy efficiency.

All EU countries must also achieve a 10% share of renewable energy in their transport sector (European Commission, 2011).

According to the '*Communication from the Commission to the European Parliament, the Council, the European economic and social committee and the Committee of the regions*' (2014), the EU has already managed to reach some key achievements of the current policy framework. In 2012 greenhouse gas emissions dropped by 18% compared to the year 1990 and are supposed to keep decreasing to 24% by 2020. The portion of renewable energy as a part of final consumed energy has raised by 13% in 2012 and is believed to increase up to 21% in 2020. 44% of the world´s renewable energy (not counting hydro) was set up by the EU at the end of 2012. The economy´s energy intensity has decreased by 24% in a period 1995-2011 and the achievement of the industry was about 30%. In the same period, the carbon intensity of the economy dropped by 28%.

Strategy 2030

On 23 October 2014, the European Council agreed on the climate and energy policy framework for the period between 2020 and 2030. The framework follows 2020 strategy and sets three main objectives to be reached by the year 2030:

- reduction of greenhouse gas emissions by at least 40% compared to 1990
- increase of renewable energy use to at least 27% of total energy consumption
- improve energy efficiency at the EU level of at least 27% compared to current criteria (European Council, 2014).

Unlike the previous 2020 strategy, the goals of new 2030 package will not be nationally binding by EU legislation. This decision was made to leave more flexibility for member states under the provisions stated in Article 194(2) of the TFEU about the national control over the energy mix. Due to the insufficiency of binding national aims, there is a risk that countries´ efforts will not total the EU aggregate commitments. Regarding this problem, possible governance scheme was proposed by the European Commission (Tagliapietra, Zachmann, 2015).

Strategy 2050

The 2050 energy strategy, or so called Energy Roadmap 2050 is a practical guide to a low-carbon Europe that explores the transition of the energy system to reach a EU´s long-term goal of decreasing greenhouse gas emissions by 80-95% compared to the year 1990. The Climate Roadmap proposes what could be the most effective way to lower the greenhouse gas emissions. The basis is built on the best facts available from industry players and academia, and elaborated by a group of reputable experts thoroughly addressing valid industry standards. The whole project is an initiative of the European Climate Foundation (European Climate Foundation, 2010).

2.4.2 Policy Documents of the United States

United States is a significant consumer, as well as producer, of energy in the world economy therefore, it plays an important role in the world energy market. Naturally, any policy that alters the energy use patterns will have an effect on the world energy market (Soytas, Sari, Ewing, 2007).

Since the oil embargo in 1970s, United States´ energy policy has focused on three main long-term targets, namely, assuring a secure supply of energy, keeping energy costs low and protecting the environment. To follow these targets, they have elaborated government programs to reduce consumption of energy through the increase of energy efficiency, promote the domestic production of traditional energy sources, and to develop new renewable energy sources that could substitute oil and other fossil fuels (Yacobucci, 2015).

In 2009, President Obama made a promise that by the year 2020 the US would decrease its greenhouse gas emissions by 17%, compared to the year 2005, if all other major economies do so as well. There has already been an important progress achieved by the current Administration, for example, doubling generation of electricity from renewable sources or establishing new fuel economy standards. Moreover, in 2012 US carbon emissions dropped to the lowest level in last twenty years though economy kept growing (Executive Office of the President, 2013).

In June 2013, The President´s Climate Action Plan has been announced. The plan aims at cutting carbon pollution and other greenhouse gases, decreasing the amount of energy used by American inhabitants and decreasing their gas and utility costs. Following the previously mentioned achievements, the plan focuses on further steps to meet the 2020 goal. It consists of large amount of different executive actions stressing the three main pillars:

- to cut carbon pollution
- to prepare for the impacts of climate change
- to lead international efforts to fight global climate change and prepare for its impacts (Executive Office of the President, 2013).

2.4.3 Policy Documents of the OECD

On June 2009, the Ministers of 34 countries adopted OECD´s Declaration on Green Growth in which they declare:

- strengthening of their efforts to pursue green growth strategies as part of their response to the current crisis acknowledging that green and growth can go hand-in-hand
- encouraging green investment and sustainable management of natural resources
- encouraging domestic policy reforms to avoid or remove environmentally harmful policies that might counteract green growth, for example subsidies to fossil fuel consumption/production
- ensuring the close co-ordination of green growth measures with labour market and human capital formation policies
- strengthening international cooperation (OECD, 2009).

The OECD was invited to develop the Green Growth Strategy to reach an economic recovery and environmentally and socially sustainable economic growth by bringing together economic, environmental, social, technological, and development aspects into a comprehensive framework. Non-OECD members, Civil Society or other International Organization were as well invited to cooperate with OECD in line with the Declaration. The Declaration follows the international climate agreement from the 15th Conference of the Parties of the UN Framework Convention on Climate Change (COP15) in Copenhagen in December 2009 (OECD, 2011). The original 34 participants were Australia, Austria, Belgium, Canada, Chile, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States and the European Community. Later Lithuania, Costa Rica, Colombia, Croatia, Latvia, Morocco, Tunisia has joined as well as OECD members in having adhered to the declaration.

Green Growth Strategy

The Green Growth Strategy, delivered in 2011, started the OECD´s longer-term agenda to support national and international efforts for greener growth. Individual countries face different constraints and opportunities due to the differen levels of their economies, socio-economic context or political and economic environments therefore it provides a flexible policy framework that can be tailored to country-specific circumstances The strategy should be considered as a strategic complement of already existing environmental and economic policy reforms (OECD, 2011).

The aim of the framework is to set incentives or institutions which raise well-being by the improvement of resource management and boosting productivity, encouragement of economic activity where it is of best for the society and encourage new possibilities of reaching the last two objectives (OECD, 2011).

There are many concrete recommendations and measurement tools ensuring that our natural heritage will continue providing the resources and environmental services on which we depend. Number of individual policy options is described and available in OECD documents, for example '*Tools for Delivering the Green Growth*'. Apart from the outlining of the options, the document also summarizes the issues needed to be considered while elaborating a green growth strategy.

3 Objectives and Methodology

3.1 Objectives

The main objective of the current meta-analysis, as described above, is to search for the evidence of any form of causality between the energy use and economic growth as well as its prevailing type. The objective is elaborated by using econometric methods. The analysis is conducted through the binomial and multinomial logit models. Further, work focuses on studying the influence of the several common study characteristics.

The thesis determines 27 characteristics with the possible influence on the result of the research that could generally be extracted from the selected papers. The chosen attributes are: geographic area, USA only, China only, EU only, number of cross sections, number of observations, length of study years, sample size, frequency, overall economic level, panel data, single region, sectorial, multiple energy types, multivariate, production control variables, price as a control variable, EKC link, estimate method of causality, cointegration testing, cointegration method, structural breaks considered, significance level used, correction for multiple testing, energy types, variables per capita and sign of causality considered.

3.2 Methodology

To investigate the presence of a significant evidence for any form of (Granger) causality and the prevailing type of the causality, with regard to the influence of multiple study characteristics, the systematic review of literature using econometric methods will be performed.

The first step towards the meta-analysis is to construct a database. This part is relatively time-consuming and includes three main activities: search for studies, selection of relevant studies and coding of studies´ attributes (mentioned above) to create a dataset. Two types of dataset have been created to serve the purposes of the analysis. By coding individual observations in the studies, the disaggregated dataset, a basis for the meta-analysis, was created. Furthermore, aggregated dataset focusing on individual studies was created to help with the statistic overview and general analysis of data. Therefore, it is necessary to diversify between two types of commentary. One based on the aggregated dataset (describing studies) and the other, resulting of the disaggregated dataset (describing individual estimations). Analysis of the disaggregated dataset is performed with the use of binomial and multinomial logistic regression, in a similar manner as in Kalimeris, Richardson & Bithas (2014).

3.2.1 Search for studies

At the beginning, it is essential to review the existing literature about the energy-economy nexus and search for the possibly useful papers. Studies were searched for on the Scopus web database, www.scopus.com. The used link was: TITLE-ABS-KEY (energy economy OR growth relationship OR causal OR nexus) AND SUBJAREA (mult OR arts OR busi OR deci OR econ OR psyc OR soci) AND PUBYEAR > 1999) AND (causality OR cointegration) AND (LIMIT-TO (SUBJAREA , "ECON")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "j").

This database was chosen because it is the largest abstract and citation database of literature: scientific journals, books and conference proceedings which brings a broad overview of global, interdisciplinary scientific information in all research fields (Elsevier, ©2016). The access to the database and full articles is provided by the Mendel University. To search for the studies in a database it is necessary to define the key words. Used key words in the current study are: energy economy or growth relationship or causal or nexus. This work focuses on more up to date papers published since 2000 therefore the year of publication was limited to bigger than 1999. The language used in all the papers is English. The studies were also ranked by the number of citations in a descending manner. The overview of the studies was then, from practical reasons, limited to 150 most cited studies.

3.2.2 Selection of relevant studies

Second step toward the creation of dataset is the selection of relevant studies from the previously constructed ovierview of the studies. At first, it was examined whether the key variables of the study include relationship between GDP and energy consumption. Papers which included only some other key variables than these were excluded from the list. Papers that included also some additional key variables beside the ones already mentioned, remained in the list of relevant literature. Secondly, study was considered relevant if all the chosen attributes, or characteristics, were present in it. Papers that failed to provide the essential input were excluded. The final number of relevant studies included in the overview is 104.

