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1. Introduction

1.1. Research objective

Environmental issues are one of the most debated problems of our times. Governments, international institutions and citizens from all around the globe are recognizing the challenges and the growing need to preserve our environment, which arise from increasing pollution and climate change. However, at the same time, the current economic system, which strives to expand economic activity and achieve economic growth in all areas, is constantly putting pressure on the natural resources. The juxtaposition of economic and environmental objectives highlight their conflicting nature and the fact that the economic growth can be detrimental to the environment. Due to its relevance, the explanation of income-pollution relationship became a hotly debated topic in the academic literature. A few decades ago, a theory called Environmental Kuznets curve (EKC) was introduced by the academic researchers, in order to gauge the consequences economic development can have on the environment. The EKC hypothesis recognizes that, in fact, income growth eventually can induce structural changes in the economy, government regulations and business practices, by way of adopting cleaner, more efficient technologies, pollution abatement techniques, or create new sustainable consumption patterns. Such changes eventually would lead to a decreasing rate of emissions and lower environmental degradation. This EKC income-pollution relationship is represented by an inverted-U shape curve.

Income per capita is the major explanatory factor in the EKC framework, and over time many additional explanatory variables were included in the analysis, such as trade, political or demographic variables. However, one important determinant of the economic activities – interest rate – has not been included in the academic literature regarding EKC research so far, despite the wide ranging implications interest rate and its movements have on an economy. Interest rate, one of the major macroeconomic policy tools, is an important determinator for taking saving and investment decisions, impacting everything from daily life choices to large-scale business investments. Level of interest rate impacts the economy, but can we draw a connection between interest rate and the environment? If low interest rates are supposed to support and encourage economic growth, in turn putting higher pressure on natural resources, and high interest rates are supposed to slow down the rate of investment, in turn leading to lower natural resource use, can we establish a direct relationship? Can these questions be answered by adopting EKC hypothesis? Therefore, the main objective of this thesis is to investigate the following questions:

- Does including interest rate to the EKC framework yield statistically significant results;
- Does inverted-U shape, typically associated with the Environmental Kuznets curve, can be applied to the relationship between interest rate variables and pollution;
- What is the nature of the relationship between interest rate and pollution, is it negatively or positively correlated;
- How do results compare for the country groups in different stages of economic development;
- How do additional explanatory variables behave in the EKC framework, adjusted for interest rate?

In order to provide the answers, a standard econometric EKC framework is applied in this thesis. A panel data EKC regression with CO_2 emissions per capita as dependent variable and real interest rate as independent variable is used in order to test the proposed relationship. Data sample used in the analysis consists of 31 countries, with panel data regressions controlled for country fixed effects. Since the data sample consists of countries in different income levels, regressions are also tested and compared for different country sub-groups depending on their level of income, in order to uncover possibly different patterns of the EKC. Furtermore, a number of additional explanatory variables has been included in the analysis.

1.2. Structure of the thesis

The thesis is structured as follows: after the introduction, the second chapter comprises literature review and introduces the hypothesis of EKC, related standard econometric EKC framework, and the current stance in the academic literature on the relationship between EKC and the interest rate. The third chapter presents the econometric model employed in the thesis, giving an overview of the data and the variables used. Fourth chapter presents the outcome of the econometric analysis, with the fifth chapter providing the summary of the results and conclusion.

2. Literature Review

In this section, EKC hypothesis and the main theories as to what causes the initial increase and eventual decrease of the pollution as the economy develops are summarized. The economic and social factors, which drive the changes in the environmental degradation trends, being responsible for the formation of the inverted-U shape of an EKC curve, as well as the standard econometric framework of EKC, are presented. At the end of the chapter, the current stance in the academic literature on the relationship between interest rate and pollution is provided.

2.1. Environmental Kuznets Curve

The EKC has its roots in the original Kuznets curve theory, which describes the relationship between income per capita and income inequality as having an inverted-U shape over time as income per capita grows (Kuznets, 1955). According to it, as the economy and income per capita develop, the income inequality in the economy initially increases, until it reaches a turning point, i.e. a certain level of income per capita, after which the income inequality starts to decrease. The theory is visually represented by a quadratic, inverted-U shape function, called Kuznets curve. In contrast to the original Kuznets curve, the Environmental Kuznets Curve (EKC) hypothesizes the inverted-U shape relationship between the income per capita and environmental degradation, as suggested in the seminal paper by Grossman and Krueger (1991). In their study, the authors tested the impact of North American Free Trade Agreement (NAFTA) and reduction of trade barriers between the United States and Mexico on the environmental quality, presenting empirical evidence and concluding that the economic growth has led to the decrease of at least few environmental pollutants. The term "Environmental Kuznets Curve" was first adopted by Panayotou (1993), in the study testing the existence of income-pollution relationship, together with the implications it would have on policy, labor market, technological advancement and external assistance. Since then, the EKC hypothesis established itself in the economic literature as a widely researched theory. It states that the environmental degradation increases as GDP per capita increases, however, only until a certain point. As income growth advances, GDP per capita reaches a certain level, where income per capita is high enough to induce changes in the economic and societal structures, which eventually would lead to the decrease in the environmental degradation (Stern, 2004). This relationship is represented by an inverted-U shape curve, as visualized in the Figure 1 below:

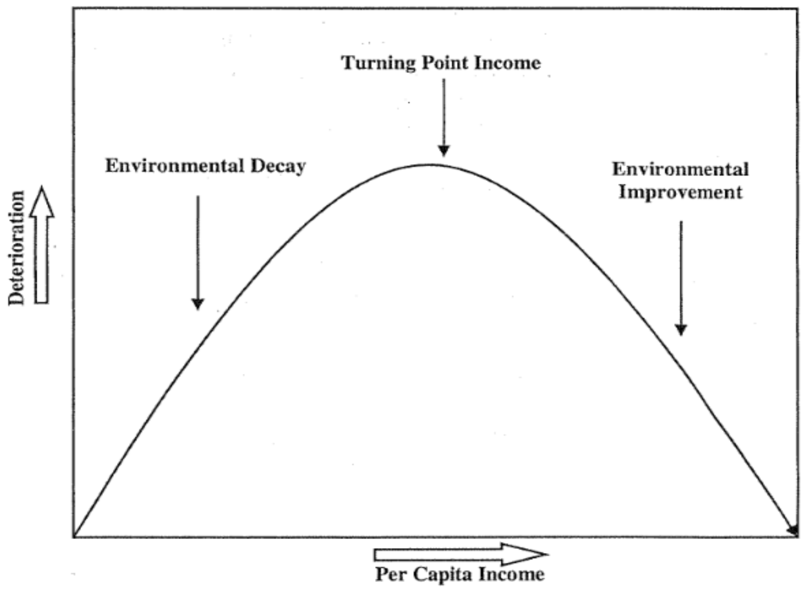

Figure 1. Environmental Kuznets Curve. ***Source:*** **Yandle et al. (2002).**

The upward-sloping part of the bell-shaped curve in Figure 1 represents the phase of increasing environmental degradation, with the peak of the curve marking the turning point income per capita, which is followed by a downward-sloping part of the curve, reflecting the improvement in the environmental deterioration (Yandle et al., 2002).

2.2. Formation of EKC

The various causes, which are responsible for the formation of the inverted-U shape of the EK-Curve, are described in the following sections, including the mention of the scale effect, which reflects the "traditional" view economic growth has on the environment.

2.2.1. Scale effect

The scale effect promotes "the traditional view that economic development and environmental quality are conflicting goals" (Stern, 2004, p. 1421). It implies that the expansion of the economic activity without any changes in the production technologies would take an especially high toll on the environment, as output to input ratio in the production would continue to remain 1:1, and where "1% increase in scale results in a 1% increase in emissions" (Stern, 2004, p. 1241). If per capita income increase is not coupled with the efficiency and productivity changes in the economic and production structures of a country, then the economic growth could not be associated with the improvements in the environmental quality, and in turn it would not lead to the formation of the Environmental Kuznets Curve.

Therefore, the scale effect by itself and the failure to increase productivity would lead us to „expect a positive slope over all income levels" (Managi, 2011, p.14) for the curve that measures the relationship between income per capita and environmental degradation, and would imply continuously negative impact of economic expansion on the environment (Managi, 2011). Consequently, inverted-U shape curve would not originate. In such case, any increases in the production would continue to exert the same negative impact on the natural resource stock, leading to evermore higher and non-subsiding environmental degradation as income per capita develops.

2.2.2. Structural changes

However, due to the economic growth and the acceleration of the economic development, the countries tend to experience various structural changes. The inverted-U shape generally reflects the transition between different types of economic structures, a “natural progression of economic development, from clean agrarian economies to polluting industrial economies to clean service economies“(Andreoni and Levinson, 2001, p. 270). At the beginning of the economic development cycle, the negative impact on the environment is marked by the rate of resource depletion, which exceeds the rate of resource regeneration, and increasing toxic waste (Panayotou, 1993). Developed economies, on the other hand, experience a shift ”towards information-intensive industries and services, coupled with increased environmental awareness, enforcement of environmental regulations, better technology and higher environmental expenditures“ (Panayotou,1993, p. 1), which eventually lead to the decline of environmental degradation. The main forces that drive the inverted-U shape EKC relationship are presented in the Figure 2 below:

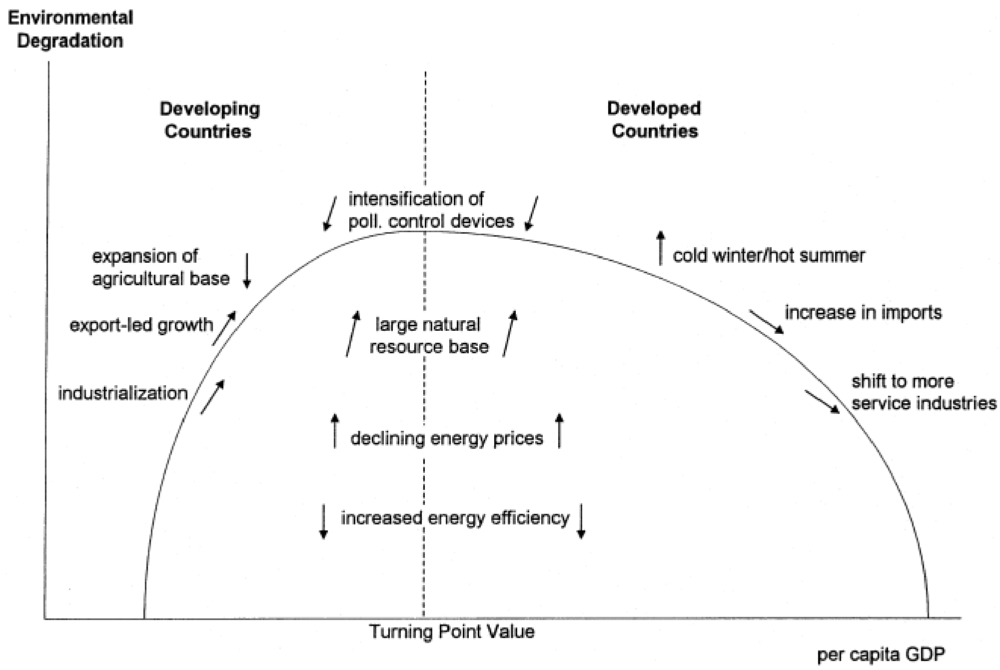

Figure 2. Conflicting dynamics of the EKC curve. ***Source:*** **Agras and Chapman, 1999.**

According to the Figure 2, as industrialization of a country is expanding, in turn the share of the agricultural activities of the economy is shrinking, and the environmental degradation is rising together with the rising income per capita. The turning point, which separates different income-pollution dynamics, and developing countries from the developed (allowing such distinction according to the graph), marks the critical income level, which spurs the technological and societal changes in the country, causing environmental degradation to decrease. As income per capita rises further, a shift towards a more service industries-orientated economy is observable, while in parallel the damage caused by the pollution is declining.

The following sub-sections describe the main underlying causes for the inverted-U pattern of the EKC.

2.2.2.1. Changes of composition of production

As already mentioned in the section above, the change from the agrarian production to pollution-intensive industrial economies would put growing pressure on the environment, represented by an upward sloping part of the curve, while service economy represents a less detrimental economic system to the environment, visualized by the downward sloping part of the EKC. In addition to that, the downward-sloping trend of an advanced economy is often coupled with the transfer of the pollution-intensive production processes to the less developed countries, in what has been defined as "pollution exporting" (Suri and Chapman, 1998). While such approach would accelerate the downward-sloping trend for an advanced economy, speeding up the decline of the environmental degradation, and even might be replicated by the developing economies later on as time progresses, it faces limitations, since "the world's poorest countries will never have even poorer countries to which they can export their pollution" (Andreoni and Levinson, 2001, p.270). Therefore, such approach cannot be indefinitely replicated, and suggests that other actions to reduce negative externalities caused by economic activities would be needed.