In some fields, there is evidence that significant results are published more quickly or frequently than the negative ones. This phenomenon is called publication bias. Meta-analyses, particularly those focused on subject matters with more recently created empirical basis, can be influenced by overrepresenting significant positive findings while null or negative ones are more likely to be published later –after the meta-analysis was performed, or not at all (Card, 2012). Publication bias is especially a threat because meta-analysis has been presented as delivering a more accurate appraisal of a research literature than traditional narrative reviews. However, if the sample of studies chosen for a review is biased, the validity of the meta-analysis´s results is threatened, regardless of how systematic and rigorous it is in other respects. Despite its threat, publication bias should not be taken as an argument against the use of a meta-analysis because such biases are present in literature no matter what methodology is used to conclude the results (Rothstein, Sutton, Borenstein, 2006).

3.2.3 Coding of attributes

Final dataset is created by coding data into a numeric form. There are also so called dummy variables. These artificial variables can take two values, 0 or 1 (binary variable), to indicate that some categorical effect is absent or present. In the case of validity of a specified criterion, values for individual studies equal 1. To introduce the dataset more in detail, the coding of individual variables is described in a following paragraph.

Geographic area is divided into 6 subcategories which are: 1=Mixed, 2=Asia and Pacific (including Australia), 3=Europe (including Turkey and Russia), 4=Latin America & the Caribbean, 5=Middle East and Africa, 6=North America.

Variables *´USA only´*, *´China only´* and *´EU only´* are based on the same principle. If a study includes only a particular country variable takes value 1. In an opposite case variable equals 0.

Number of cross sections is an integer number indicating the number of countries/regions/sectors in the study.

Number of observations indicates the number of period observations which depends on the number of cross sections, frequency at which the data were collected and the length of the study in years. It is important to mention that when analysing panel data the number of observations in one year (considering frequency=1) is one even though the number of cross sections is higher. The reason is that countries are analysed together as a one panel.

Length of study years naturally displays the length of the study period in years.

Sample size is calculated as number of cross sections multiplied by the length of study years.

Year of publication was coded according to the date of publication, from 2000 to 2015.

Frequency specifies the rate at which data were collected (annually, quarterly, monthly, other). Because almost all data were annual (except for two observations), additional dummy variable annual data is used instead.

Overall economic level classifies countries in 4 categories: 1=Low and lower-income economies, 2=Middle-income economies, 3=High-income economies, 4=Mixed.

Dummy variables are used to indicate whether the study uses *panel data* and whether a study focuses on a *single region*.

Variable *Sectorial* deals with the sectorial energy consumption or GDP measurement used in the study, using following coding: aggregate data=1, sectorial data=2 and both=3.

Production control variables represents four subcategories selected according to a production variable included in a study: 1=None 2=Capital, 3=Labour, 4=Both.

Estimation method of causality depends on the different method used to examine the causality between the energy consumption and GDP. This paper considers 5 options of this variable: 1=Standard gr. Causality (Engle-Granger, Sims), 2=Modified gr. Causality (Hsiao, TY), 3=ARDL, 4=Panel causality tests and 5=Other.

Cointegration methods are represented as: 1=None, 2=Engle-Granger, 3=Johansen, 4=Panel - Pedroni/Larsson, 5=Other.

Significance level used is coded as 1 (5%), 2 (10%), 3 (both) or 4 (not specified).

There are different *energy types* that can be used in a study to specify energy consumption. The coding options are defined as follows: 1=Aggregate/all, 2=Fossil fuels (oil, gas, coal), 3=Electricity, 4=Renewables, 5=Nuclear heat or 6=Exergy.

Variables measurement in the studies can be expressed as total=1, per capita=2 or in both measures=3.

The study might consider the *sign of causality* as well (value of 3) or it can do it only partially in cointegration equation (indicated by value 2) as well as it might be unclear (=4) or not considered at all (=1).

Other variables like *multiple energy types, multivariate, price as a control variable, EKC link, cointegration testing, structural breaks considered* or *correction for multiple testing* take value 1 if the attribute is present in a study, otherwise are 0.

Dependent variable called *Basic causality direction concluded* defines the type of causality which resulted in individual studies. Coding, particularly for the purposes of multinomial logit model, is following: 1 is for neutrality, 2 for growth, 3 for conservation and 4 for feedback hypothesis. In the binary regression model we answer the question whether the relationship between the energy consumption and GDP exists or does not exist. For this purpose the dummy variable called *Causality* is created, with value 0 indicating the neutrality hypothesis and 1 otherwise.

After coding of data and completing the data set, binomial and multinomial logit models may be applied to perform a meta-analysis. All the tables and figures displaying and commenting results in the current work are based on the own calculations using the Gretl programme if not stated otherwise.

3.2.4 Binary logit model

In all cases where the variable can take only two possible values, such variable is called binary. The two outcomes are labelled as 1 ('success') and 2 ('failure'). In this work, the model is supposed to find out what determines Yi^* or whether there is a causality found in the ith study ($Yi^*=1$), or the causality is missing ($Yi^*=0$). This dependent variable can be influenced by several independent variables that have been already specified above (Heijl et al., 2004).

The dependence then corresponds to the following model:

$$Yi^* = \beta Xi + \mathcal{E}, \qquad (1)$$

$$Yi^* = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_k X_{ki} + \varepsilon_i \quad (2)$$

where index i serves for the description of individual observations (studies). Yi* is so called latent (unobserved) variable and Ɛi has normal distribution $\varepsilon \sim [0, 1]$. Yi can be seen as an indicator and if the latent indicator is positive then: Yi= {0, 1} when Yi* > 0, $-\varepsilon < \beta X_i$, otherwise 0 (Verbeek, 2004).

Following paragraphs are derived from the book Němec, (2012), if not stated otherwise. The probability of the choice 1 can be expressed as:

$$Pr(Y_i = 1) = Pr(Y_i^* \geq 0) = Pr(\beta X_i + \varepsilon_i \geq 0) = Pr(\varepsilon_i \geq -\beta X_i) \quad (3)$$

Model is defined and in the case of interpretation of estimates´ results we proceed as follows. Since the variables take values 0 (absence of causality) and 1(existence of causality), we consider the probability of a given option. Because Ɛi has logistic distribution, the probabilities are given as:

$$Pr(Y_i = 1) = \exp(\beta X_i) / (1 + \exp(\beta X_i)) \quad (4)$$

$$Pr(Y_i = 0) = 1 / (1 + \exp(\beta X_i)) \quad (5)$$

These relationships can be used to interpret the results of a logit model. In regression models, coefficients are interpreted as measuring the marginal impacts of explanatory variables on the explaining variable. In the case of logit models, the interpretation is not completely direct. We report coefficient, p-values and the marginal impact of the variable X on the probability of the option 1. Marginal impact of X on the probability 1in logit model is:

$$\frac{\exp(\beta X_i)}{1+\exp(\beta X_i)} \; \frac{1}{1+\exp(\beta X_i)} \quad \beta \quad (6)$$

Another usual way of interpreting the marginal effects is the use of odds ratio. Odds ratio is the ratio of probabilities of the choice of each alternative.

$$\frac{Pr(Y_i = 1)}{Pr(Y_i = 0)} \quad (7)$$

Odds ratio can be, on the basis of previous explanations (see formula 4 and 5), rewritten into the form:

$$\exp(\beta X_i) \quad (8)$$

The logarithm of the odds ratio is then, in this case, βX_i. The interpretation of the parameter β is following: if X is increased by one unit the logarithm of odds ratio changes by β units. In Gretl programme, marginal effects are labeled as 'slope'.

3.2.5 Multinomial logit model

The data are called multinomial when the explaining variable has a finite number of possible outcomes. This occurs when we can choose among more than two options. These options can be ordered (for instance, how much one agrees or disagrees with something) or unordered (for instance, the choice of travel means by commuters). In our model, we are searching for the type of a causality between energy consumption and economic growth therefore, the options are unordered. Y_i can take values 0, 1, 2, …, J. Y_{ji} then represents the type of causality in the i^{th} study (Heij et al., 2004).

The aforementioned types of causality (outcome categories) are characterized as follows:

- j=1: absence of causality (E≠GDP)
- j=2: causality running from energy consumption to GDP growth (E→GDP)
- j=3: causality running from GDP growth to energy consumption (GDP→E)
- j=4: bi-directional causality (E↔GDP).

In multinomial logit regression, one of the outcome categories is always hold as a reference category and each of other three categories are compared to it. In practice, the choice of a reference category among outcome categories is indifferent. The results are always the same. The Gretl programme uses the first alternative (absence of causal relationship) as a reference one. Hence, this analysis fits simultaneously three models:

- E→GDP compared to E≠GDP
- GDP→E compared to E≠GDP
- E↔GDP compared to E≠GDP.

Types of causality are dependent on the explanatory variables defined above. The following regression model is defined:

$$Y^*_{ji} = \beta_j + \beta_{j1}X_{1i} + \beta_{j2}X_{2i} + \ldots + \beta_{jk}X_{ki} + \varepsilon_{ji} \quad (9)$$

The attention should be paid to the down indexes. Unlike binary model, there is not only one regression but J different regressions (each for the comparison of all alternatives to the reference alternative). There are different coefficients in each of the regressions. β_j is a constant containing difference in utilities between an alternative J and the reference alternative. β_{j1} is the coefficient of the first explanatory variable in the regression, etc (Němec, 2012).

The probability that the type of causality j is present in the i^{th} study, in the case of multinomial logit model, is given as

$$\Pr(Y_i=j) \quad \frac{\exp(\beta_j X_i)}{1+\sum_{s=1}^{J} \exp(\beta_s X_i)} \quad (10)$$

where for the simplification of the formula, the regression dependence with one explanatory variable is considered (Němec, 2012).

3.2.6 Multicollinearity

One of the good things about logistic regression is that it is very similar to ordinary linear regression analysis, however some of the negative features of linear regression also apply to logistic regression. One of them is multicollinearity occurring when there are strong linear dependencies among the explanatory variables. The basic feature is that if two or more variables are highly correlated, it is hard to get good estimates of their effects on a dependent variable. Multicollinearity makes coefficients more unstable, though it does not bias them. Standard errors can get large and individual variables that seem to have weak effects can have strong effects as a group. Luckily, the consequences only apply to variables that are collinear (Allison, 2012).

3.2.7 Zero cells and (quasi) complete separation problem

There are two related problems with similar symptoms as multicollinearity that might occur. Mentioned problems are zero cell count and complete separation.

Menard (2002) characterizes zero cell count as an indicator that the dependent variable is the same for one or more categorical independent variables. For example, if all the countries in the Europe category for geographical area reported finding causality or not finding causality (considering bivariate model). Due to this, there would be a problem with a zero cell in the contingency table displaying relationship between the existence of causality and geographical area. The odds would be 0 or 1 for an entire group of cases resulting in a very high estimated standard error for the coefficient associated with the category as well as coefficients for which that category serves as a reference category. This problem is specifically relevant to categorical nominal variables. There are three possibilities of what could be done if the problem occurs:

- accepting the high standard errors, together with the uncertainty about the values of coefficients,
- modifying the categorical independent variable by revoking categories or excluding the problematic category,
- adding a constant to each zero cell of the contingency table.

The second problem is a complete separation which arises when the prediction of the dependent variable with the explanatory variables is too successful. Logistic regression coefficients and their standard errors will then tend to be extremely large and the dependent variable will be predicted perfectly. If the problem of complete separation occurs in a bivariate model, the logistic regression model cannot be calculated (Menard, 2010).

If the separation is not complete (quasi-complete separation), coefficients and their standard errors are still going to be very large. A quasi-complete separation is indicating that for some subset of the data, the outcomes can be classified perfectly. Quasi-complete separation can be detected with zero cell count in the contingency tables of relevant variables (Matignon, 2005). Even though, there is actually nothing wrong with this phenomenon, as the perfect prediction is what is wanted to be achieved, from a practical point of view, one should be suspicious because it almost never happens in the real world research. It might indicate problems in the data or analysis, like having almost the same number of variables as cases to be analysed (Menard, 2010).

4 Results

In this part of the thesis, the meta-analysis of the given studies is executed. Moreover, the search for the factual relevance of empirical papers in policy documents, especially of the EU, US and OECD, is performed. Firstly, a statistic overview of the studies with focus on the most interesting characteristics is given to deliver a general picture about the dataset used in the following analysis. Secondly, a binary logit model is elaborated and reasoning beyond results is provided. Thirdly, multinomial logit model is performed and a relevant commentary is given to support the results. Last but not least, it is concluded whether some of the papers used for the purposes of meta-analysis have been used for the elaboration of policy documents.

As it was mentioned before there is 104 studies in total, coded individually per individual estimation of samples used in the studies (in total 351 observations). The studies used in the current analysis were published by 13 journals. Most of them, specifically 56 studies, were published in one journal - Eenrgy Economics - representing 54% of all the papers. The second most frequent publisher of energy-economy nexus studies from this work is International Journal of Energy Economics and Policy accounting for 17% of used studies. From the remaining 11 journlas, each accounts only for a small percentage of published papers. It could be concluded that most of the energy-economy nexus studies are published by one journal. The diagram with complete representation of publishing journals is shown in Figure 1.

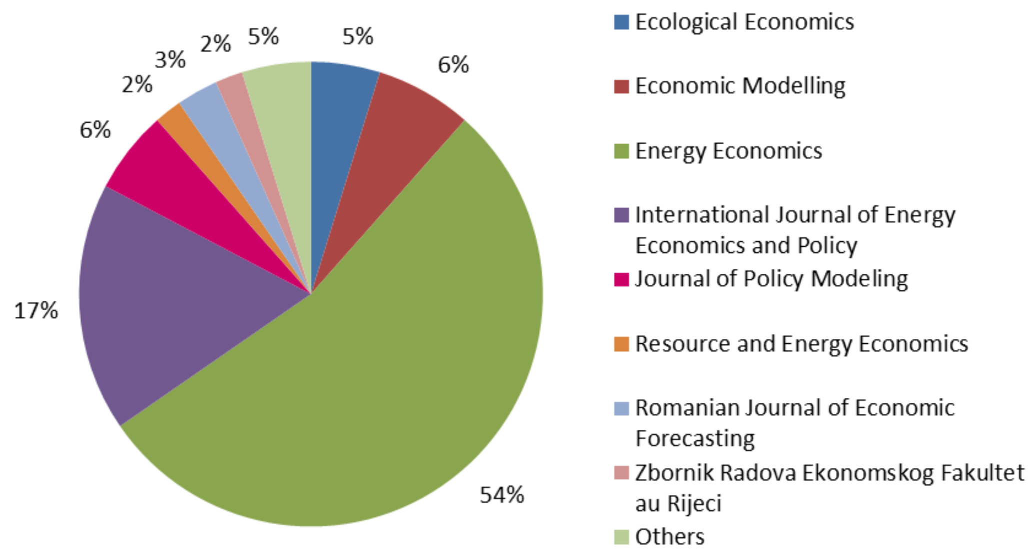

Figure 1: Representation of Publishing Journals

The vast majority of the studies rely on annual data and use very long time spans (median length is 36 years) but only 41 of them consider the possibility of structural breaks´ presence in the data. Only 30.77% of the studies report results where no causality between energy consumption and economic growth was found. Table 1 shows the frequencies of the four basic causality directions considering the individual observations. Only about 29% of studies use panel data and the most frequent number of cross sections was 1. The typical focus is on developing countries, with only about 37% of the observations including countries classified as high-income economies. Vast majority of the studies use samples with less than 100 observations.

Table 1: Frequences of the basic causality directions

Causality direction	Frequency	Relative
1	100	28.49%
2	79	22.51%
3	84	23.93%
4	88	25.07%

In Table 2 you can see that the most of the observations analysed the causal relationship in the Middle East and Africa, more precisely 105 observations. Europe and North America which can be considered to have the most developed countries together account for 106 observations which makes it less than one third of total observations. 36 observations account for mixed geographic area. The group of 209 observations was acquired from rather developing areas therefore we can sum up that, from a geographical position, much more studies in our dataset are focusing on and analyzing developing countries rather than the developed ones.

Table 2:Frequency distribution of geographic areas

Geographic area	Absolute	Relative
Mixed	36	10.26%
Asia and Pacific (including Australia)	93	26.50%
Europe (including Turekey and Russia)	83	23.65%
Latin America and the Caribbean	11	3.13%
Middle East and Africa	105	29.91%
North America	23	6.55%

Another common characteristic of the dataset is the length of study years. All papers focused on a very long study periods. The mean length of study period of observations was 36.35 years. The minimum amount of study years in the 104 papers was 9 and maximum 150 years. None of the 104 papers analysed shorter time periods. Although the papers studied quite wide time periods there were very few of them that considered structural breaks in their analysis which could cause unexpected shifts in time series and lead to forecasting errors and unreliability of the model in general. Figure 2 displays the frequency distribution of the study periods.