2.2.2.2. Technological changes

The techniques of production, together with the development of an economy, would face the improvements in the efficiency - improvements in the state of technology would bring about the changes on both productivity's side, as well as changes related to the emissions output (Stern, 2004). Fewer inputs would be needed for the same amount of the final output in the process of creating goods and/or services, and more efficient use of resources would weigh positively on the stock of natural resource base. In turn, we would see the negative impact on the environment decreasing, which would eventually correspond to the downward-sloping part of the EK-curve. Additionally, the technological change in less developed economies could be accelerated by the transfer of the modern and efficient technologies - less developed countries could speed up the process of the technological change due the so-called “latecomer advantage” (Taguchi, 2011). As countries would adopt the already established cleaner and environmentally-friendly processes from the richer economies, by replacing old inefficient factors of production, the EKC curve for such countries would “shift to the lower left” (Uchiyama, 2016, p.27), expediting the development of the inverted-U shape curve for the lower income economies.

2.2.2.3. A stronger preference for the environment

For the economically poor and deprived populations of developing countries and countries in the lower stage of economic development, the priorities are ensuring the basic amenities and the material well-being, with less regard towards preserving the environment, therefore, “in the earlier stages of economic development, increased pollution is regarded as an acceptable side effect of economic growth” (Arrow et al., 1995, p. 92). Once a sufficiently high level of income is attained, people’s preferences would shift and assign more value towards the environment and environmental amenities; likewise it is likely that in turn with people’s preferences the new environmental laws and institutions would also be established (Arrow et al., 1995).

For this reason, we would expect the economically poor countries to show increasing environmental deterioration in the EKC framework as their income per capita rises, with the change in the society towards more sustainable consumption and/or production patterns depending on how the preferences of the society would shift in the face of “the tradeoff between consumption and pollution” (Stokey, 1998, p.2). A critical income level is necessary to replace dirty industries and production technologies with cleaner and environmentally-friendly methods, after which we can expect the EKC to exhibit a downward-sloping path (Stokey, 1998).

2.2.2.4. The introduction of institutions that internalize external diseconomies

The introduction of institutional reforms, such as environmental legislation and the market-based incentives to reduce environmental impacts, which would focus on decreasing the negative externalities caused by polluting production processes, is cited as one of the reasons which would cause the downward-sloping part of the EKC curve (Arrow et al., 1995). However, a certain and relatively high enough level of income is needed, since “appropriately internalizing those externalities requires relatively advanced institutions for collective decision-making that may only be implementable in developed economies” (Andreoni and Levinson 2001, p. 270). Varying abilities of countries in different economic development stages to implement the necessary environmental regulations is acknowledged, however, a possibility exists for the developing economies to jump the learning curve. By implementing the necessary legislative changes and introducing pollution abatement technologies based on what is already working in the other countries, the EKC would shift to the lower left for the developing countries due to the so-called “latecomer advantage” (Alonzo and Puzon, 2012). In addition, international assistance could act as one of the possible ways of attaining an institutional framework needed to deal with environmental issues in less developed countries, if the countries are unable to enact efficient policies and set up effective environmental legislation themselves and on their own (Jones and Manuelli, 1995).

2.2.2.5 The effects of increasing returns to scale in abatement activities

One explanation for the inverted-U shape of EKC can be derived from the link arising between pollution and abatement technologies. The EKC can be explained by applying theory of increasing returns to abatement technologies, following the argumentation that “the more gross pollution there is before abatement, the less costly it is to abate one unit of that pollution“ (Andreoni and Levinson, 2001, p. 272). The differences in abating pollution between different countries can be attributed to the size of the economy and explained through the application of fixed and marginal costs reasoning. For a small economy, the fixed costs on installing pollution abatement technologies are relatively higher than for a bigger economy, for this reason the smaller economy “may rely on a technology with low fixed costs and high marginal costs” (Andreoni and Levinson, 2001, p. 278). Production and rising income per capita in small economies under these circumstances would cause increasing environmental deterioration and would be responsible for the upward sloping part of the EK-Curve. Larger economies, on the other hand, would take advantage of their size and economies of scale to get a good return on investment in the abatement technologies. It would enable them to produce under lower marginal costs in comparison to smaller countries, with the employment of the clean technologies eventually leading to a downward-sloping part of the EK-curve (Andreoni and Levinson, 2001).

2.2.2.6 Trade relationships

Trade relationships play a relevant role in the dispersion of pollution centers and are therefore deemed as “an important structural aspect of the EKC“(Agras and Chapman, 1999, p. 268). As visible from the Figure 2 in section 2.2.2., developing countries are associated with the export-led growth, together with the development of the pollution-intensive industries, while the developed countries tend towards the imports of such goods, thus avoiding the negative environmental consequences associated with the expansion of the industrial sector.

The positive effects of opening up the country to the international trade can arise from investing in new and cleaner technologies, in order to comply with possibly higher environmental standards of the trading partner countries, and such leading to less pollution (Shafik and Bandyopadhyay, 1992). As the volume of trade rises, it consequently may lead to the economic growth, and at the same time “as income rises through trade, environmental regulation is tightened that spurs pollution reducing innovation” (Dinda, 2004, p. 436).

However, some researchers argue that trade liberalization could be damaging to the environment. There are apprehensions surrounding trade liberalization, since some researchers assume that „the environmental standards will tend toward a lowest common denominator“(Grossman and Krueger, 1991, p. 2.), if countries would engage in trade competition. Sheer expansion of economic activities due to the expansion of trade sector of a country, with no technological changes in the production processes, would increase the pollution ceteris paribus; likewise, if the environmental standards in a country are improved due to the imports of the pollution intensive goods, thus avoiding dirty production process locally, in turn the environment quality of the other nations is compromised (Agras and Chapman, 1999). These ambiguous and uneven effects of free trade on the environment are noted in the academic literature, admitting that expansion of trade would be "both increasing pollution and motivating reductions in it"(Dinda, 2004, p. 436).

2.3. Standard Econometric Framework of EKC

The EKC curve has been subject to various modifications, and depending on the topic of the analysis and the variables, which are chosen for the research and proposed analytical problem, it can take on different forms. However, at the core of it one standard expression is the backbone of EKC theory and for the analytical purposes serves as a starting point, which can be adapted by varying degree to suit the research question. In line with Stern (2004), the standard form of the EKC regression, establishing a quadratic relationship between the per capita emissions and income per capita of a certain country, can be given as follows:

$$\ln\left(\frac{E}{P}\right)_{it} = \alpha_i + \gamma_t + \beta_1 \ln\left(\frac{GDP}{P}\right)_{it} + \beta_2 (\ln\left(\frac{GDP}{P}\right))^2{}_{it} + \varepsilon_{it}\,, \qquad (1)$$

where E indicates emissions or environmental degradation variable, P is population, GDP is gross domestic product, i denotes countries or cities, t denotes time, ε stands for stochastic error term, and ln for natural logarithm. The model is usually estimated using panel data analysis, where α_i denotes site specific effect, and γ_t stands for time specific effect. α_i and γ_t are treated as regression parameters in the fixed-effects model, and as components of random disturbance, if the random effects model is used.

A logarithmic expression of the equation does not allow the dependent variables to become zero or receive negative values, otherwise the regressions are deemed by some researchers as "inappropriate, except in case of deforestation where afforestation can occur" (Stern 2004, p. 1422). Therefore, the use of non-logarithmic EKC curve depends on the subject in question, and is allowed under the circumstances, when the indicators by their very nature can acquire negative values.

EKC with an inverted-U shape is thought to exist, if the coefficients of the equation (1) are statistically significant and acquire following values: β_1 coefficient for linear income term has positive value ($\beta_1 > 0$) and β_2 coefficient for the income squared term acquires negative value ($\beta_2 < 0$). The turning point of the quadratic function as in equation (1) corresponds to the critical per-capita income level, denoting the point in the economic development of a country as the environmental degradation begins to decrease, and is given as $\exp(-\beta_1/(2\beta_2))$. It indicates the income level of the country, where it is high enough as to cause social and economic shift, leading to the decreasing emissions per capita as the income per capita grows further.

The standard EKC model as in above equation (1) can be modified, as to further expand the research into the relationship between environmental degradation and economic development. In line with Agras and Chapman (1999), an equation, which adds additional explanatory variables to the regression, and is viewed by some researchers as a standard model, is presented below:

$$\ln\left(\frac{E}{P}\right)_{it} = \alpha_i + \gamma_t + \beta_1 \ln\left(\frac{GDP}{P}\right)_{it} + \beta_2 (\ln\left(\frac{GDP}{P}\right))^2{}_{it} + \beta_k \ln(Z_{it}) + \varepsilon_{it}, \qquad (2)$$

where E indicates emissions or environmental degradation variable, P is population, GDP is gross domestic product, i denotes countries or cities, t denotes time, ε stands for stochastic error term, and ln for natural logarithm. α_i denotes site specific effect, and γ_t stands for time specific effect. Z_{it} indicates any additional explanatory variable that is added to the regression equation, such as population density, trade or investment variables (Agras and Chapman, 1999). Since the choice of additional explanatory variables is practically unlimited, such expression of the equation makes it well suited for the research of the interaction between various factors in order to determine their relevance to the development of the environmental degradation.

For the purpose of describing a standard EKC regression, an addition of a cubic term to the polynomial equation is relevant. Such equation was already tested in the seminal paper by Grossman and Krueger (1991), where the cubic expression was found to be generally more fitting than the quadratic one, although in many cases the estimated relationship between pollution and income is found to be roughly the same. The equation, with an additional cubic term would have the following form:

$$\ln\left(\frac{E}{P}\right)_{it} = \alpha_i + \gamma_t + \beta_1 \ln\left(\frac{GDP}{P}\right)_{it} + \beta_2(\ln\left(\frac{GDP}{P}\right))^2_{it} + \beta_3(\ln\left(\frac{GDP}{P}\right))^3_{it} + \beta_k \ln(Z_{it}) + \varepsilon_{it}. \qquad (3)$$

where E indicates emissions or environmental degradation variable, P is population, GDP is gross domestic product, i denotes countries or cities, t denotes time, ε stands for stochastic error term, and ln for natural logarithm. α_i denotes site specific effect, γ_t stands for time specific effect, and Z_{it} indicates any additional explanatory variable.

If β_1 for linear income variable has positive value ($\beta_1 > 0$), β_2 coefficient for the income squared term has negative value ($\beta_2 < 0$) and β_3 coefficient for the cubic term has positive value ($\beta_3 > 0$), the EKC as in equation (3) takes on the form of the inverted-N curve, representing the worsening of pollution at the very high income levels (see Figure 3). However, in the analytical framework the cubic polynomial function can also simply represent the "approximation to a logarithmic curve" (Stern, 2004, p. 1222).

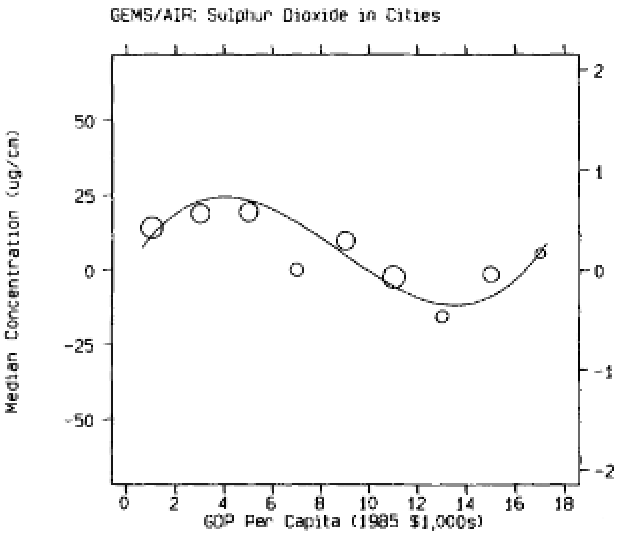

Figure 3. Cubic EKC pattern. ***Source*****: Grossman and Krueger, 1995.**

Depending on the signs of the coefficients, EKC can acquire different patterns. Using cubic function as a starting point to analyze the shapes of EKC, the patterns found in the academic literature can be summarized as in the Figure 4 on the next page:

Inverted-U shape	U shape	N shape	Inverted-N shape	Monotonically increasing	Monotonically decreasing	Level
$\beta_1 > 0$ $\beta_2 < 0$ $\beta_3 = 0$	$\beta_1 < 0$ $\beta_2 > 0$ $\beta_3 = 0$	$\beta_1 > 0$ $\beta_2 < 0$ $\beta_3 > 0$	$\beta_1 < 0$ $\beta_2 > 0$ $\beta_3 < 0$	$\beta_1 > 0$ $\beta_2 = \beta_3 = 0$	$\beta_1 < 0$ $\beta_2 = \beta_3 = 0$	$\beta_1 = \beta_2 = \beta_3 = 0$

Figure 4. EKC patterns according to the coefficient. *Source*: Lopez-Menendez et al., 2014.

In addition to quadratic (U-shape and inverted-U shape) and cubic (N-shape and inverted-N shape) curves, monotonically increasing and/or decreasing patterns are also present for the income-pollution relationship. While quadratic and cubic EKC functions reflect an evolving EKC pattern as time progresses, monotonically increasing pattern would imply that environmental degradation does not subside over time and continues to increase as income per capita develops. Monotonically decreasing pattern would imply that pollution constantly deteriorates over time as income per capita grows (Lopez-Menendez et al., 2014).

2.4. Interest rate in the academic literature

2.4.1. General overview

Interest rates are important determinants of the economic activities, guiding the decisions of private individuals, businesses, as well as governmental and non-governmental entities. Exhaustive literature on interest rates underlines an important role it has in making intertemporal decisions between present and future consumption (Fisher, 1930; Modigliani, 1966), as well as in choosing between savings or investment, as highlighted by the famous IS-LM model (Hicks 1937; Hansen 1953).