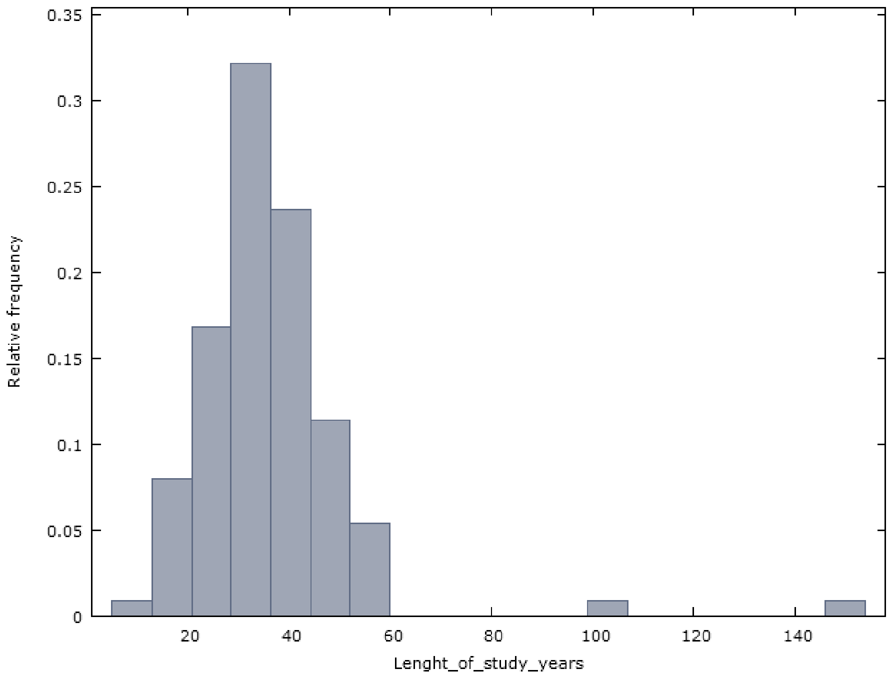

Figure 2: Frequency distribution of the study periods

4.1 Binary Logit Model

To examine the causal relationship in this study we, at first, estimated a binary logit model. Variable Annual was automatically excluded from the model due to the perfect prediction caused by insufficient variability in the data. All studies used annual data with only three exemptions (Oh, Lee, 2004; Shbia, Shahbaz, Hambdi, 2014 and Kayhan, Adiguzel, Bayat, Lebe, 2010).

Subsequently, the three binary logit models were created, namely Model 1, Model 2 and Model 3. The comparison of models is shown in Table 3. The numbers in brackets refer to the numbers of correctly predicted cases in absolute and relative values. There are three values for every variable in each model: Coefficient, p-value and marginal effect.

Table 3: Binary Logit Models

Variable	Model 1 (251; 71.5%)			Model 2 (269; 76.6%) Likelihood ratio test = 71.888			Model 3 (267; 76.1%) Likelihood ratio test = 64.630		
	Coefficient	**P-value**	**Marginal effect**	**Coefficient**	**P-value**	**Marginal effect**	**Coefficient**	**P-value**	**Marginal effect**
constant	0.920	0.000		165.659	0.091		0.348	0.285	
Geographic area				-0.100	0.347	-0.018			
USA only				**-1.700**	**0.034**	**-0.400**	-1.667	0.021	-0.386
China only				1.157	0.286	0.155			
No of observations				0.006	0.628	0.001			
Year of publication				-0.082	0.093	-0.015			
Panel data				**1.823**	**0.000**	**0.244**	1.795	0.000	0.250
Single region				0.672	0.069	0.114	0.800	0.020	0.138
Sectorial				0.047	0.898	0.009	0.544	0.049	0.102
Multivariate				**0.626**	**0.045**	**0.114**			
Price as control variable				0.311	0.482	0.054			
Estimation method of causality				**-0.237**	**0.041**	**-0.043**	-0.273	0.011	-0.051
Structural breaks considered				**0.903**	**0.017**	**0.151**	0.845	0.015	0.146
Correction for multiple testing				**-2.106**	**0.004**	**-0.478**	-2.434	0.001	-0.543
Energy types				0.302	0.062	0.055	0.308	0.034	0.058
Variables per capita				-0.291	0.136	-0.053			

Starting Model 1 is a simple naïve model. Note that the naïve model correctly predicted 251 cases out of 351 observations representing 71.5%.

Model 2 is the model with highest number of correctly predicted cases, i.e. 76.6% (269 observations). Considering the 5% significance level, there are 6 significant predictors: USA only, Panel data, Multivariate, Estimation method of causality, Structural breaks considered and Correction for multiple testing. The values of significant variables are marked bold in the table. Particularly interesting feature are the negative signs of several predictors, namely USA only, Estimation method of causality and Correction for multiple testing. The negative sign of the significant variable suggests that the presence of the characteristic in a study decreases the probability that we find causality. Therefore, there is a lower probability to find causality in USA. As it was mentioned in the methodology part, marginal effect measures the impact of the variable X on the probability of the option 1. The probability to find the causality in USA is lower by a calculated value (0.400). More advanced causality detection methods apparently reduce the chances to find causality as well as consideration of correction for multiple testing. It seems that there is a higher probability to find causality when using panel data, considering structural breaks and analysing mutivariate models. The impact of variables is again expressed by the values referred in the column Marginal effect. However, there are still many insignificant variables.

Model 3 provides the final model form after running a sequential elimination tests using two sided p-value (0.05). This model correctly predicted 267 cases what represent 76.1% of the observations. Compared to the Model 2 it is only 2 observations less. There are eight significant variables apart. These are shown in the Table 6. Three of the variables (USA only, Estimation method of causality and Correction for multiple testing) have negative signs of their coefficients. The effect are the same as described in the paragraph above. Four remaining variables have positive sign indicating that their presence in the study increases the probability to find causality between energy consumption and economic growth. Using panel data, focusing on single region and consideration of structural breaks improve the chances to find the causality. There is also the evidence that the same positive contribution is reached if the specific energy type is used to measure the energy consumption instead of aggregate energy consumption.

We can see that there are several significant variables in the final model, however their influence on the dependent variable and prediction capacity is rather low. The main problem with many of the study characteristics is their low frequency in the dataset (i.e. insufficient variability of the studies). For example, there are only 16 observations from USA or 18 observation with the presence of correction for multiple testing. Moreover, as it was already mentioned, only 41 studies consider structural breaks and only 33 use panel data.

4.2 Multinomial Logit Model

The next step in the current work´s analysis is to elaborate a multinomial logit model to identify important factors influencing the prevailing type of some hypothesis. As it was depicted in the literature review, there are 4 types of hypotheses, each identifying a direction of causal relationship between energy consumption and economic growth. In these types of models one of the outcome categories is hold as a reference category and each of other three categories are compared to it. The Gretl program uses the first type of causality, or no causality, as the reference category. We can consider the three basic models each of them is based on the three regressions as it was explained the chapter Methodology.

Model 4 which represents naïve model including only a constant. This model correctly predicted only 100 observations out of the total number 351 (i. e. with a ratio of success of 28.5%).

Model 5 including all the variables correctly predicted 174 cases what represent 49,6% of observations. The prediction success continues to be very low. The significant variables in the case of causality direction 2 in this model considering the 5% significance level are Multiple energy types and Correction for multiple testing, both decreasing the probability to find causality running from the energy consumption to economic growth compared to the case of finding no causality. If the significance level is set to 10%, number of significant variables increases to five. Additional significant variables are Year of publication, Panel data and Variables per capita. Year of publication and Correction for multiple testing decrease the probability to find causality in comparison with the reference level. On the contrary, variable Panel data increases this probability.

The probability to find causality running from economic growth to energy consumption (again compared to no causal relationship found) increases when analysing panel data which was the only significant variable considering the 5% significance level. Considering the 10% significance level there is one more significant variable which is *Estimation method of causality*. This variable decreases the probability of finding the causality relationship.

In the case of the last bidirectional causality, there are two influencing variables, namely Panel data and Energy types both increasing the probability to find this type of causality compared to the first hypothesis. At the higher 10% significance level, the group of significant variables also includes Single region, Multivariate, Estimation method of causality and Variables per capita. Variables Single region and Multivariate increase and variables Estimation method of causality and Variables per capita decreases the probability to find the bidirectional causality in comparison with the reference category.

In this model some of the variables have very high standard errors compared to the others. Namely the variables Number of observations, Length of study years and Annual. Therefore, the collinearity test was performed (values of variance inflation factor (VIF) higher than 10 may indicate a collinearity problem). The results of collinearity test are shown in Table 4. There are four such variables, namely Number of cross sections, Number of observations, Length of study years and Sample size. Variables Number of observations and Length of study years are very similar and due to the annual frequency used in almost all studies their values are identical in most of the cases. Due to this, it is not necessary to keep both of the variables in the model. The decision about which of these two variables to eliminate was based on the improvement of the model if the specific variable was eliminated. The model´s prediction success increased more when we eliminated the variable Length of study years. Similarly the variable Sample size was eliminated as well. After removing of these variables, the VIF values in collinearity test were lower than 10 for all the variables included in the model indicating there should not be the problem with collinearity.

Table 4: Collinearity test of multinomial logit model

Variable	VIF
Geographic area	1.993
USA only	1.378
China only	1.438
EU only	1.840
No of cross sections	21.552
No of observations	20.237
Length of study years	18.869
Sample size	23.596
Year of publication	2.021
Overall economic level	2.430
Panel data	3.244
Single region	1.920
Sectorial	1.622
Multiple energy types	1.956
Multivariate	3.870
Production control variables	2.766
Price as control variable	1.831
EKC link	1.588
Estimation method of causality	2.496
Cointegration testing	5.325
Cointegration method	5.495
Structural breaks considered	2.189
Significance level used	1.589
Correction for multiple testing	2.139
Energy types	1.846
Variables per capita	2.065
Sign of causality considered	2.367
Annual	6.091

The variable Annual was also among the variables with high standard errors but its variance inflation factor was lower than 10. From the previous analysis, it was concluded that the variable Annual has a very low informative value due to the annual collection of data in majority of studies. The find the reasoning behind the high standard errors, the analysis of data using contingency tables was performed. The cross-tabulation of dependent variable and variable Annual showed that there are only 6 observations with frequency other than annual relating to the low informative value. The result is shown in Table 5. The quasi complete separation problem can be seen. As it was mentioned in the methodology part, quasi-complete separation states that for some subset of the data, the outcomes can be classified perfectly. When looking at the first type of causality the table shows that if dependent variable Y=1 the variable Annual equals 1 or X=1. For these reasons, the variable annual was removed from the model.