Various studies have been published about the effects the level of interest rates has on the economy, and it is widely acknowledged that the financial system has a major impact on the economic growth (Arestis and Demetriades, 1997). Generally, a higher interest rate would imply that savings decision is more attractive to a value maximizing individual than investing, leading to the conclusion that saving decisions are "interest elastic" (Olson and Bailey, 1981, p.1). Modigliani (1986) adds to that by admitting that no evidence is available to state that the savings decision is independent of interest rates. The investment decisions are subject to the movements of interest rates as well, where the rate of private investment is “negatively related to real interest rates” (Greene and Villanueva, 1991, p.33). An increase in interest rate would generally lead to a decrease in investments, while lower interest rate would support an investment decision.

Here and further it is assumed that the low interest rate environment in general supports the investment and, consequently, economic growth, whereas high interest rate has an opposite effect on the economic agents. A high interest rate would make investment decisions less attractive, consequently incentivizing to make a savings decision instead, and slowing down the economic expansion.

2.4.2. Interest rate and EKC

The studies dedicated to the EKC hypothesis do not explicitly include interest rate in the analysis, and focus on various other economic, political or societal determinants instead. Published economic literature on the relationship between interest rate and pollution is limited, and so far “there are no econometric analyses considering the interest rate as an explanatory variable of pollution dynamics” (Di Vita, 2008, p.226).

Di Vita (2008) uses a Ramsey-Cass-Koopmans model to investigate the income-pollution relationship, and comes to the conclusion that the inverted-U shape might be caused by the behavior of interest rate. The author concludes that only after attaining a higher level of income countries would start implementing environmental policies, while at the lower levels of income individuals would prefer to satisfy their present needs, and do not take into account the negative externalities the pollution might cause. Therefore, the interest rate is presented as a factor in taking an intertemporal decision between the present and the future consumption. The findings are in line with the EKC explanations stated in the section 2.2. of this thesis, where the shift in people’s preferences is stated as one of the causes of the inverted-U shape of EK-curve. However, no studies are available for the relationship between the interest rate and pollution using standard EKC econometric framework regression analysis.

3. Econometric Model

The following section describes the dependent and independent variables that have been included in the framework of this thesis, noting their relevance in the ongoing academic EKC research. All definitions of the variables and the list of the countries used in the regression analysis are presented in the Annex 3 (Data Sources and Definitions) and Annex 4 (Classification of countries according to the level of income). Regressions (1) and (2), as described in the section 2.3, were modified accordingly to include the following variables in this thesis.

All data for dependent, independent and additional control variables were collected from the World Bank World Development Indicators (WDI) database. The timeframe of the analysis covers 16 years for the period of 1990-2005. The periodicity of all data is annual.

3.1. Dependent variable - CO2 emissions per capita

Due to its relevance and the crucial role it plays in the processes of global warming, CO2 emissions per capita is chosen to be the dependent variable and the measure of environmental degradation in the framework of this thesis. CO2 per capita variable was used in numerous previous publications analyzing EKC relationships (e.g. Holtz-Eakin and Selden (1995); Shafik (1994); Moomaw and Unruh (1997); Unruh and Moomaw (1998)). The research and global consensus tend to „indicate that CO2 emissions will continue to rise as countries pursue economic growth policies"(Moomah and Unruh, 1997, p. 4), and the importance of continuously analyzing the CO2 emissions as to find the best environmental and economic policies to urgently tackle, stabilize and reduce the problems that arise with rising CO2 emissions underlines the choice of the dependent variable.

3.2. Independent variable - Real interest rate

In line with the topic of this thesis, the real interest rate is chosen as the main independent variable for the analysis. As already mentioned in the section 2.4.2, interest rate has not been the subject of research in the academic literature concerning EKC before, however, due to the relevance it has on the economy and the economic growth, it would be interesting to see if a statistically significant relationship between environmental degradation and the interest rate exists, and if so, could we associate it with the inverted-U shape found in the standard EKC framework.

3.3. Additional Explanatory Variables

GDP per capita. GDP per capita variable is part of the standard EKC framework, and indeed most studies conclude that income has the most significant effect on environmental quality of all explanatory variables (Agras and Chapman, 1999). For this reason, GDP per capita is included and tested in the framework of this thesis as an additional explanatory variable.

Trade intensity. The relationship between trade and environment has received wide attention in the academic literature, with international trade deemed as "one of the most important factors that can explain EKC"(Dinda, 2004, p.436). Trade variables have been employed by many researchers, including Grossman and Krueger (1991) in their seminal paper, which is widely viewed as establishing the EKC concept itself. The ratio of the sum of exports and imports to the GDP of a nation is used in the regression analysis of this thesis, as it is most often used trade variable in the EKC literature (Agras and Chapman, 1999).

Population density. Population variables are included as additional explanatory variables into the EKC analysis by a number of scholars (e.g. Grossman and Krueger, 1991; Selden and Song, 1994; Panayotou, 1997). Selden and Song (1994) call patterns of population growth rates among nations as one of the key factors to consider in the pollution-GDP relationship. The population density is therefore included into our analysis as an additional explanatory variable. A negative population density coefficient sign is expected by some researchers, arguing that least dense countries would not prioritize the preservation of the environment (Selden and Song, 1994). However, Panayotou (1997) finds that the rise in population density does have a negative effect on the environmental degradation, since "denser population overwhelms the population pressure for more pollution abatement "(Panayotou, 1997, p. 479).

Alternative energy. Alternative energy generation and consumption is widely acknowledged as means to combat pollution and climate change, with “renewable energy sources […] expected to play an outstanding role in the reduction of environmental costs” (Lopez-Menendez et al., 2014, p. 370). Negative and statistically significant relationships in the EKC framework between variables related to renewable energies and environmental deterioration have been observed (Lopez-Menendez et al., 2014). Likewise, electricity production from renewable sources is associated with a decrease in CO_2 emissions (Sulaiman et al., 2013). In the framework of this thesis, 3 following alternative energy variables are tested as additional explanatory factors of the main regression, to measure their impact on CO_2 per capita emissions: share of alternative and nuclear energy (as of total energy use), share of renewable energy consumption (as of of total final energy consumption), and share of renewable energy output (as of total electricity output).

3.4. Countries

The significance of interest rate and additional explanatory variables is tested for a large number of countries, using panel data analysis and controlling for the country fixed effects. All countries are tested on a few levels: on a global level, i.e. for the full set and disregarding the differences in the level of national income, as well as performing the analysis using more granular approach. The full set of the countries is divided into the buckets of different income levels, in order to investigate if different patterns in the relationship between interest rate, additional explanatory variables and environmental degradation exist for the countries in different stages of the economic development. For this purpose, the country income categorization is made according to World Bank classification. The income levels of the countries, for the current 2018 fiscal year and using World Bank Atlas method, are classified as:

- Low income economies - defined as those with a GNI per capita of $1,005 or less in 2016;
- Lower middle income economies - defined as those with a GNI per capita between $1,006 and $3,955 in 2016;

- Upper middle income economies - defined as those with a GNI per capita between \$3,956 and \$12,235 in 2016;
- High income economies - defined as those with a GNI per capita of \$12,236 or more in 2016.

The set of the countries, for which the data as described above in sections 3.1.-3.3. was available for the time period of 16 years (1990-2005), contains 31 countries in total over all income categories:

- High income group (11 countries),
- Upper middle income group (11 countries),
- Lower middle income group (9 countries).

Due to limited data availability, no countries, which belong to low income economies group, were tested in the analysis. All countries that were used in the regression analysis are listed in the Table A.33 of the Annex 4.

4. Results

The following section presents the results of the regression analysis for the Environmental Kuznets Curve, adjusted for the interest rate variable, as well as the additional explanatory variables. It is broken down into sub-sections, which carry the name of the independent variables used in the regression.

4.1. Real interest rate

Based on the available data set, the panel data regression analysis was performed, taking into consideration country fixed effects. Adapting the standard regression equation (1) as described in the section 2.3., the interest rate variable is included, and the regression takes on the following form:

$$\boldsymbol{CO_{2_{it}} = c_{it} + \beta_0 Real\ i.r._{it} + \beta_1 Real\ i.r._{it}^2 + \epsilon_{it},}$$

where CO2 are CO2 emissions per capita, c is a constant term, Real i.r. denotes real interest rate, $\boldsymbol{\beta_0}$ and $\boldsymbol{\beta_1}$ are coefficients of interest rate variable terms, t stands for time (years 1990-2005), i denotes country in the dataset (31 countries in total) and ϵ_{it} is an error term corresponding to fixed effects error term $\epsilon_{it}=\alpha_{it}+u_{it}$.

Following hypothesis for the beta coefficients was tested:

H_0: $\beta_0 = 0$, $\beta_1 = 0$,

H_1: $\beta_0 \neq 0$, $\beta_1 \neq 0$.

After running panel data regression analysis for 31 countries over the period of 16 years (1990-2005), and controlling for the country fixed effects, the results for statistical significance are presented in the output Table 1 below.

In the output Table 1 C denotes the constant term (corresponding to c_{it}), with the expressions REAL and REAL^2 standing for the coefficients for the real interest rate variables (β_0 and β_1, respectively):

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/10/17 Time: 15:33
Sample: 1990 2005
Periods included: 16
Cross-sections included: 31
Total panel (balanced) observations: 496

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.508845	0.033941	132.8420	0.0000
REAL	-0.000932	0.003744	-0.248798	0.8036
REAL^2	-4.05E-05	9.96E-05	-0.406146	0.6848

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.984951	Mean dependent var	4.494591
Adjusted R-squared	0.983911	S.D. dependent var	4.140337
S.E. of regression	0.525165	Akaike info criterion	1.614009
Sum squared resid	127.6948	Schwarz criterion	1.893882
Log likelihood	-367.2741	Hannan-Quinn criter.	1.723868
F-statistic	946.9984	Durbin-Watson stat	0.511049
Prob(F-statistic)	0.000000		

Table 1. Real interest rate vs. CO2 per capita, all countries.

The results show that the typical inverted-U shape is not applicable for the Environmental Kuznets Curve, adjusted for the interest rate variable. The coefficients for both interest rate terms are negative and do not follow the suggested pattern, typically associated with the EKC curves. On the contrary, the coefficient β_0 (REAL) acquires value -0.000932, with the coefficient β_1 (REAL^2) receiving value -4.05E-05. Furthermore, both coefficients are statistically insignificant at the 5%, as well as at the 10% significance level: p-values (0.8036 for REAL and 0.6848 for REAL^2) suggest that we cannot reject the null hypothesis stated above, and we do not find a statistically significant relationship between CO2 emissions per capita and the real interest rate of the economy.

Panel data analysis, performed separately for the sub-groups of countries based on their income level, confirms the result described above (see Annex 2 – Tables A.1-A.4). In order to investigate possible different patterns of the pollution-interest rate relationship for the countries based on their income level, the panel data regression in the same form and accounting for the country fixed effects was tested for 3 different sub-groups, which together would constitute the whole sample of 31 countries. The above regression was run separately for high income countries group, as well as for upper middle income and lower middle income countries. The results show that statistically significant coefficients of the terms are not found for the countries in different income classes, neither.

4.2. Year-to-Year change in Real interest rate

The data sample was adjusted to perform a regression test, based on the year-to-year changes of the variables. Year-to-Year (YtY) change of CO2 per capita was regressed on corresponding YtY change of the real interest rate. In this case, our regression equation takes the following form:

$$\boldsymbol{\Delta CO_{2_{it}} = c_{it} + \beta_0 \Delta Real\ i.r._{it} + \beta_1 \Delta Real\ i.r._{it}^2 + \epsilon_{it},}$$

where ΔCO2 are CO2 emissions per capita Year-to-Year change, c is a constant, ΔReal i.r. denotes Year-to-Year real interest rate change, $\boldsymbol{\beta_0}$ and $\boldsymbol{\beta_1}$ are coefficients of interest rate variable terms, t stands for time (time periods), i denotes country in the dataset (for 31 countries in total), and ϵ_{it} is an error term corresponding to fixed effects error term $\epsilon_{it}=\alpha_{it}+u_{it}$. The data set is reduced to 15 time points, since comparing yearly changes eliminates one variable compared to a full data set.

Following hypothesis for the beta coefficients was tested:

H_0: $\beta_0 = 0$, $\beta_1 = 0$,

H_1: $\beta_0 \neq 0$, $\beta_1 \neq 0$.

After running panel data regression analysis for 31 countries for the 15 points in time, and controlling for the country fixed effects, the results for statistical significance are as follows, and presented in the output Table 2 below:

Dependent Variable: CO2DELTA
Method: Panel Least Squares
Date: 09/19/17 Time: 16:10
Sample (adjusted): 1991 2005
Periods included: 15
Cross-sections included: 31
Total panel (balanced) observations: 465

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.046178	0.017946	2.573155	0.0104
REALDELTA	0.002284	0.001853	1.232467	0.2184
REALDELTA^2	4.29E-05	7.40E-05	0.580485	0.5619

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.044502	Mean dependent var	0.048967
Adjusted R-squared	-0.026276	S.D. dependent var	0.358581
S.E. of regression	0.363262	Akaike info criterion	0.880938
Sum squared resid	57.00635	Schwarz criterion	1.174889
Log likelihood	-171.8180	Hannan-Quinn criter.	0.996637
F-statistic	0.628757	Durbin-Watson stat	2.318824
Prob(F-statistic)	0.945073		

Table 2. Real interest rate YtY change vs. CO2 per capita YtY change, all countries.