Table 5: Contingency table Basic causality direction concluded (rows), Annual (columns)

	[0]	[1]	Total
[1]		100	100
[2]	2	77	79
[3]	2	82	84
[4]	2	86	86
Total	6	345	351

There were other two variables with extremely high standard errors but only in a specific regression model. The variable *USA only* had suspiciously high values of standard errors in the first regression which analyses causality running from energy consumption to GDP growth compared to the reference category- no causality found. The justification can be seen in the contingency table shown in Table 6. Note that there are no observations of USA that would resulted in the second type of the causality direction, the cell is empty causing the high standard errors. Even though, there was not problem with collinearity in this case it is obvious that the variable *USA only* has a low variety and therefore low informative value as there are only 11 out of 351 observations with this characteristic. It is not necessary to keep the variable in the model hence the variable can be removed.

Table 6: Contingency table Basic causality direction concluded (columns), USA only (rows)

	[1]	[2]	[3]	[4]	Total
[0]	93	79	82	86	340
[1]	7		2	2	11
Total	100	79	84	88	351

The same issue was detected with the variable Correction for the multiple testing, see Table 7. There is one zero cell causing the problem with high standard errors. Because the correction for multiple testing was used only in a very small amount of cases, the variable was eliminated from the model.

Table 7: Contingency table Basic causality direction concluded (columns), Correction for multiple testing (rows)

	[1]	[2]	[3]	[4]	Total
[0]	86	77	82	88	333
[1]	14	2	2		18
Total	100	79	84	88	351

After elimination of the problematic variables, the model correctly predicted 170 cases (48.4%), likelihood ratio test equaled 151.53. The search for the model with the highest prediction success followed. It was performed by the gradual elimination of variables and comparisons of qualities of different resulted models.

The final concluded model has 14 variables including constant. There are other 10 redundant variables that were removed from the model. The prediction success remains low, the same as in the case of the model without problematic variables. However, considering significance of variables, likelihood ratio test the results are better than what was reached before and the best from the models that were reached during the path of finding the model.

In the first regression, there are six significant variables, specifically Number of observations, Panel data, Multiple energy types, Multivariate, Cointegration testing and Variables per capita. Four of the variables increase the probability and two decrease the probability to find causality running from energy consumption to GDP growth compared to the no causality found which represents the reference category. The results suggest that the higher the number of observations in a study the higher is the probability to find the causal relationship. The same effect is elaborated if the study analyses panel data, multivariate model or cointegration. On the contrary, if a study includes multiple energy types or uses variables per capita rather than aggregate variables the probability of finding causality type two declines.

The second regression also contains six significant variables, though, they differ from the first regression with only two variables being mutual. Again four variables increase and two variables decrease the probability to find causality running from GDP growth compared to no causality found. Variables Number of observations and Panel data have both positive signs. Analysing data at the sectorial level rather than aggregate increases the probability to find the causality, the same as the inclusion of the price as a control variable in the study. Focus on a specific geographic area and higher overall economic level decrease the possibility to find the third type of causality in comparison with no causal relationship found.

Table 8: Model with the highest prediction success

Variable	Coefficient	Z	p-value
Basic causality direction concluded = 2			
Constant	166.187	1.423	0.155
Number of observations	0.023	1.784	0.074
Panel data	1.241	1.892	0.059
Multiple energy types	-1.101	-2.648	0.008
Multivariate	1.074	2.825	0.005
Cointegration testing	1.021	2.372	0.018
Variables per capita	-0.508	-2.181	0.029
Basic causality direction concluded = 3			
Constant	87.742	0.744	0.457
Geographic area	-0.230	-1.827	0.068
Number of observations	0.023	1.696	0.090
Overall economic level	-0.448	-2.191	0.029
Panel data	1.408	2.120	0.034
Sectorial	1.021	2.419	0.016
Price as control variable	1.094	2.184	0.029
Basic causality direction concluded = 4			
Constant	238.862	1.927	0.054
Geographic area	-0.251	-1.985	0.047
Number of observations	0.028	2.139	0.033
Year of publication	-0.121	-1.955	0.051
Overall economic level	-0.447	-2.058	0.040
Panel data	2.435	3.698	0.000
Sectiorial	0.760	1.681	0.093
Multivariate	1.327	3.234	0.001
Price as control variable	1.032	2.065	0.039
Cointegration testing	1.678	3.339	0.001
Significance level used	0.522	1.931	0.054
Energy types	0.354	2.072	0.038
Variables per capita	-0.564	-2.345	0.019

Feature of the third regression is that there is the highest number of significant variables, 12 in total. Geographic area, Number of observations, Panel data, Sectorial, Overall economic level and Price as control variable have the same signs with the same effect of the increasing and decreasing the probability to find the respective type of causality which is the probability to find bidirectional causality compared to no causality found. The additional variables Year of publication and Variables per capita have negative signs and hence decrease the probability. The newer the study, the lower the probability. Use of analysis at the sectorial level rather than aggregate declines the probability as well. On the other side, analysing multivariate model, cointegration testing, higher significance level and specific energy types all increase the probability to find the evidence of bidirectional causality compared to the reference category. The significance level used as a measure in this model was 10%. The model is shown in Table 8. For the simplification of the table, only values for the significant variables and constants are provided.

In the previous model, it can be seen that there are two significant variables common for all the regressions. There is a possibility to create a model with only significant variables that are valid for the three regressions. These two variables are Number of observations and Panel data. After removing other variables and keeping only the mentioned two in the model, Number of observations resulted to be insignificant leaving the model with only one common significant variable. The p-values in all three cases even comply with the lower 5% significance level. The values are shown in Table 9. The coefficients of the variable Panel data are positive implying that analysing Panel data increases the probability to find causal relationship compared to the situation when no causality is found. Nevertheless, from the binary logit model, it is known that the prediction capacity of Panel data is quite low as there are only 33 out of 104 studies analysing panel data. The impact of the variable on the probability to find certain type of causality direction compared to the no causality found is very low as well. Hence, the importance of this result is rather questionable.

Table 9: Model with significant variables only

Variable	Coefficient	z	p-value
Basic causality direction concluded = 2			
Constant	-0.378	-2.315	0.021
Panel data	1.072	2.316	0.021
Basic causality direction concluded = 3			
Constant	-0.302	-1.890	0.059
Panel data	0.995	2.156	0.031
Basic causality direction concluded = 4			
Constant	-0.496	-2.929	0.003
Panel data	1.882	4.378	0.000

To study the data more thoroughly, we can consider the link between individual geographic areas or individual countries and the type of causality direction that resulted in the studies. The aim is to find out whether there are similar results for similar or concrete countries. Table 10 displays the cross tabulation of the variable Geographic area (rows) against dependent variable Basic causality direction concluded (columns). From the table, it is visible that the results for individual geographic areas vary and one specific type of causality direction for one geographic area cannot be concluded. However, in all the geographic areas, except of North America (6), the existence of causal relationship between energy consumption and economic growth largerly prevails compared to no causal relationship found.

We can see an empty cell in the row for the geographic area number 3 – Latin America and the Caribbean at the intersection with column 3 – causality running from GDP growth to energy consumption. This means that none of the studies proved the existence of such causal relationship in this geographic area.

Table 10: Contingency table Geographic area (columns), Basic causality direction concluded (rows)

	[1]	[2]	[3]	[4]	Total
[1]	5	5	10	16	36
[2]	18	24	23	28	93
[3]	31	24	15	13	83
[4]	3	6		2	11
[5]	29	18	33	25	105
[6]	14	2	3	4	23
Total	100	79	84	88	351

To be more detailed, the orientation can be moved to individual countries. Naturally, countries with only one observation were not considered. By studying the dataset, the results suggesting the possibility of consensus were found in following countries:

In the case of Algeria three (Squalli, 2007; Wolde-Rufael, 2005 and Eddrief-Cherfi, 2012) of four studies found the causality running from GDP growth to energy consumption. It could be said that there is a probability of this fundamental relationship though the number of studies can be considered quite low to make such conclusion. If this is true, Algeria is less energy dependent and any conservation policies concerning energy consumption have little or no adverse effect on economic growth.

The similar example is Cameroon where the neutrality hypothesis is proved in three studies (Wolde-Rufael, 2010; Akinlo, 2008; Esso, 2010) out of the total number of four. The neutrality hypothesis suggests that the consumption of energy has no impact on the country´s GDP.

The situation in Croatia is studied only in two papers (Vlahinić-Dizdarević & Žikovič, 2010; Gelo, 2009) both proving the existence of causality running from GDP growth to energy consumption. Due to the low amount of proof, this result is questionable.

Gabon accounts for two observations in two studies as well (Wolde-Rufael, 2011; Wolde Rufael 2005), both supporting the bidirectional hypothesis. Again there is a minimum number of observations.

Kenya is also one of the countries with very similar results. Four out of five studies (Wolde-Rufael, 2009; Wolde-Rufael, 2007; Akinlo, 2008 and Esso, 2010) support the neutrality hypothesis – no causality found.

Russia accounts for four observations in three studies (Soytas, 2003; Wolde-Rufael, 2014 and Naser, 2014) all resulting in the neutrality hypothesis. It could be said that for Russia the causal relationship between energy consumption and economic growth does not exist (considering the current dataset).

Although, the evidence of not reaching the consensus for the US was provided by analysing studies focusing solely on the US, in the previous chapter, taking all the US observations into account (including ones from studies concentrating on more countries) changes the situations. There is a possibility to conclude the same result for the US as it is for Russia. There are 16 observations of the US, 11 observations from 9 studies support the null hypothesis (Soytas & Sari, 2008; Soytas, Sari & Ewing, 2007; Cleveland, Kaufmann & Stern, 2000; Chiou-Wei, Chen & Zhu, 2008; Tugcu, Ozturk & Aslan, 2012; Lee & Chiu, 2011; Lee & Chien, 2010; Gross, 2012; Balcilar, Ozdemir & Arslanturk, 2010) and only 5 observations found either bidirectional causality or causality running from GDP to energy consumption. None of the observations found the second type of the causality, one running from energy consumption to GDP growth what means that the US is not energy dependent and reductions in energy consumption do not have a negative impact on the GDP growth.

To sum up, it is obvious that it is hard to reach consensus in the majority of countries. There are only seven out of 83 individual countries reaching the similar results so as the one specific type of causality direction could be concluded. However, many of them have very low amount of observations doubting their results´ veritability. The most promising results acquired from this study are for Kenya, Russia and the US, all supporting the neutrality hypothesis or no causal relaitonship between energy consumption and economic growth.

Another option of a deeper analysis could be the inspection of the impact of the variable *Estimation method of causality* and reflection of a methodical bias. For a better insight, the cross tabulation of the variable *Estimation method of causality* against the variable *Basic causality direction found* can be provided, see Table 11.

Table 11: Contingency table Estimation method of causality (rows), Basic causality direction concluded (columns)

	[1]	[2]	[3]	[4]	Total
[1]	28	22	29	31	110
[2]	27	17	28	14	86
[3]		8		6	14
[4]	4	14	6	21	45
[5]	41	18	21	16	96
Total	100	79	84	88	351

The table shows that the most frequent estimation method is the first one – Standard Granger causality (Engle-Granger, Sims). There is no specific causality direction reached by using the method. The frequencies of each type of causality are very similar. The second most used method in the current dataset is ‘Other’ (than specified in first four categories). The most common result reached by other methods is the neutrality hypothesis (41 observations), however, this category might include several methods hence the frequencies of causality direction concluded are probably reached by different types of causality testing. The method

Modified Granger causality (Hsiao, TY) accounts for 86 observations. Again no particular causality direction resulted by analysing data with this method though the values suggests it is more probable to get the result of the first (no causality found) and third (causality running from GDP to energy consumption) type of causal relationship. The second least used method is a Panel causality test reaching mixed causality directions results. The numbers show that there is a higher probability to reach the second or fourth type of causality direction. The least used method of causality testing is ARDL applied to only 14 observations. There are two empty cells implying that no causality and causality running from GDP growth to energy consumption did not result when applying this method. In other words when analysing data using ARDL model, the second and fourth types of causality direction were concluded. Nevertheless, it does not have to mean that the use of this method influence the direction of the causality found. As it was mentioned above, the method is the least frequent one and the empty cells are most probably the results of the fact that the method is not widely used among the most cited papers, thus the number of observaions related to it does not provide for sufficient outcome.

According to this review, the variable *Estimation method of causality* is not influencing the basic causality direction concluded. In the previous analyses, *Estimation method of causality* resulted significant only in the binary logit models – and partially in the initial model of multinomial logit analysis (when considering higher 10% significance level). However, the binary logit models only analyse whether the causality between the energy consumption and economic growth exists or not. They do not focus on the individual basic causality directions concluded. Hence, the influence of the *Estimation method of causality* is limited to this scope only. In the initial model of multinomial analysis, there were problems with collinearity of some independent variables and after the correction of these and modification of the model, the variable resulted to be insignificant. Therefore, it can be sumed up that the method of testing the (Granger) causality does not affect the basic type of causality concluded and there should not be the reflection of a methodical bias.

4.3 Relevance of the empirical studies

Partial aim of this thesis is to find out whether the influential papers used in the meta-analysis are also reflected in the policy documents of EU, US and OECD. At first, the relevant papers should be selected from the sample of 104 top-cited papers. The selection is based on the presence of the relevant countries in the study. The search started by looking for the references in documents already used for the purposes of this diploma thesis. Then, with the help of the webpage google.scholar.com the citations of each of the relevant studies were analysed. Another alternative was to search directly on the webpages of mentioned groups or countries. The key words used for the search were either the study title, name of the author, 'energy economy nexus' or 'energy consumption and economic growth'.

After studying the list of empirical papers, it was found out that there are 29 studies including European Union countries, each of which is widely cited. However, only 17 of them are concentrating solely on the EU countries hence only these were taken into consideration. The search showed that none of the influential papers is cited in any EU policy document. EU seems to use only its own works for the elaboration of such documents.

In the case of US, there are three studies focusing solely on the US. It is supposed that they might have the biggest chance to be cited in any documentation concerning the USA energy policy. Again, no relevance of the studies in the US policy documents was found during the search.

The last ones examined were the studies targeting OECD countries and there referrence in OECD policy documents. Considered studies were ones focusing solely on OECD countries and studies analysing individual OECD countries. Papers analysing large mixed areas were excluded along with the papers analysing non-OECD countries. There are 4 studies focusing solely on the groups of OECD countries and 22 studies of individual OECD members. Due to the former results, outcome of the search was expected and proved to be the same as in the previous cases.

The inability to find out the relevance of the influancial papers in the current work, does not inherently mean that none of the 104 studies could be found in the policy documents during further searches. Some of the studies were not taken into consideration at the first place due to their concentration on very broad areas. However, the probability that some of th studies occurs in the policy documents is very low. It can be said that, in general, influential papers, specifically the ones included in this analysis, are not reflected in the policy documents of the EU, US or OECD.

5 Discussion and Recommendations

Discussion analyses and evaluates reached results, it gives answers to the questions, tasks and aims set at the beginning of this diploma thesis. Recommendations represent proposals for the improvement of conducting the research and analysis in this field to get better results.

The identification of a consensus in the field of Energy-Economy Nexus literature and important factors (characteristics) influencing the prevailing type of some hypothesis was performed by the means of a meta-analysis, concretely binary logit model and multinomial logit model. In the case of binary logit model, the existence or non-existence of causal relationship was examined. The multinomial regression targeted four basic hypotheses, namely neutrality, conservation, growth and bidirectional hopothesis. The partial goal was evaluated on the basis of studying and reviewing energy policy documents of the EU, US and OECD.

5.1 Statistical Overview

At the beginning, the statistical overview of studies delivered the most interesting features of the dataset. The total number of studies included in the dataset is 104 accounting for 351 individual observations. Two types of dataset were created for the purposes of this diploma thesis. Disaggregated dataset focuses on individual observations and serves as a basis for conducting a meta-analysis. Aggregated dataset concerns individual studies and helps with the statistic overview and general analysis of data. What needs to be stressed from the statistical overview is that the 104 top-cited papers are quite similar.

The common features of the datasets are as follows. It was found out that most of the energy-economy nexus studies (54%) is published by one journal – Energy Economics. The other individual publishers reperesent considerably smaller fractions of published papers. Only about 30% of papers report neutrality hypothesis or no causality between energy consumption and economic growth. Therefore, it can be concluded that there is a higher tendency to use and cite papers which found some evidence of causality rather than ones in which the causality is absent. All the studies, apart from 4, studied annual data. Most of the observations studied aggregate energy. Low number of studies investigated causality at the sectorial level. The typical focus is on developing countries and less than 40% of the observations contain countries classified as high-income economies. Panel data are used by less than one third of the studies. Concerning geographic area, the Middle East and Africa were the most observed areas.

The other common characteristic of the dataset is a very long study period with the mean length of study years that equals 36.35 years. The minimum and maximum amount of years were 9 and 150, respectively. Despite the papers studied such long periods, not many of them considered presence of structural breaks in their analysis, though such step could cause unexpected shifts in time series and lead to forecasting errors and unreliability of a model in general.

5.2 Binary Logit Model

Binary logit model examines whether there is or is not the causality between the energy consumption and economic growth. There were three models created in the binary logit regression. Simple naïve model including only constant, model with the highest prediction success and final model including only siginificant variables. Final model was created after sequential elimination test using two sided p-value (0.05). The prediction succes of the model was 76% and contained 8 influential variables. The effect of three variables (USA only, Estimation method of causality and Correction for multiple testing) on the dependent variable was negative due to the negative signs of coefficients. The negative effect means that their presence in the study decreases the possibility to find causality. Four remaining variables (Panel data, Single region, Consideration of structural breaks, Energy types) had, on the other hand, positive effect. Their presence or use of a specific type, in case of energy, increases the probability of finding causality.