In the output Table 2 C denotes the constant term (corresponding to c_{it}), with the expressions REALDELTA and REALDELTA^2 standing for the coefficients of real interest rate terms, which represent the Year-to-Year changes ($\boldsymbol{\beta_0}$ and $\boldsymbol{\beta_1}$, respectively).

Controlling for the country fixed effects, the results show that the typical inverted-U shape form cannot be found for the Environmental Kuznets Curve, adjusted for the interest rate variable yearly change. The coefficient REALDELTA acquires positive value (0.002284), with the coefficient REALDELTA^2 taking on small, but positive value as well (coefficient value 4.29E-05). However, both coefficients are statistically insignificant, at 5%, as well at 10%, confidence level, p-values (0.2184 and 0.5619 for $\boldsymbol{\beta_0}$ and $\boldsymbol{\beta_1}$, respectively) suggest that we cannot reject our null hypothesis, and we do not find a statistically significant relationship between yearly change in CO2 emissions per capita and the yearly change in the real interest rate of the economy.

While inverted-U shape and statistically significant coefficients of the terms cannot be confirmed globally (i.e. for the whole set of countries), analysis for the country subgroups based on their income level shows some different results (see Annex 2, Tables A.5-A.8). While for High income countries the results are similar (statistically insignificant coefficients for both terms), interesting outcome is observed for the group of countries that fall into lower income categories (Upper middle income group and Lower middle income group). The results are presented in the output Tables 3 and 4 below:

Dependent Variable: DELTACO2
Method: Panel Least Squares
Date: 09/19/17 Time: 20:43
Sample (adjusted): 1991 2005
Periods included: 15
Cross-sections included: 11
Total panel (balanced) observations: 165

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.047270	0.030141	1.568297	0.1189
DELTAREAL	0.011502	0.003174	3.623322	0.0004
DELTAREAL^2	0.000392	0.000167	2.351730	0.0200

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.138978	Mean dependent var	0.073610
Adjusted R-squared	0.071003	S.D. dependent var	0.365163
S.E. of regression	0.351961	Akaike info criterion	0.824918
Sum squared resid	18.82923	Schwarz criterion	1.069628
Log likelihood	-55.05570	Hannan-Quinn criter.	0.924254
F-statistic	2.044539	Durbin-Watson stat	2.274490
Prob(F-statistic)	0.023932		

Table 3. Real interest rate YtY change vs. CO2 per capita YtY change, upper middle income countries.

Both coefficients for upper middle income countries in Table 3 are positive (0.011502 for $\boldsymbol{\beta_0}$ and 0.000392 for $\boldsymbol{\beta_1}$), and statistically significant at 5% confidence level (p-values 0.0004 and 0.02, respectively). The typical EKC pattern of inverted-U shape is not found; however, the results suggest that the yearly change in CO2 emissions per capita is positively correlated with the yearly change in the real interest rates of the economy. The relationship between the dependent and independent variables indicates that the yearly increase in the real interest rate could be associated with the positive change in the CO_2 emissions per capita during the same time period, i.e. an increase.

As it is visible from the Table 4 on the next page, statistically significant result is also produced for the Lower middle income countries, however, only for the first term DELTAREAL (i.e. β_0/DELTAREAL coefficient, with negative value -0.001551):

Dependent Variable: DELTACO2
Method: Panel Least Squares
Date: 09/19/17 Time: 21:28
Sample (adjusted): 1991 2005
Periods included: 15
Cross-sections included: 9
Total panel (balanced) observations: 135

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.018662	0.008840	2.110982	0.0368
DELTAREAL	-0.001551	0.000591	-2.625764	0.0097
DELTAREAL^2	-2.78E-05	2.10E-05	-1.325111	0.1876

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.094401	Mean dependent var	0.014079
Adjusted R-squared	0.021369	S.D. dependent var	0.093497
S.E. of regression	0.092492	Akaike info criterion	-1.845409
Sum squared resid	1.060802	Schwarz criterion	-1.608683
Log likelihood	135.5651	Hannan-Quinn criter.	-1.749210
F-statistic	1.292599	Durbin-Watson stat	2.454987
Prob(F-statistic)	0.241763		

Table 4. Real interest rate YtY change vs. CO2 per capita YtY change, lower middle income countries.

While the coefficient for the first term is statistically significant both at 5% and 1% confidence levels (p-value 0.0097), the coefficient DELTAREAL^2 for the squared term is statistically insignificant (p-value 0.1876). The results suggest that the YtY change in the real interest rate of the economy is negatively correlated with the yearly change of CO_2 emissions per capita during the same time period – any YtY increase in the real interest rate is associated with the decrease of environmental pollution per capita in the same time period. The suggested relationship is linear, i.e. the inverted-U shape typical to EKC curves is not found.

All in all, in the slightly less developed (lower middle income) countries, an increase in real interest rate leads to a negative change in emission per capita – a decrease, while more developed countries (upper middle income) show that the yearly increase in the real interest rate is correlated with a positive change in emissions per capita – an increase.

4.3. Income per capita

Introducing additional control variables yields some interesting results. Income per capita, usually employed for the purposes of establishing EKC, has been included as an additional explanatory variable, and the regression takes on the following form:

$$CO_{2_{it}} = c_{it} + \beta_0 Real\ i.r._{it} + \beta_1 Real\ i.r._{it}^2 + \beta_2 GDP + \epsilon_{it},$$

where CO2 are CO2 emissions per capita, c is a constant, Real i.r. denotes real interest rate, GDP denotes GDP per capita, β_0 and β_1 are coefficients of interest rate variable terms, β_2 - coefficient for GDP per capita variable, t stands for time (years 1990-2005), i denotes country in the dataset (for 31 countries in total) and ϵ_{it} is an error term corresponding to fixed effects error term $\epsilon_{it}=\alpha_{it}+u_{it}$.

Following hypothesis for the beta coefficients was tested:

H_0: $\beta_0 = 0$, $\beta_1=0$, $\beta_2=0$,

H_1: $\beta_0 \neq 0$, $\beta_1 \neq 0$, $\beta_2 \neq 0$.

After running panel data regression analysis for 31 countries over the period of 16 years (1990-2005), and controlling for the country fixed effects, the results for statistical significance are as follows, and visible in the output Table 5 on the next page:

Dependent Variable: CO2 Method: Panel Least Squares Date: 09/11/17 Time: 21:47 Sample: 1990 2005 Periods included: 16 Cross-sections included: 31 Total panel (balanced) observations: 496				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.226594	0.130452	24.73403	0.0000
REAL	0.004105	0.003428	1.197548	0.2317
REAL^2	-8.73E-05	9.04E-05	-0.965510	0.3348
GDP	8.21E-05	8.12E-06	10.11422	0.0000
Effects Specification				
Cross-section fixed (dummy variables)				
R-squared	0.987679	Mean dependent var	4.494591	
Adjusted R-squared	0.986799	S.D. dependent var	4.140337	
S.E. of regression	0.475699	Akaike info criterion	1.418024	
Sum squared resid	104.5459	Schwarz criterion	1.706378	
Log likelihood	-317.6700	Hannan-Quinn criter.	1.531213	
F-statistic	1122.312	Durbin-Watson stat	0.624785	
Prob(F-statistic)	0.000000			

Table 5. Real interest rate vs. CO2 per capita and GDP per capita, all countries.

As it is visible from the output, the real interest rate variables, although following the inverted-U shape pattern (positive coefficient β_0 at 0.004105 and negative β_1 at -8.73E-05, implying inverted-U shape) are statistically insignificant (p-values at 0.2317 and 0.3284, respectively). However, the coefficient of GDP per capita variable is statistically significant and has a positive sign, implying that as the income level per capita increases, environmental degradation follows the same direction, increasing as well. The significance of the GDP per capita variable is not surprising, bearing in mind that the statistically significant relationship between environmental degradation and income per capita has been observed in many research papers before. The results are similar for the lower and upper middle income groups (see Annex 2, Tables A.9-A.12).

An interesting outcome is observed for high income country group (see Table 6 on the next page). After performing the regression test for 11 high income countries, taking into account country fixed effects and including GDP per capita as an additional explanatory variable, we see that the real interest rate variables follow inverted-U shape pattern (positive coefficient β_0/REAL at 0.079257 and negative coefficient for β_1/REAL^2 at -0.003696), both significant at 5% confidence level (REAL p-value at 0.009 and REAL^2 p-value at 0.0469). Coefficient for GDP per capita variable (GDP) is statistically significant and positive, implying that an increase in income level per capita is correlated with increasing CO2 emissions per capita.

Although real interest rate alone is a poor predictor for pollution dynamics, as it is visible from the regression results in the section 4.1., together with the inclusion of GDP per capita variable we see that the interest rate takes on additional significance in explaining the development of CO2 per capita. Together with the GDP per capita, which is highly significant, interest rates for high income countries seem to have an influence in CO2 per capita development. Real interest rate has a positive correlation with the CO2 per capita emissions, and rise in interest rates seems to increase pollution (REAL is positive at 0.079257); however, at higher interest rates it starts to exert negative influence (REAL^2 at -0.003696), i.e. CO2 per capita emissions start to decrease. It suggests that indeed higher interest rate can be associated with the reduction in the environmental pollution, possibly by reducing incentives in borrowing money and deterring investment. However, the result has to be viewed with caution, since it does not apply for the majority of the countries in the other income classes.

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/11/17 Time: 21:50
Sample: 1990 2005
Periods included: 16
Cross-sections included: 11
Total panel (balanced) observations: 176

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.218991	0.518223	10.07094	0.0000
REAL	0.079257	0.029998	2.642054	0.0090
REAL^2	-0.003696	0.001845	-2.002805	0.0469
GDP	9.03E-05	1.24E-05	7.304537	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.970474	Mean dependent var	8.792845
Adjusted R-squared	0.968104	S.D. dependent var	3.297408
S.E. of regression	0.588896	Akaike info criterion	1.855069
Sum squared resid	56.18138	Schwarz criterion	2.107267
Log likelihood	-149.2461	Hannan-Quinn criter.	1.957359
F-statistic	409.5874	Durbin-Watson stat	0.709264
Prob(F-statistic)	0.000000		

Table 6. Real interest rate vs. CO2 per capita and GDP per capita, high income countries.

4.4. Trade intensity

Based on the available data set, panel data regression analysis was performed by taking into consideration country fixed effects. Trade intensity, which is measured as a ratio of sum of exports and imports to the GDP, has been included as an additional explanatory variable to the regression. The regression takes on the following form:

$$CO_{2_{it}} = c_{it} + \beta_0 Real\ i.r._{it} + \beta_1 Real\ i.r._{it}^2 + \beta_2 Trade\ + \epsilon_{it},$$

where CO2 are CO2 emissions per capita, c is a constant, Real i.r. denotes real interest rate, β_0 and β_1 are coefficients of interest rate variable terms, β_2 – coefficient for trade intensity variable, t stands for time (years 1990-2005), i denotes country in the dataset (for 31 countries in total) and ϵ_{it} is an error term corresponding to fixed effects error term $\epsilon_{it}=\alpha_{it}+u_{it}$. ***Trade*** stands for trade intensity variable (ratio of sum of exports and imports to the GDP).

Following hypothesis for the beta coefficients was tested:

H_0: $\beta_0 = 0, \beta_1 = 0, \beta_2 = 0,$

H_1: $\beta_0 \neq 0, \beta_1 \neq 0, \beta_2 \neq 0$

After running panel data regression analysis for 31 countries over the period of 16 years (1990-2005), and controlling for the country fixed effects, the results for statistical significance are as follows, and visualized in the output Table 7 below:

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/12/17 Time: 20:20
Sample: 1990 2005
Periods included: 16
Cross-sections included: 31
Total panel (balanced) observations: 496

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.604368	0.148766	24.22836	0.0000
REAL	0.001646	0.003624	0.454092	0.6500
REAL^2	-7.65E-05	9.60E-05	-0.796564	0.4261
TRADE	0.012655	0.002031	6.231631	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.986118	Mean dependent var	4.494591
Adjusted R-squared	0.985127	S.D. dependent var	4.140337
S.E. of regression	0.504940	Akaike info criterion	1.537333
Sum squared resid	117.7937	Schwarz criterion	1.825687
Log likelihood	-347.2585	Hannan-Quinn criter.	1.650521
F-statistic	994.5157	Durbin-Watson stat	0.590413
Prob(F-statistic)	0.000000		

Table 7. Real interest rate vs. CO2 per capita and Trade intensity, all countries.

The result shows that the trade variable is statistically significant, and has a positive sign (coefficient β_2/TRADE has a positive value of 0.012644, with very small p-value 0.0000). It suggests that an increase in trading activities would lead to the increase in environmental degradation, and in line with the apprehensions expressed by some researchers that trade has a negative influence on the environment (as in section 2.2.2.6). Real interest rate variables are statistically insignificant (p-values for $\boldsymbol{\beta_0}$ and $\boldsymbol{\beta_1}$ are 0.65 and 0.4261, respectively). When the regressions are performed for the subgroups of the sample, i.e. for the groups of countries in different economic development stages, it confirms the main result (see Annex 2, Tables A.13–A.16). The β_2 coefficient/TRADE acquires a positive sign and is statistically significant for all income groups. Still, some differences between income levels exist and have to be taken into account, e.g. for the lower middle income group the TRADE coefficient is statistically insignificant at 1% confidence level (Table A.16 in Annex 2).

4.5. Population density

Panel data regression analysis was performed with population density as an additional explanatory variable, taking into consideration country fixed effects. The regression takes on the following form:

$$\boldsymbol{CO2_{it} = c_{it} + \beta_0 Real\ i.r._{it} + \beta_1 Real\ i.r._{it}^2 + \beta_2 Pop.d. + \epsilon_{it},}$$

where CO2 are CO2 emissions per capita, c is a constant, Real i.r. denotes real interest rate, $\boldsymbol{\beta_0}$ and $\boldsymbol{\beta_1}$ are coefficients of interest rate variable terms, $\boldsymbol{\beta_2}$ – coefficient for population density variable, t stands for time (years 1990-2005), i denotes country in the dataset (for 31 countries in total) and ϵ_{it} is an error term corresponding to fixed effect error term $\epsilon_{it}=\alpha_{it}+u_{it}$. ***Pop. d.*** stands for population density.

Following hypothesis for the beta coefficients was tested:

H_0: $\beta_0 = 0$, $\beta_1=0$, $\beta_2=0$,

H_1: $\beta_0\neq0$, $\beta_1\neq0$, $\beta_2\neq0$.

After running panel data regression analysis for 31 countries over the period of 16 years (1990-2005), and controlling for the country fixed effects, the results for statistical significance are as follows, and visualized in the output Table 8 below.

The results show that the coefficient for population density is positive and statistically significant, with real interest rate not producing different results compared to previous results (as before, statistically insignificant, with p-values for β_0 and β_1 at 0.8132 and 0.7685, respectively).

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/22/17 Time: 17:34
Sample: 1990 2005
Periods included: 16
Cross-sections included: 31
Total panel (balanced) observations: 496

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.643524	0.196860	18.50817	0.0000
REAL	-0.000868	0.003670	-0.236399	0.8132
REAL^2	-2.88E-05	9.77E-05	-0.294510	0.7685
POPD	0.005431	0.001218	4.459761	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.985572	Mean dependent var	4.494591
Adjusted R-squared	0.984542	S.D. dependent var	4.140337
S.E. of regression	0.514770	Akaike info criterion	1.575891
Sum squared resid	122.4243	Schwarz criterion	1.864245
Log likelihood	-356.8210	Hannan-Quinn criter.	1.689079
F-statistic	956.3691	Durbin-Watson stat	0.529259
Prob(F-statistic)	0.000000		

Table 8. Real interest rate vs. CO2 per capita and Population density, all countries.

The output suggests that the population density and CO2 emissions per capita have a positive relationship, i.e. any increase in the population density is associated with the increase in the emissions of the pollutant observed. The result is in line with the previous findings of some researchers, such as Panayotou (1997), who also find a negative influence of growing population on the environment (as mentioned in section 3.3.) It follows a quite intuitive explanation that as the population grows, the pressure on the natural resources increases, as sustaining a higher number of people would require more resources. When the regression was tested for the countries in different groups of income levels, the results are very similar and do not differ among the income buckets (see Annex 2, Tables A.17-A.21), suggesting that the same relationship between population density and CO2 emissions per capita holds for various income levels.

4.6. Energy production and use

Additional explanatory variables, related to the alternative energy production and use, are included in the analysis:

- alternative and nuclear energy (% of total energy use),
- renewable energy consumption (% of total final energy consumption), and
- renewable electricity output (% of total electricity output).

By keeping the real interest rate variables and changing the additional control variable, 3 different regressions were constructed:

$$\boldsymbol{CO_{2_{it}} = c_{it} + \beta_0 Real\ i.r._{it} + \beta_1 Real\ i.r._{it}^2 + \beta_2 Alt.en. + \epsilon_{it},}$$

$$\boldsymbol{CO_{2_{it}} = c_{it} + \beta_0 Real\ i.r._{it} + \beta_1 Real\ i.r._{it}^2 + \beta_2 Ren.out. + \epsilon_{it},}$$

$$\boldsymbol{CO_{2_{it}} = c_{it} + \beta_0 Real\ i.r._{it} + \beta_1 Real\ i.r._{it}^2 + \beta_2 Ren.cons. + \epsilon_{it},}$$

where CO2 are CO2 emissions per capita, c is a constant, Real i.r. denotes real interest rate, $\boldsymbol{\beta_0}$ and $\boldsymbol{\beta_1}$ are coefficients of interest rate variable terms, t stands for time (years 1990-2005), i denotes country in the dataset (for 31 countries in total) and ϵ_{it} is an error term corresponding to fixed effect error term $\epsilon_{it}=\alpha_{it}+u_{it}$. Control variables are denoted by abbreviations **Alt. en.** (for alternative and nuclear energy, % of total energy use), **Ren. out.** (for renewable energy output, % of total electricity output) and **Ren. cons.** (for renewable energy consumption, % of total final energy consumption). $\boldsymbol{\beta_2}$ is the coefficient of the energy variables.

All three regressions were tested separately, with the following hypothesis for the beta coefficients:

H_0: $\beta_0 = 0$, $\beta_1=0$, $\beta_2=0$,

H_1: $\beta_0 \neq 0$, $\beta_1 \neq 0$, $\beta_2 \neq 0$.

4.6.1. Alternative and nuclear energy share

The following panel data regression, which includes alternative and nuclear energy share as an additional explanatory variable, was tested, controlling for the country fixed effects, with the results presented in the Table 9:

$$\boldsymbol{CO_{2_{it}} = c_{it} + \beta_0 Real\ i.r._{it} + \beta_1 Real\ i.r._{it}^2 + \beta_2 Alt.en. + \epsilon_{it}}$$

Dependent Variable: CO2				
Method: Panel Least Squares				
Date: 09/12/17 Time: 20:17				
Sample: 1990 2005				
Periods included: 16				
Cross-sections included: 31				
Total panel (balanced) observations: 496				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.812813	0.146448	32.86355	0.0000
REAL	-0.001006	0.003730	-0.269656	0.7875
REAL^2	-4.32E-05	9.93E-05	-0.435160	0.6636
ALT	-0.028009	0.013130	-2.133238	0.0334
Effects Specification				
Cross-section fixed (dummy variables)				
R-squared	0.985098	Mean dependent var	4.494591	
Adjusted R-squared	0.984034	S.D. dependent var	4.140337	
S.E. of regression	0.523163	Akaike info criterion	1.608239	
Sum squared resid	126.4493	Schwarz criterion	1.896593	
Log likelihood	-364.8433	Hannan-Quinn criter.	1.721427	
F-statistic	925.4818	Durbin-Watson stat	0.486266	
Prob(F-statistic)	0.000000			

Table 9. Real interest rate vs. CO2 per capita and Alternative energy, all countries.

The results show that the coefficient for alternative energy variable (ALT, corresponding to β_2 of the above stated regression) takes on a negative sign (-0.028009), and is statistically significant at 5% confidence level (p-value 0.0334). The real interest rate variables are statistically insignificant. The result suggests a quite intuitive explanation that as the share of energy produced by alternative energy sources increases, it is associated with a decrease in CO2 emissions per capita. However, the results for the country subgroups based on the income level show an important difference between nations in different economic development stages. While the result holds for high income countries (i.e. β_2 coefficient is negative and statistically significant at -0.087577), the results for upper middle and lower middle income countries are statistically insignificant (p-values 0.5128 and 0.7269, respectively), suggesting that for the countries in lower stages of economic development the share of alternative energy is not correlated with the CO2 emissions per capita, and we could not associated the increase in the share of alternative energy with the reduction in CO2 emissions per capita (see Annex 2, Tables A.21-A.24).

4.6.2. Renewable energy output

Following panel data regression, which includes renewable energy consumption share as an additional explanatory variable, was tested, controlling for the country fixed effects, with the results presented in the Table 10:

$$CO_{2_{it}} = c_{it} + \beta_0 Real\ i.r._{it} + \beta_1 Real\ i.r._{it}^2 + \beta_2 Ren.out. + \epsilon_{it}$$

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/23/17 Time: 15:54
Sample: 1990 2005
Periods included: 16
Cross-sections included: 31
Total panel (balanced) observations: 496

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.340535	0.148559	35.94882	0.0000
REAL	-0.001979	0.003626	-0.545802	0.5855
REAL^2	-1.99E-05	9.64E-05	-0.206582	0.8364
RENELO	-0.020971	0.003653	-5.740269	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.985953	Mean dependent var	4.494591
Adjusted R-squared	0.984950	S.D. dependent var	4.140337
S.E. of regression	0.507932	Akaike info criterion	1.549148
Sum squared resid	119.1937	Schwarz criterion	1.837502
Log likelihood	-350.1886	Hannan-Quinn criter.	1.662336
F-statistic	982.6701	Durbin-Watson stat	0.523101
Prob(F-statistic)	0.000000		

Table 10. Real interest rate vs. CO2 per capita and Renewable energy output, all countries.

The coefficient for the renewable energy output RENELO, corresponding to β_2 of the above state regression, is negative and statistically significant (β_2 is -0.020971, with p-value very small 0.0000), as is visible in the Table 10. Similar outcome is observed when the regression analysis is performed separately for the countries in different income groups (negative and statistically significant coefficients β_2 for all income groups – see Annex 2, Tables A. 25-A.28). The results suggest that any increase in renewable energy output is correlated with the decrease in CO2 emissions per capita, independent of the country's level of income.

4.6.3. Renewable electricity consumption

Following panel data regression, which includes renewable electricity consumption share as an additional explanatory variable, was tested, controlling for the country fixed effects, with the results presented in the Table 11:

$$\boldsymbol{CO_{2_{it}} = c_{it} + \beta_0 Real\ i.r._{it} + \beta_1 Real\ i.r._{it}^2 + \beta_2 Ren.cons. + \epsilon_{it}}$$

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/23/17 Time: 15:53
Sample: 1990 2005
Periods included: 16
Cross-sections included: 31
Total panel (balanced) observations: 496

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.691454	0.189135	30.09207	0.0000
REAL	-0.001487	0.003596	-0.413435	0.6795
REAL^2	9.87E-06	9.60E-05	0.102809	0.9182
RENEC	-0.036882	0.005810	-6.347660	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.986159	Mean dependent var	4.494591
Adjusted R-squared	0.985170	S.D. dependent var	4.140337
S.E. of regression	0.504206	Akaike info criterion	1.534423
Sum squared resid	117.4514	Schwarz criterion	1.822777
Log likelihood	-346.5368	Hannan-Quinn criter.	1.647611
F-statistic	997.4548	Durbin-Watson stat	0.537542
Prob(F-statistic)	0.000000		

Table 11. Real interest rate vs. CO2 per capita and Renewable electricity consumption, all countries.

The coefficient for the renewable energy consumption variable RENEC, corresponding to the coefficient β_2 of the regression stated above, takes on a negative sign and is statistically significant (β_2 is at -0.36882, with p-value very small 0.0000), as in the Table 11. Similar outcome is observed when the regression analysis is performed separately for the countries in different income groups (negative and statistically significant coefficients β_2 for all income groups – see Annex 2, Tables A.29-A.32).

The results show that irrespective of the renewable/alternative energy variable that was tested in the regression, the outcome is similar. All three variables prove to be statistically significant on the global level (i.e. for the whole set of the countries) and with a negative coefficient sign, complying with the assumption that as the shares of renewable energy production or consumption increase, the effect on the environmental degradation is negative, i.e. the measure of pollution is decreasing. However, lower income countries (upper middle and lower middle income economies) show that at least for one variable, the share of alternative energy, is not associated with the reduction of CO2 emissions per capita.

5. Summary and Conclusions

The thesis is based on the Environmental Kuznets curve theory, and uses the EKC framework to investigate a possible relationship between interest rate and environmental degradation. Previously not included in the EKC theory, and as an important determinant of the economic landscape of a country, the interest rate variable (real interest rate) is regressed on CO2 emissions per capita using standard EKC regression equation. Using panel data regressions and a data set of 31 countries for years 1990-2005, the analysis tries to determine if a statistically significant relationship between these two variables exists. Furthermore, a number of additional explanatory variables was included in the analysis.

Based on the results of the panel data regressions described in the section 4, the following conclusions can be made:

1. In general, no statistically significant relationship between the real interest rate and CO2 emissions per capita can be established. We cannot see any significant positive, negative, or a standard inverted-U shape correlation, associated with EKC, between the two mentioned variables. Neither of the country subgroups suggests a different result. Therefore, by way of adapting a standard EKC framework and including interest rate as the main independent variable, we can conclude that the changes of pollution levels cannot be explained by the movements in the real interest rates alone.

Still, it has to be mentioned, that real interest rate seems to be significant in one case indeed – together with the GDP per income variable for high income countries. However, we may conclude that here the GDP per capita variable has the most of the explanatory power, and the interest rate only complements the income variable.