However, it can be seen that the influence on the dependent variable and prediction capacity is rather low. The main problem with many of the study characteristics is their low representation in the dataset (i.e. insufficient variability of the studies). For example, there are only 16 observations from USA or 18 observation with the presence of correction for multiple testing. Moreover, as it was already mentioned, only 41 studies consider structural breaks and only 33 use panel data.

5.3 Multinomial Logit Model

Multinomial logit model Concerns 4 types of hypotheses, one of which is hold as the outcome or referernce category so there are three regressions in total. There were three models created for the purposes of mutinomial logit regression as well. The models are the same as in the case of the binary logit regression. All the three models resulted with very low prediction success. At the beginning of modeling the final model, some of the variables were excluded from the model due to the high values of their variance inflation factors and problems with collinearity. In the model with the highest prediction success, there were several siginificant variables with possible influence on the basic causality direction concluded. The siginificant variables differed in each of the regressions. The only variables common for all models were Number of observations and Panel data. However, final model includes only one – Panel data as the variable Number of observations resulted to be insignificant in this model. The effect of Panel data on the dependent variable was again positive meaning that analysing panel data increases the probabilty to find certain direction of causality compared to the no causality found.

Nevertheless, the previous analysis showed that the prediction capacity of Panel data is quite low because there are only 33 out of 104 studies analysing panel data. The impact of the variable is thus very low as well. The importance of this result is rather questionable.

The further analysis of the data focused on the similar results for geographic areas or concrete countries. The results for individual geographic areas varied and one specific type of causality direction for one geographic area could not be concluded. However, in all the geographic areas, except of North America (6), the finding of causal relationship between energy consumption and economic growth largerly prevailed compared to no causal relationship found. Considering the individual countries, in only 7 (Algeria, Cameroon, Croatia, Gabon, Kenya, Russia, the US) out of 83 individual countries the similar results were reached so as the one specific type of causality direction could be concluded. However, many of the countries had very low amount of observations doubting their results veritability. The most promising results acquired from the current work are for Kenya, Russia and the US, all supporting the neutrality hypothesis or no causal relaitonship between energy consumption and economic growth.

The *Estimation method of causality* was decided not to have an impact on the basic causality direction concluded in a study. This outcome was supported by the review of the cross tabulation of the two referring variables and multinomial regression analysis.

The outcomes of the meta-analysis are similar to the ones reached in the work of Kalimeris et al. Even though, some of the variables resulted to be signicant, there low informative value and marginal effect decreased the importance itself. It could be said that none of the variables could be concluded to substantially influence the direction of the causality. The general direction of causal relationship cannot be concluded as well growing a strong suspicion whether there actually is any evidence for the validity of the topic.

5.4 Relevance of the Empirical Studies

The analysis of the presence of influencing empirical papers in the policy documents resulted in finding no evidence of the papers´ relevancy. The search targeting this aim was not successful. In general, influential papers, specifically the ones included in this analysis, are not reflected in the policy documents of the EU, US or OECD. The actors seem to rely on their own studies and publications or possibly some other papers which were not included in the current dataset. From practical reasons not all of the studies were part of the search, thus there is a possiblity that some of them could be found in the policy documents though from the empirical research it is evident that the probability is minimal.

5.5 Recommendations

The results of this study clearly show the need to increase the heterogenity of the studies included in the sample. A lot of the 104 top-cited studies have many same characteristics. In general, the empirical studies should likely focus on filling the deficiencies, rather than continue with the “me too” research. Among the recommendations are:

- to use higher frequencies than annual,
- to include the structural breaks in cases of studies spanning several decades,
- to use multiple types of energy variables,
- to use data at the lower than aggregate level,
- to increase the number of observations.

All the recommendations are based on the previous analysis and justification is provided there. Due to the high similarity of study characteristics many variables, even when significant, had a very low overall impact and lost their informative value.

6 Conclusion

The aim of the thesis was to identify whether there is a consensus in the field of Energy-Economy Nexus literature. The used econometric methods served to conduct the systematic review of empirical literature to investigate the presence of a significant evidence for any form of (Granger) causality and the prevailing type of the causality, with regard to the influence of multiple study characteristics, such as the geographic area, sample size, length of the study period etc. Partial goal of the thesis was to review the factual relevance of the empirical literature for the policy makers. Notably whether the "influential" papers (as indicated by the number of citations) are also reflected, for example in the EU, US or OECD policy documents.

Binary logit model and multinomial logit model were used to verify the given hypotheses. In general, the results showed that all the variables possibly influencing the existence of the causality or concrete type of the causality direction concluded are inconclusive or do not demonstrate their sufficient impact. It was not proved that the choice of a certain type of estimation method would remarkably contribute to the existence of one basic direction of causality. Also, the evidence that the specific type of causality would result in certain geographic areas or individual countries was low. There were some exmples of countries reaching similar results, however, the amount of observations concerning them was generally quite low for a confident, or any conclusion at all. The sample size, cointegration method, EKC link or analysing single region did not contribute to the existence of causality either. Inconclusion of the most variables was due to their low presence in the studies and limited informative value. All the studies used annual data with only three exemptions (Oh, Lee, 2004; Shbia, Shahbaz, Hambdi, 2014 and Kayhan, Adiguzel, Bayat, Lebe, 2010). As it was metioned above, there are only 16 observations from the USA or 18 observation with the presence of correction for multiple testing. Moreover, only 41 studies considered structural breaks and only 33 used panel data. Majority of the papers studies the relationship at the aggregate level, the amount of papers analysing the sectorial level is low. Similarly to the variable USA only, China only accounts for no more than 19 observations. These outcomes support the ongoing debate of not finding the consensus in this field. The main issue of the top 104 top-cited papers was the homogenity of their characteristics.

As it can be seen in the literary chapters, the EU, US as well as OECD are very concerned about the topic and effort to reduce carbon emissions, and EU is even considered to be the the most active group with respect to the negotiations for the environmental protection. However, the inability to find the reflection of influencial papers, included in the dataset, in the policy documents of the EU, US or OECD was proven. It seems that groups do not consider the empirical papers in their decion-making process.

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Appendices

A Overview of the analysed studies

ID	Authors	Country of the 1st author	Year	Study period	Geographical area	Causality Type	Panel data
1	J. Asafu-Adjaye	Australia	2000	24	4 countries of South Asia	E->GDP E↔GDP	No
2	U. Soytas, R. Sari	Turkey	2003	43	top 10 emerging markets and G7 (no China)	E≠GDP E->GDP GDP→E E↔GDP	No
3	C.-C. Lee	Taiwan	2005	27	18 developing countries	E->GDP	Yes
4	U. Soytas, R. Sari, B. T. Ewing	Turkey	2007	45	USA	E≠GDP	No
5	W. Oh, K. Lee	South Korea	2004	30	South Korea	E↔GDP	No
6	C.-C. Lee, C.-P. Chang	Taiwan	2008	32	16 Asian countries	E->GDP	Yes
7	U. Soytas, R. Sari	Turkey	2009	41	Turkey	E≠GDP	No
8	N. Apergis, J. E. Payne	Greece	2009	25	Central America	E->GDP	Yes
9	J. B. Ang	Australia	2008	29	Malaysia	GDP→E	No
10	C. J. Cleveland, R. K. Kaufmann, D. I. Stern	USA	2000	50	USA	E≠GDP GDP→E	No
11	G. Altinay, E. Karagol	Turkey	2005	51	Turkey	E->GDP	No
12	B.-N. Huang, M. J. Hwang	Taiwan	2008	32	82 countries of the world	E≠GDP GDP→E E↔GDP	Yes
13	J. Squalli	UAE	2007	24	OPEC members	E->GDP GDP→E E↔GDP	No
14	G. Hondroyiannis, S. Lolos, E. Papapetrou	Greece	2002	37	Greece	E↔GDP	No
15	J. Yuan, C. Zhao, S. Yu, Z. Hu	China	2007	27	China	E->GDP	No
16	S. Paul, R. N. Bhattacharya	India	2004	47	India	E↔GDP	No
17	P. K. Narayan,	Australia	2007	32	Fiji Islands	E->GDP	No
18	W. Lise, K. Van Montfort	Netherlands	2007	34	Turkey	GDP→E	No