2. Additional independent variables have a lot of explanatory power in comparison to real interest rate. Statistically significant coefficients are present for almost all tested cases:

- An increase in GDP per capita is positively correlated with the CO2 per capita emissions.
- Expansion of trade activities is correlated with an increase of CO2 per capita emissions, suggesting a negative effect on the environment.
- Increase in population density leads to an increase of CO2 per capita emissions, suggesting a negative effect on the environment.
- Increase in the share of alternative and nuclear energy is correlated with a decrease in CO2 per capita emissions, however, it is insignificant for the less economically developed countries.
- Increase in renewable energy and consumption share is correlated with a decrease in CO2 per capita emissions.

3. The results suggest some differences exist based on the income level of a country at least for a number of variables. Although the majority of the variables behave in the same way for the most of the findings, and independent of the income level, some differences do exist. Yearly change in real interest rate is correlated with a yearly change in CO2 per capita emissions for countries in lower economic stages of development, suggesting them to be more sensitive to real interest rate changes. However, most noticeably the alternative energy share is not significant for the less economically developed countries, suggesting that for such countries sustainable economic practices and alternative energy sources do not have any significant influence in reducing negative environmental impacts. The results may imply that such countries haven't reached the critical income level necessary to implement environmentally friendly policies or adopt environmentally friendly production processes yet. Less developed countries therefore could profit from the external assistance and international support from the more developed countries, in order to catch up with economically more advanced economies, and benefit from the so-called “latecomer advantage”.

In conclusion, although we see that the real interest rate alone did not prove to explain pollution dynamics, the results of the thesis may still contribute to the future research, focused on explaining the causes of the inverted-U EKC shape. Real interest rate is significant with the CO2 movements for high income countries together with GDP per income, while yearly interest rate change is correlated with the changes in pollution for at least a number of countries. With growing climate concerns, more research and more sophisticated models would be needed to further investigate the ongoing pollution dynamics.

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Annex 1. Abstract

Over the past few decades, the theory of the environmental Kuznets curve (EKC), establishing the inverted-U shape relationship between environmental degradation and income per capita of a country, has been widely described and researched throughout the academic literature. Various economic and social indicators have been included in EKC analysis as well; however, one variable that has not yet received explicit attention in the EKC framework is interest rate. As an important indicator of the economic conditions of a country, influencing the behavior of economic agents, including patterns of investment, consumption and saving, it has been chosen as an independent variable in the EKC framework of the analysis. This thesis is based on the econometric framework, which uses standard quadratic EKC function, adapted to include interest rate indicator (real interest rate). Controlling for the country fixed effects, the significance and impact of interest rates on the pollution variable (CO_2 emissions per capita) is tested for a set of countries using panel data regression analysis. Additional explanatory variables (GDP per capita, trade, population and alternative energy indicators) are tested as well. While additional explanatory variables show statistically significant correlation with the pollution variable, the analysis fails to find a statistically significant relationship between real interest rate and CO_2 per capita emissions alone. The findings may contribute to future research, focused on explaining the causes of inverted-U shape EKC dynamics.

Zusammenfassung

In den letzten Jahrzehnten wurde die Theorie der Umwelt-Kuznets-Kurve (EKC), die die umgekehrte U-förmige Beziehung zwischen Umweltzerstörung und Pro-Kopf-Einkommen eines Landes darstellt, in der wissenschaftlichen Literatur ausführlich beschrieben und erforscht. Verschiedene wirtschaftliche und soziale Indikatoren wurden ebenfalls in Analysen miteinbezogen, die die Beziehung zwischen Umweltzertsörung und Einkommen beschreiben. Eine Variable, die im EKC-Rahmen noch nicht explizit berücksichtigt wurde, ist jedoch der Zinssatz. Als wichtiger Indikator für die wirtschaftlichen Bedingungen eines Landes, der das Verhalten von Wirtschaftssubjekten beeinflusst, einschließlich der Investitions-, Konsum- und Sparentscheidungen, wurde der Zinssatz als unabhängige Variable im EKC-Rahmen dieser Analyse gewählt. Diese Arbeit basiert auf dem ökonometrischen Rahmenwerk, das eine standardmäßige quadratische EKC-Funktion verwendet, angepasst an den Zinsindikator (Realzins). Unter Konstanthaltung landesspezifischer Effekte werden anhand von Paneldatenregressionsanalysen die Bedeutung und der Einfluss der Zinssätze auf die Umweltverschmutzungsvariable (CO2-Emissionen pro Kopf) für eine Reihe von Ländern getestet. Zusätzliche Erklärungsvariablen (BIP pro Kopf, Handels-, Bevölkerungs- und alternativenergiespezifische Indikatoren) werden ebenfalls getestet. Während zusätzliche erklärende Variablen eine statistisch signifikante Korrelation mit der Verschmutzungsvariablen zeigen, findet die Analyse keinen statistisch signifikanten Zusammenhang zwischen dem realen Zinssatz und den pro Kopf CO2 Emissionen. Die Ergebnisse der vorliegenden Untersuchung leisten einen Beitrag zu zukünftigen Forschungsvorhaben zur Erklärung der Ursachen von EKC-Dynamiken in der umgekehrten U-Form.

Annex 2. Data output

All regression analysis performed using eViews 8.

Regression 4.1. Real interest rate.

$$CO_{2_{it}} = c_{it} + \beta_0 Real\ i.r._{it} + \beta_1 Real\ i.r._{it}^2 + \epsilon_{it}$$

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/10/17 Time: 15:33
Sample: 1990 2005
Periods included: 16
Cross-sections included: 31
Total panel (balanced) observations: 496

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.508845	0.033941	132.8420	0.0000
REAL	-0.000932	0.003744	-0.248798	0.8036
REAL^2	-4.05E-05	9.96E-05	-0.406146	0.6848

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.984951	Mean dependent var	4.494591
Adjusted R-squared	0.983911	S.D. dependent var	4.140337
S.E. of regression	0.525165	Akaike info criterion	1.614009
Sum squared resid	127.6948	Schwarz criterion	1.893882
Log likelihood	-367.2741	Hannan-Quinn criter.	1.723868
F-statistic	946.9984	Durbin-Watson stat	0.511049
Prob(F-statistic)	0.000000		

Table A. 1. Real interest rate vs. CO2 per capita, all countries.

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/10/17 Time: 18:02
Sample: 1990 2005
Periods included: 16
Cross-sections included: 11
Total panel (balanced) observations: 176

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	8.941326	0.108259	82.59204	0.0000
REAL	-0.019221	0.030803	-0.624008	0.5335
REAL^2	-0.001170	0.002084	-0.561741	0.5751

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.960749	Mean dependent var	8.792845
Adjusted R-squared	0.957859	S.D. dependent var	3.297408
S.E. of regression	0.676899	Akaike info criterion	2.128403
Sum squared resid	74.68525	Schwarz criterion	2.362586
Log likelihood	-174.2995	Hannan-Quinn criter.	2.223387
F-statistic	332.4795	Durbin-Watson stat	0.535226
Prob(F-statistic)	0.000000		

Table A. 2. Real interest rate vs. CO2 per capita, high income countries.

Dependent Variable: CO2				
Method: Panel Least Squares				
Date: 09/10/17 Time: 18:27				
Sample: 1990 2005				
Periods included: 16				
Cross-sections included: 11				
Total panel (balanced) observations: 176				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.367260	0.060052	56.07271	0.0000
REAL	0.004031	0.006686	0.602855	0.5474
REAL^2	-8.45E-05	0.000153	-0.552847	0.5811
Effects Specification				
Cross-section fixed (dummy variables)				
R-squared	0.947408	Mean dependent var		3.385842
Adjusted R-squared	0.943536	S.D. dependent var		2.277847
S.E. of regression	0.541265	Akaike info criterion		1.681180
Sum squared resid	47.75384	Schwarz criterion		1.915363
Log likelihood	-134.9438	Hannan-Quinn criter.		1.776163
F-statistic	244.6935	Durbin-Watson stat		0.501415
Prob(F-statistic)	0.000000			

Table A. 3. Real interest rate vs. CO2 per capita, upper middle income countries.

Dependent Variable: CO2				
Method: Panel Least Squares				
Date: 09/11/17 Time: 21:39				
Sample: 1990 2005				
Periods included: 16				
Cross-sections included: 9				
Total panel (balanced) observations: 144				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.603927	0.017108	35.30147	0.0000
REAL	0.000755	0.001302	0.579730	0.5631
REAL^2	-5.92E-05	3.86E-05	-1.534033	0.1274
Effects Specification				
Cross-section fixed (dummy variables)				
R-squared	0.856896	Mean dependent var		0.596305
Adjusted R-squared	0.846136	S.D. dependent var		0.359195
S.E. of regression	0.140896	Akaike info criterion		-1.008278
Sum squared resid	2.640269	Schwarz criterion		-0.781417
Log likelihood	83.59598	Hannan-Quinn criter.		-0.916094
F-statistic	79.63921	Durbin-Watson stat		0.487518
Prob(F-statistic)	0.000000			

Table A. 4. Real interest rate vs. CO2 per capita, lower middle income countries.

Regression 4.2. Year-to-Year change in Real interest rate.

$$\Delta CO_{2_{it}} = c_{it} + \beta_0 \Delta Real\ i.r._{it} + \beta_1 \Delta Real\ i.r._{it}^2 + \epsilon_{it}$$

Dependent Variable: CO2DELTA
Method: Panel Least Squares
Date: 09/19/17 Time: 16:10
Sample (adjusted): 1991 2005
Periods included: 15
Cross-sections included: 31
Total panel (balanced) observations: 465

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.046178	0.017946	2.573155	0.0104
REALDELTA	0.002284	0.001853	1.232467	0.2184
REALDELTA^2	4.29E-05	7.40E-05	0.580485	0.5619

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.044502	Mean dependent var	0.048967
Adjusted R-squared	-0.026276	S.D. dependent var	0.358581
S.E. of regression	0.363262	Akaike info criterion	0.880938
Sum squared resid	57.00635	Schwarz criterion	1.174889
Log likelihood	-171.8180	Hannan-Quinn criter.	0.996637
F-statistic	0.628757	Durbin-Watson stat	2.318824
Prob(F-statistic)	0.945073		

Table A. 5. Real interest rate YtY change vs. CO2 per capita YtY change, all countries.

Dependent Variable: DELTACO2
Method: Panel Least Squares
Date: 09/19/17 Time: 20:41
Sample (adjusted): 1991 2005
Periods included: 15
Cross-sections included: 11
Total panel (balanced) observations: 165

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.035580	0.039984	0.889875	0.3749
DELTAREAL	-0.000504	0.013110	-0.038439	0.9694
DELTAREAL^2	0.001905	0.001651	1.153969	0.2503

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.041596	Mean dependent var	0.052869
Adjusted R-squared	-0.034068	S.D. dependent var	0.470823
S.E. of regression	0.478775	Akaike info criterion	1.440340
Sum squared resid	34.84232	Schwarz criterion	1.685051
Log likelihood	-105.8281	Hannan-Quinn criter.	1.539677
F-statistic	0.549746	Durbin-Watson stat	2.272890
Prob(F-statistic)	0.878757		

Table A. 6. Real interest rate YtY change vs. CO2 per capita YtY change, high income countries.

Dependent Variable: DELTACO2
Method: Panel Least Squares
Date: 09/19/17 Time: 20:43
Sample (adjusted): 1991 2005
Periods included: 15
Cross-sections included: 11
Total panel (balanced) observations: 165

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.047270	0.030141	1.568297	0.1189
DELTAREAL	0.011502	0.003174	3.623322	0.0004
DELTAREAL^2	0.000392	0.000167	2.351730	0.0200

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.138978	Mean dependent var	0.073610
Adjusted R-squared	0.071003	S.D. dependent var	0.365163
S.E. of regression	0.351961	Akaike info criterion	0.824918
Sum squared resid	18.82923	Schwarz criterion	1.069628
Log likelihood	-55.05570	Hannan-Quinn criter.	0.924254
F-statistic	2.044539	Durbin-Watson stat	2.274490
Prob(F-statistic)	0.023932		

Table A. 7. Real interest rate YtY change vs. CO2 per capita YtY change, upper middle income countries.

Dependent Variable: DELTACO2
Method: Panel Least Squares
Date: 09/19/17 Time: 21:28
Sample (adjusted): 1991 2005
Periods included: 15
Cross-sections included: 9
Total panel (balanced) observations: 135

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.018662	0.008840	2.110982	0.0368
DELTAREAL	-0.001551	0.000591	-2.625764	0.0097
DELTAREAL^2	-2.78E-05	2.10E-05	-1.325111	0.1876

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.094401	Mean dependent var	0.014079
Adjusted R-squared	0.021369	S.D. dependent var	0.093497
S.E. of regression	0.092492	Akaike info criterion	-1.845409
Sum squared resid	1.060802	Schwarz criterion	-1.608683
Log likelihood	135.5651	Hannan-Quinn criter.	-1.749210
F-statistic	1.292599	Durbin-Watson stat	2.454987
Prob(F-statistic)	0.241763		

Table A. 8. Real interest rate YtY change vs. CO2 per capita YtY change, lower middle income countries.

Regression 4.3. Income per capita.

$$CO_{2_{it}} = c_{it} + \beta_0 Real\ i.r._{it} + \beta_1 Real\ i.r._{it}^2 + \beta_2 GDP + \epsilon_{it}$$

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/11/17 Time: 21:47
Sample: 1990 2005
Periods included: 16
Cross-sections included: 31
Total panel (balanced) observations: 496

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.226594	0.130452	24.73403	0.0000
REAL	0.004105	0.003428	1.197548	0.2317
REAL^2	-8.73E-05	9.04E-05	-0.965510	0.3348
GDP	8.21E-05	8.12E-06	10.11422	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.987679	Mean dependent var	4.494591
Adjusted R-squared	0.986799	S.D. dependent var	4.140337
S.E. of regression	0.475699	Akaike info criterion	1.418024
Sum squared resid	104.5459	Schwarz criterion	1.706378
Log likelihood	-317.6700	Hannan-Quinn criter.	1.531213
F-statistic	1122.312	Durbin-Watson stat	0.624785
Prob(F-statistic)	0.000000		

Table A. 9. Real interest rate vs. CO2 per capita and GDP per capita, all countries.

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/11/17 Time: 21:50
Sample: 1990 2005
Periods included: 16
Cross-sections included: 11
Total panel (balanced) observations: 176

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.218991	0.518223	10.07094	0.0000
REAL	0.079257	0.029998	2.642054	0.0090
REAL^2	-0.003696	0.001845	-2.002805	0.0469
GDP	9.03E-05	1.24E-05	7.304537	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.970474	Mean dependent var	8.792845
Adjusted R-squared	0.968104	S.D. dependent var	3.297408
S.E. of regression	0.588896	Akaike info criterion	1.855069
Sum squared resid	56.18138	Schwarz criterion	2.107267
Log likelihood	-149.2461	Hannan-Quinn criter.	1.957359
F-statistic	409.5874	Durbin-Watson stat	0.709264
Prob(F-statistic)	0.000000		

Table A. 10. Real interest rate vs. CO2 per capita and GDP per capita, high income countries.

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/11/17 Time: 21:51
Sample: 1990 2005
Periods included: 16
Cross-sections included: 11
Total panel (balanced) observations: 176

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.937984	0.301850	3.107448	0.0022
REAL	0.002993	0.005646	0.530103	0.5968
REAL^2	-7.46E-05	0.000129	-0.578059	0.5640
GDP	0.000472	5.78E-05	8.163950	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.962738	Mean dependent var	3.385842
Adjusted R-squared	0.959748	S.D. dependent var	2.277847
S.E. of regression	0.457002	Akaike info criterion	1.347947
Sum squared resid	33.83389	Schwarz criterion	1.600145
Log likelihood	-104.6193	Hannan-Quinn criter.	1.450237
F-statistic	321.9699	Durbin-Watson stat	0.813983
Prob(F-statistic)	0.000000		

Table A. 11. Real interest rate vs. CO2 per capita and GDP per capita, upper middle income countries.

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/11/17 Time: 21:57
Sample: 1990 2005
Periods included: 16
Cross-sections included: 9
Total panel (balanced) observations: 144

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.237495	0.125054	-1.899146	0.0597
REAL	-0.000713	0.001146	-0.622508	0.5347
REAL^2	-6.31E-06	3.42E-05	-0.184178	0.8542
GDP	0.000645	9.52E-05	6.776060	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.893827	Mean dependent var	0.596305
Adjusted R-squared	0.884979	S.D. dependent var	0.359195
S.E. of regression	0.121820	Akaike info criterion	-1.292893
Sum squared resid	1.958888	Schwarz criterion	-1.045408
Log likelihood	105.0883	Hannan-Quinn criter.	-1.192329
F-statistic	101.0231	Durbin-Watson stat	0.723786
Prob(F-statistic)	0.000000		

Table A. 12. Real interest rate vs. CO2 per capita and GDP per capita, lower middle income countries.

Regression 4.4. Trade intensity.

$$CO_{2_{it}} = c_{it} + \beta_0 Real\ i.r._{it} + \beta_1 Real\ i.r._{it}^2 + \beta_2 Trade + \epsilon_{it}$$

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/12/17 Time: 20:20
Sample: 1990 2005
Periods included: 16
Cross-sections included: 31
Total panel (balanced) observations: 496

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.604368	0.148766	24.22836	0.0000
REAL	0.001646	0.003624	0.454092	0.6500
REAL^2	-7.65E-05	9.60E-05	-0.796564	0.4261
TRADE	0.012655	0.002031	6.231631	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.986118	Mean dependent var	4.494591
Adjusted R-squared	0.985127	S.D. dependent var	4.140337
S.E. of regression	0.504940	Akaike info criterion	1.537333
Sum squared resid	117.7937	Schwarz criterion	1.825687
Log likelihood	-347.2585	Hannan-Quinn criter.	1.650521
F-statistic	994.5157	Durbin-Watson stat	0.590413
Prob(F-statistic)	0.000000		

Table A. 13. Real interest rate vs. CO2 per capita and Trade intensity, all countries.

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/12/17 Time: 20:32
Sample: 1990 2005
Periods included: 16
Cross-sections included: 11
Total panel (balanced) observations: 176

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	7.002304	0.545427	12.83820	0.0000
REAL	0.010484	0.030828	0.340066	0.7342
REAL^2	-0.001547	0.002013	-0.768471	0.4433
TRADE	0.031265	0.008632	3.622083	0.0004

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.963690	Mean dependent var	8.792845
Adjusted R-squared	0.960776	S.D. dependent var	3.297408
S.E. of regression	0.653056	Akaike info criterion	2.061894
Sum squared resid	69.09003	Schwarz criterion	2.314092
Log likelihood	-167.4467	Hannan-Quinn criter.	2.164185
F-statistic	330.7325	Durbin-Watson stat	0.630408
Prob(F-statistic)	0.000000		

Table A. 14. Real interest rate vs. CO2 per capita and Trade intensity, high income countries.

Dependent Variable: CO2				
Method: Panel Least Squares				
Date: 09/12/17 Time: 20:41				
Sample: 1990 2005				
Periods included: 16				
Cross-sections included: 11				
Total panel (balanced) observations: 176				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.490959	0.285432	5.223521	0.0000
REAL	0.010999	0.006027	1.825047	0.0698
REAL^2	-0.000154	0.000136	-1.130355	0.2600
TRADE	0.020577	0.003075	6.691330	0.0000
Effects Specification				
Cross-section fixed (dummy variables)				
R-squared	0.958796	Mean dependent var		3.385842
Adjusted R-squared	0.955489	S.D. dependent var		2.277847
S.E. of regression	0.480570	Akaike info criterion		1.448514
Sum squared resid	37.41343	Schwarz criterion		1.700711
Log likelihood	-113.4692	Hannan-Quinn criter.		1.550804
F-statistic	289.9730	Durbin-Watson stat		0.714381
Prob(F-statistic)	0.000000			

Table A. 15. Real interest rate vs. CO2 per capita and Trade intensity, upper middle income countries.

Dependent Variable: CO2				
Method: Panel Least Squares				
Date: 09/12/17 Time: 20:43				
Sample: 1990 2005				
Periods included: 16				
Cross-sections included: 9				
Total panel (balanced) observations: 144				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.476704	0.052509	9.078467	0.0000
REAL	0.000812	0.001275	0.636409	0.5256
REAL^2	-6.68E-05	3.79E-05	-1.761721	0.0804
TRADE	0.002034	0.000796	2.556630	0.0117
Effects Specification				
Cross-section fixed (dummy variables)				
R-squared	0.863648	Mean dependent var		0.596305
Adjusted R-squared	0.852285	S.D. dependent var		0.359195
S.E. of regression	0.138052	Akaike info criterion		-1.042719
Sum squared resid	2.515697	Schwarz criterion		-0.795235
Log likelihood	87.07580	Hannan-Quinn criter.		-0.942156
F-statistic	76.00724	Durbin-Watson stat		0.501018
Prob(F-statistic)	0.000000			

Table A. 16. Real interest rate vs. CO2 per capita and Trade intensity variable, lower middle income countries

Regression 4.5. Population density.

$$CO_{2_{it}} = c_{it} + \beta_0 Real\ i.r._{it} + \beta_1 Real\ i.r._{it}^2 + \beta_2 Pop.d. + \epsilon_{it}$$

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/22/17 Time: 17:34
Sample: 1990 2005
Periods included: 16
Cross-sections included: 31
Total panel (balanced) observations: 496

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.643524	0.196860	18.50817	0.0000
REAL	-0.000868	0.003670	-0.236399	0.8132
REAL^2	-2.88E-05	9.77E-05	-0.294510	0.7685
POPD	0.005431	0.001218	4.459761	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.985572	Mean dependent var	4.494591
Adjusted R-squared	0.984542	S.D. dependent var	4.140337
S.E. of regression	0.514770	Akaike info criterion	1.575891
Sum squared resid	122.4243	Schwarz criterion	1.864245
Log likelihood	-356.8210	Hannan-Quinn criter.	1.689079
F-statistic	956.3691	Durbin-Watson stat	0.529259
Prob(F-statistic)	0.000000		

Table A. 17. Real interest rate vs. CO2 per capita and Population density, all countries.

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/22/17 Time: 17:39
Sample: 1990 2005
Periods included: 16
Cross-sections included: 11
Total panel (balanced) observations: 176

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.318875	1.203598	1.095777	0.2748
REAL	-0.008952	0.027692	-0.323290	0.7469
REAL^2	-0.001129	0.001870	-0.603533	0.5470
POPD	0.043705	0.006879	6.353789	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.968579	Mean dependent var	8.792845
Adjusted R-squared	0.966058	S.D. dependent var	3.297408
S.E. of regression	0.607496	Akaike info criterion	1.917262
Sum squared resid	59.78640	Schwarz criterion	2.169460
Log likelihood	-154.7191	Hannan-Quinn criter.	2.019552
F-statistic	384.1385	Durbin-Watson stat	0.637615
Prob(F-statistic)	0.000000		

Table A. 18. Real interest rate vs. CO2 per capita and Population density, high income countries.

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/22/17 Time: 17:44
Sample: 1990 2005
Periods included: 16
Cross-sections included: 11
Total panel (balanced) observations: 176

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.298803	0.405594	0.736705	0.4624
REAL	0.004080	0.005753	0.709273	0.4792
REAL^2	-4.57E-05	0.000132	-0.346948	0.7291
POPD	0.028227	0.003701	7.627483	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.961304	Mean dependent var	3.385842
Adjusted R-squared	0.958199	S.D. dependent var	2.277847
S.E. of regression	0.465711	Akaike info criterion	1.385701
Sum squared resid	35.13568	Schwarz criterion	1.637899
Log likelihood	-107.9417	Hannan-Quinn criter.	1.487991
F-statistic	309.5790	Durbin-Watson stat	0.650781
Prob(F-statistic)	0.000000		

Table A. 19. Real interest rate vs. CO2 per capita and Population density, upper middle income countries.

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/22/17 Time: 17:47
Sample: 1990 2005
Periods included: 16
Cross-sections included: 9
Total panel (balanced) observations: 144

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.384119	0.072665	5.286137	0.0000
REAL	0.000745	0.001261	0.591053	0.5555
REAL^2	-5.54E-05	3.74E-05	-1.481500	0.1409
POPD	0.001078	0.000347	3.106854	0.0023

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.866647	Mean dependent var	0.596305
Adjusted R-squared	0.855534	S.D. dependent var	0.359195
S.E. of regression	0.136525	Akaike info criterion	-1.064964
Sum squared resid	2.460355	Schwarz criterion	-0.817479
Log likelihood	88.67740	Hannan-Quinn criter.	-0.964400
F-statistic	77.98684	Durbin-Watson stat	0.518300
Prob(F-statistic)	0.000000		

Table A. 20. Real interest rate vs. CO2 per capita and Population density variable, upper middle income countries.

Regression 4.6.1. Alternative and nuclear energy share.

$$CO_{2_{it}} = c_{it} + \beta_0 Real\ i.r._{it} + \beta_1 Real\ i.r._{it}^2 + \beta_2 Alt.en. + \epsilon_{it}$$

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/12/17 Time: 20:17
Sample: 1990 2005
Periods included: 16
Cross-sections included: 31
Total panel (balanced) observations: 496

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.812813	0.146448	32.86355	0.0000
REAL	-0.001006	0.003730	-0.269656	0.7875
REAL^2	-4.32E-05	9.93E-05	-0.435160	0.6636
ALT	-0.028009	0.013130	-2.133238	0.0334

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.985098	Mean dependent var	4.494591
Adjusted R-squared	0.984034	S.D. dependent var	4.140337
S.E. of regression	0.523163	Akaike info criterion	1.608239
Sum squared resid	126.4493	Schwarz criterion	1.896593
Log likelihood	-364.8433	Hannan-Quinn criter.	1.721427
F-statistic	925.4818	Durbin-Watson stat	0.486266
Prob(F-statistic)	0.000000		

Table A. 21. Real interest rate vs. CO2 per capita and Alternative energy, all countries.