19	Y. Wolde-Rufael	UK	2009	34	17 African countries	E≠GDP E->GDP GDP→E E↔GDP	No
20	S. Z. Chiou-Wei, C.-F. Chen, Z. Zhu	Taiwan	2008	53	Asian countries and USA	E≠GDP E->GDP GDP→E E↔GDP	No
21	Y. Wolde-Rufael	UK	2005	31	19 African countries	E≠GDP E->GDP GDP→E E↔GDP	No
22	A. E. Akinlo	Nigeria	2008	24	11 African countries	E≠GDP GDP→E E↔GDP	No
23	N. Apergis, J. E. Payne	Greece	2009	15	Former Soviet Union	E↔GDP	Yes
24	N. M. Odhiambo	South Africa	2009	36	South Africa	E↔GDP	No
25	W. Oh, K. Lee	South Korea	2004	20	South Korea	GDP→E	No
26	C.-C. Lee, C.-P. Chang, P.-F. Chen	Taiwan	2008	42	22 OECD countries	E->GDP E↔GDP	Yes
27	N. Apergis, J. E. Payne	Greece	2010	24	19 developed & developing countries	E↔GDP	Yes
28	M. Zamani	Iran	2007	37	Iran	GDP→E E↔GDP	No
29	A. Belke, F. Dobnik, C. Deger	Germany	2011	27	25 OECD countries	E↔GDP	Yes
30	K. Menyah, Y. Wolde-Rufael	UK	2010	42	South Africa	E->GDP	No
31	N. Apergis, J. E. Payne	Greece	2012	18	80 countries	E↔GDP	Yes
32	N. Apergis, J. E. Payne	Greece	2010	16	13 countries of Eurasia	E↔GDP	Yes
33	A. N. Menegaki	Greece	2011	11	27 European countries	E≠GDP	Yes
34	S. Z. Tsani	UK	2010	47	Greece	E≠GDP E->GDP E↔GDP	No
35	N. Apergis, J. E. Payne	Greece	2010	26	9 South American countries	E->GDP	Yes

36	A. Acaravci, I. Ozturk	Turkey	2010	17	15 transition countries	E≠GDP	Yes
37	A. E. Akinlo	Nigeria	2009	27	Nigeria	E->GDP	No
38	I. M. Ouédraogo	Burkina Faso	2010	36	Burkina Faso	E↔GDP	No
39	M. Hamit-Haggar	Canada	2012	18	Canada	E≠GDP	No
40	C. T. Tugcu, I. Ozturk, A. Aslan	Turkey	2012	30	G7 countries	E≠GDP E->GDP GDP→E E↔GDP	No
41	V. Mishra, R. Smyth, S. Sharma	Australia	2009	26	9 Pacific islands	E↔GDP	Yes
42	Y. Wolde-Rufael, K. Menyah	UK	2010	35	9 developed countries	E->GDP GDP→E E↔GDP	No
43	J. A. Fuinhas, A. C. Marques	Portugal	2012	45	Portugal, Italy, Greece, Spain, Turkey	E↔GDP	Yes
44	M. Shahbaz, M. Zeshan, T. Afza	Pakistan	2012	40	Pakistan	E↔GDP	No
45	H. Bloch, S. Rafiq, R. Salim	Australia	2012	32,44	China	E->GDP E↔GDP	No
46	F. Islam, M. Shahbaz, A. U. Ahmed, Md. M. Alam	US	2013	39	Malaysia	E↔GDP	No
47	N. Apergis, J. E. Payne	Greece	2010	26	16 countries	E↔GDP	Yes
48	A. Omri	Tunisia	2013	22	14 MENA countries	E↔GDP	Yes
49	L. J. Esso	France	2010	38	7 African countries	E≠GDP GDP→E E↔GDP	No
50	C.-C. Lee, Y-B. Chiu	Taiwan	2011	44	Highly industrialized countries	E≠GDP GDP→E E↔GDP	No
51	C. Zhang, J. Xu	China	2012	14	China	GDP→E E↔GDP	No
52	S. Farhani, J. B. Rejeb	Tunisia	2012	36	15 MENA countries	GDP→E	Yes

53	Md Shahiduzzaman, K. Alam	Australia	2012	50	Australia	E↔GDP	No
54	P. K. Adom	Ghana	2011	38	Ghana	GDP→E	No
55	C.-C. Lee, M.-S. Chien	Taiwan	2010	31,37, 42	G7	E≠GDP E->GDP GDP→E	No
56	A. Acaravci	Turkey	2010	38	Turkey	E->GDP	No
57	I. Ozturk, G. S. Uddin	Turkey	2012	37	India	E↔GDP	No
58	R. Sbia, M. Shahbaz, H. Hamdi	UAE	2014	37	UAE	E↔GDP	No
59	N. S. Quedraogo	France	2013	29	15 ECOWAS countries	E->GDP	Yes
60	E. Lau, X.-H. Chye, C.-K. Choong	Malaysia	2011	27	17 Asian countries	GDP→E	Yes
61	T. Dergiades, G. Martinopoulos, L. Tsoulfidis	Greece	2013	48	Greece	E->GDP	No
62	M. Abid, M. Sebri	Tunisia	2012	28	Tunisia	E≠GDP GDP→E E↔GDP	No
63	M. E. Bildirici, F. Kayikçi	Turkey	2012	20	Former Soviet Republics	E->GDP E↔GDP	Yes
64	S. S. Adebola	Malaysia	2011	29	Botswana	E->GDP	No
65	U. Soytas, R. Sari	Turkey	2006	32	China	E≠GDP	No
66	D. I. Stern, K. Enflo	Australia	2013	100	Sweden	E≠GDP E->GDP GDP→E	No
67	R. Coers, M. Sanders	Netherlands	2013	40	30 OECD countries	GDP→E	Yes
68	M. S. Kahsai, C. Nondo, P. V. Schaeffer, T. G. Gebremedhin	US	2012	28	40 countries of Sub-Saharan Africa	E↔GDP	Yes
69	P. A. Kwakwa	Ghana	2012	27	Ghana	GDP→E E↔GDP	No
70	Y. Jafari, J. Othman, A. H. S. M. Nor	Malaysia	2012	28	Indonesia	E≠GDP	No
71	N. Apergis	Greece	2012	18	25 developed & 55 developing contries	E↔GDP	Yes

72	N. Apergis, D. Danuletiu	Greece	2012	12	Romania	E->GDP	No
73	A. Kasman, Y. S. Duman	Turkey	2015	19	New EU member & cindidate countries	E↔GDP	Yes
74	O. Damette, M. Seghir	France	2013	21	Oil exporting countries	GDP→E	Yes
75	S. Eddrief-Cherfi, B. Kourbali	Algeria	2012	44	Algeria	GDP→E	No
76	B. P. Paul, G. S. Uddin	US	2011	40	Bangladesh	GDP→E	No
77	E. Yıldırım, D. Sukruoglu	Turkey	2014	41	11 countries	E≠GDP E->GDP	No
78	N. Vlahinić-Dizdarević, S. Žiković	Croatia	2010	14	Croatia	GDP→E	No
79	O. A. Onafowora, O. Owoye	USA	2014	41	Brazil, China, Egypt, Japan, Mexico, Nigeria, South Korea, South Afrcia	E->GDP	No
80	M. Saatci, Y. Dumrul	Turkey	2013	49	Turkey	E->GDP	No
81	T. Gelo	Croatia	2009	53	Croatia	GDP→E	No
82	H. Bloch, S. Rafiq, R. Salim	Australia	2015	17, 47	China	E↔GDP	No
83	Y. Wolde-Rufael	UK	2014	36	15 transition countries	E≠GDP E->GDP GDP→E	No
84	C. Dritsaki, M. Dritsaki	Macedonia	2014	50	Greece, Spain, Portugal	E↔GDP	Yes
85	O. Ucan, E. Aricioglu, Ucel	Turkey	2014	21	15 EU countries	E->GDP	Yes
86	H. Naser	UK	2014	56	Russia, China, South Korea, India	E≠GDP E->GDP GDP→E E↔GDP	No
87	O. Ocal, I. Ozturk, A. Aslan	Turkey	2013	27	Turkey	E≠GDP	No

88	H. Kalyoncu, F. Gürsoy, H. Göcen	Turkey	2013	15	Georgia, Azerbaijan, Armenia	E≠GDP GDP→E	No
89	V. Bobinaite, A. Juozapaviciene, I. Konstantinaviciute	Lithuania	2011	20	Lithuania	E->GDP	No
90	S. Kayhan, U. Adiguzel, T. Bayat, F. Lebe	Romania	2010	9	Romania	E->GDP	No
91	E. Dogan	USA	2014	41	Kenya, Benin, Kongo, Zimbabwe	E≠GDP E->GDP	No
92	Z. Yang, Y. Zhao	China	2014	39	India	E->GDP	No
93	B. P. Abalaba, M. A. Dada	Nigeria	2013	40	Nigeria	E≠GDP	No
94	M. Shahbaz, S. Khan, M. I. Tahir	Pakistan	2013	41	China	E->GDP	No
95	M. Kaplan, I. Ozturk, H. Kalyoncu	Turkey	2011	36	Turkey	E↔GDP	No
96	T. Lorde, K. Waithe, B. Francis	Barbados	2010	45	Barbados	E↔GDP	No
97	P. T. Binh	Vietnam	2011	35	Vietnam	GDP→E	No
98	C. Gross	Germany	2012	38	USA	E≠GDP GDP→E E↔GDP	No
99	V. Costantini, C. Martini	Italy	2010	36, 46	71 countries	E≠GDP E->GDP GDP→E E↔GDP	Yes
100	P. K. Narayan, S. Popp	Australia	2012	47	G7	E≠GDP E->GDP	No
101	M. Balcilar, Z. A. Ozdemir, Y. Arslanturk	Turkey	2010	27	93 countries	E≠GDP E->GDP	Yes
102	C. A. U. Ighodaro	Nigeria	2010	36	Nigeria	E->GDP GDP→E	No
103	A. K. Tiwari	India	2011	38	India	GDP→E	No
104	A. Georgantopoulos	Greece	2012	31	Greece	E->GDP	No

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