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/12/17 Time: 20:26
Sample: 1990 2005
Periods included: 16
Cross-sections included: 11
Total panel (balanced) observations: 176

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	10.61351	0.532000	19.95019	0.0000
REAL	-0.017810	0.029965	-0.594374	0.5531
REAL^2	-0.001075	0.002027	-0.530288	0.5966
ALT	-0.087577	0.027311	-3.206639	0.0016

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.963092	Mean dependent var	8.792845
Adjusted R-squared	0.960130	S.D. dependent var	3.297408
S.E. of regression	0.658411	Akaike info criterion	2.078227
Sum squared resid	70.22773	Schwarz criterion	2.330425
Log likelihood	-168.8840	Hannan-Quinn criter.	2.180517
F-statistic	325.1727	Durbin-Watson stat	0.458507
Prob(F-statistic)	0.000000		

Table A. 22. Real interest rate vs. CO2 per capita and Alternative energy, high income countries.

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/12/17 Time: 20:27
Sample: 1990 2005
Periods included: 16
Cross-sections included: 11
Total panel (balanced) observations: 176

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.276566	0.150791	21.72917	0.0000
REAL	0.004038	0.006698	0.602899	0.5474
REAL^2	-8.33E-05	0.000153	-0.543799	0.5873
ALT	0.013002	0.019823	0.655909	0.5128

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.947547	Mean dependent var	3.385842
Adjusted R-squared	0.943338	S.D. dependent var	2.277847
S.E. of regression	0.542214	Akaike info criterion	1.689891
Sum squared resid	47.62735	Schwarz criterion	1.942089
Log likelihood	-134.7104	Hannan-Quinn criter.	1.792181
F-statistic	225.1144	Durbin-Watson stat	0.509379
Prob(F-statistic)	0.000000		

Table A. 23. Real interest rate vs. CO2 per capita and Alternative energy, upper middle income countries.

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/12/17 Time: 20:29
Sample: 1990 2005
Periods included: 16
Cross-sections included: 9
Total panel (balanced) observations: 144

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.620617	0.050678	12.24637	0.0000
REAL	0.000727	0.001308	0.555953	0.5792
REAL^2	-5.95E-05	3.87E-05	-1.538386	0.1263
ALT	-0.003098	0.008852	-0.350022	0.7269

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.857028	Mean dependent var	0.596305
Adjusted R-squared	0.845114	S.D. dependent var	0.359195
S.E. of regression	0.141363	Akaike info criterion	-0.995316
Sum squared resid	2.637821	Schwarz criterion	-0.747832
Log likelihood	83.66278	Hannan-Quinn criter.	-0.894753
F-statistic	71.93275	Durbin-Watson stat	0.487404
Prob(F-statistic)	0.000000		

Table A. 24. Real interest rate vs. CO2 per capita and Alternative energy, lower middle income countries.

Regression 4.6.2. Renewable energy output.

$$CO_{2_{it}} = c_{it} + \beta_0 Real\, i.r._{it} + \beta_1 Real\, i.r._{it}^2 + \beta_2 Ren.out. + \epsilon_{it}$$

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/23/17 Time: 15:54
Sample: 1990 2005
Periods included: 16
Cross-sections included: 31
Total panel (balanced) observations: 496

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.340535	0.148559	35.94882	0.0000
REAL	-0.001979	0.003626	-0.545802	0.5855
REAL^2	-1.99E-05	9.64E-05	-0.206582	0.8364
RENELO	-0.020971	0.003653	-5.740269	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.985953	Mean dependent var	4.494591
Adjusted R-squared	0.984950	S.D. dependent var	4.140337
S.E. of regression	0.507932	Akaike info criterion	1.549148
Sum squared resid	119.1937	Schwarz criterion	1.837502
Log likelihood	-350.1886	Hannan-Quinn criter.	1.662336
F-statistic	982.6701	Durbin-Watson stat	0.523101
Prob(F-statistic)	0.000000		

Table A. 25. Real interest rate vs. CO2 per capita and Renewable energy output, all countries.

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/23/17 Time: 15:57
Sample: 1990 2005
Periods included: 16
Cross-sections included: 11
Total panel (balanced) observations: 176

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	10.57261	0.300350	35.20097	0.0000
REAL	0.009839	0.028605	0.343948	0.7313
REAL^2	-0.003284	0.001940	-1.693284	0.0923
RENELO	-0.063093	0.010968	-5.752458	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.967407	Mean dependent var	8.792845
Adjusted R-squared	0.964791	S.D. dependent var	3.297408
S.E. of regression	0.618727	Akaike info criterion	1.953898
Sum squared resid	62.01734	Schwarz criterion	2.206096
Log likelihood	-157.9430	Hannan-Quinn criter.	2.056188
F-statistic	369.8717	Durbin-Watson stat	0.559727
Prob(F-statistic)	0.000000		

Table A. 26. Real interest rate vs. CO2 per capita and Renewable energy output, high income countries.

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/23/17 Time: 16:01
Sample: 1990 2005
Periods included: 16
Cross-sections included: 11
Total panel (balanced) observations: 176

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.831872	0.339409	14.23615	0.0000
REAL	0.006299	0.006363	0.989965	0.3237
REAL^2	-8.21E-05	0.000145	-0.565862	0.5723
RENELO	-0.037203	0.008499	-4.377275	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.952970	Mean dependent var	3.385842
Adjusted R-squared	0.949196	S.D. dependent var	2.277847
S.E. of regression	0.513419	Akaike info criterion	1.580756
Sum squared resid	42.70313	Schwarz criterion	1.832954
Log likelihood	-125.1065	Hannan-Quinn criter.	1.683046
F-statistic	252.5100	Durbin-Watson stat	0.566751
Prob(F-statistic)	0.000000		

Table A. 27. Real interest rate vs. CO2 per capita and Renewable energy output, upper middle income countries.

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/23/17 Time: 16:00
Sample: 1990 2005
Periods included: 16
Cross-sections included: 9
Total panel (balanced) observations: 144

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.927541	0.066825	13.88019	0.0000
REAL	-6.37E-06	0.001208	-0.005269	0.9958
REAL^2	-5.38E-05	3.55E-05	-1.514478	0.1323
RENELO	-0.005862	0.001176	-4.983190	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.879554	Mean dependent var	0.596305
Adjusted R-squared	0.869517	S.D. dependent var	0.359195
S.E. of regression	0.129750	Akaike info criterion	-1.166763
Sum squared resid	2.222220	Schwarz criterion	-0.919279
Log likelihood	96.00694	Hannan-Quinn criter.	-1.066199
F-statistic	87.62993	Durbin-Watson stat	0.561189
Prob(F-statistic)	0.000000		

Table A. 28. Real interest rate vs. CO2 per capita and Renewable energy output, lower middle income countries.

Regression 4.6.3. Renewable electricity consumption.

$$CO_{2_{it}} = c_{it} + \beta_0 Real\ i.r._{it} + \beta_1 Real\ i.r._{it}^2 + \beta_2 Ren.cons. + \epsilon_{it}$$

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/23/17 Time: 15:53
Sample: 1990 2005
Periods included: 16
Cross-sections included: 31
Total panel (balanced) observations: 496

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.691454	0.189135	30.09207	0.0000
REAL	-0.001487	0.003596	-0.413435	0.6795
REAL^2	9.87E-06	9.60E-05	0.102809	0.9182
RENEC	-0.036882	0.005810	-6.347660	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.986159	Mean dependent var	4.494591
Adjusted R-squared	0.985170	S.D. dependent var	4.140337
S.E. of regression	0.504206	Akaike info criterion	1.534423
Sum squared resid	117.4514	Schwarz criterion	1.822777
Log likelihood	-346.5368	Hannan-Quinn criter.	1.647611
F-statistic	997.4548	Durbin-Watson stat	0.537542
Prob(F-statistic)	0.000000		

Table A. 29. Real interest rate vs. CO2 per capita and Renewable electricity consumption, all countries.

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/23/17 Time: 15:56
Sample: 1990 2005
Periods included: 16
Cross-sections included: 11
Total panel (balanced) observations: 176

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	10.58076	0.604616	17.49995	0.0000
REAL	-0.019676	0.030199	-0.651558	0.5156
REAL^2	-0.001553	0.002047	-0.758529	0.4492
RENEC	-0.095833	0.034794	-2.754292	0.0066

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.962505	Mean dependent var	8.792845
Adjusted R-squared	0.959496	S.D. dependent var	3.297408
S.E. of regression	0.663624	Akaike info criterion	2.094002
Sum squared resid	71.34435	Schwarz criterion	2.346200
Log likelihood	-170.2722	Hannan-Quinn criter.	2.196292
F-statistic	319.8884	Durbin-Watson stat	0.510057
Prob(F-statistic)	0.000000		

Table A. 30. Real interest rate vs. CO2 per capita and Renewable electricity consumption, high income countries.

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/23/17 Time: 16:01
Sample: 1990 2005
Periods included: 16
Cross-sections included: 11
Total panel (balanced) observations: 176

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.746483	0.186934	25.39121	0.0000
REAL	0.004909	0.005744	0.854620	0.3940
REAL^2	-6.69E-05	0.000131	-0.508991	0.6115
RENEC	-0.061917	0.008066	-7.676146	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.961435	Mean dependent var	3.385842
Adjusted R-squared	0.958340	S.D. dependent var	2.277847
S.E. of regression	0.464926	Akaike info criterion	1.382324
Sum squared resid	35.01724	Schwarz criterion	1.634522
Log likelihood	-107.6446	Hannan-Quinn criter.	1.484615
F-statistic	310.6683	Durbin-Watson stat	0.662750
Prob(F-statistic)	0.000000		

Table A. 31. Real interest rate vs. CO2 per capita and Renewable electricity consumption, upper middle income countries.

Dependent Variable: CO2
Method: Panel Least Squares
Date: 09/23/17 Time: 15:59
Sample: 1990 2005
Periods included: 16
Cross-sections included: 9
Total panel (balanced) observations: 144

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.295253	0.130416	9.931684	0.0000
REAL	0.000525	0.001186	0.442998	0.6585
REAL^2	-3.19E-05	3.55E-05	-0.898656	0.3705
RENEC	-0.011107	0.002080	-5.339119	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.882311	Mean dependent var	0.596305
Adjusted R-squared	0.872504	S.D. dependent var	0.359195
S.E. of regression	0.128256	Akaike info criterion	-1.189919
Sum squared resid	2.171353	Schwarz criterion	-0.942435
Log likelihood	97.67418	Hannan-Quinn criter.	-1.089355
F-statistic	89.96389	Durbin-Watson stat	0.625248
Prob(F-statistic)	0.000000		

Table A. 32. Real interest rate vs. CO2 per capita and Renewable electricity consumption, lower middle income countries.

Annex 3. Data Sources and Definitions.

The source of all data used in the analysis is World Bank database (WDI – World Development Indicators).

All data accessed and used in the regression analysis as of 08.09.2017.

CO2 emissions (metric tons per capita). Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring. *Source*: Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States. https://data.worldbank.org/indicator/EN.ATM.CO2E.PC

Real interest rate (%). Real interest rate is the lending interest rate adjusted for inflation as measured by the GDP deflator. The terms and conditions attached to lending rates differ by country, however, limiting their comparability. *Source*: International Monetary Fund, International Financial Statistics and data files using World Bank data on the GDP deflator. https://data.worldbank.org/indicator/FR.INR.RINR

GDP per capita (constant 2010 US$). GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2010 U.S. dollars. *Source*: World Bank national accounts data, and OECD National Accounts data files. https://data.worldbank.org/indicator/NY.GDP.PCAP.KD

Population density (people per sq. km of land area). Population density is midyear population divided by land area in square kilometers. Population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship--except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of their country of origin. Land area is a country's total area, excluding area under inland water bodies, national claims to continental shelf, and exclusive economic zones. In most cases the definition of inland water bodies includes major rivers and lakes. *Source*: Food and Agriculture Organization and World Bank population estimates. https://data.worldbank.org/indicator/EN.POP.DNST

Renewable energy consumption (% of total final energy consumption). Renewable energy consumption is the share of renewable energy in total final energy consumption. Source: World Bank, Sustainable Energy for All (SE4ALL) database from the SE4ALL Global Tracking Framework led jointly by the World Bank, International Energy Agency, and the Energy Sector Management Assistance Program. https://data.worldbank.org/indicator/EG.FEC.RNEW.ZS

Renewable electricity output (% of total electricity output). Renewable electricity is the share of electrity generated by renewable power plants in total electricity generated by all types of plants. Source: World Bank, Sustainable Energy for All (SE4ALL) database from the SE4ALL Global Tracking Framework led jointly by the World Bank, International Energy Agency, and the Energy Sector Management Assistance Program. https://data.worldbank.org/indicator/EG.ELC.RNEW.ZS

Alternative and nuclear energy (% of total energy use). Clean energy is noncarbohydrate energy that does not produce carbon dioxide when generated. It includes hydropower and nuclear, geothermal, and solar power, among others. Source: IEA Statistics © OECD/IEA 2014 (iea.org/stats/index.asp), subject to iea.org/t&c/termsandconditions.
https://data.worldbank.org/indicator/EG.USE.COMM.CL.ZS

Trade (% of GDP). Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product. *Source*: World Bank national accounts data, and OECD National Accounts data files. https://data.worldbank.org/indicator/NE.TRD.GNFS.ZS

Annex 4. Classification of countries according to the level of income.

According to the World Bank Atlas method, for the current 2018 fiscal year the countries are classified as in Table A.33 below.

Name of the Country	Income Category
Australia	High income
Chile	High income
Finland	High income
France	High income
United Kingdom	High income
Italy	High income
Japan	High income
Korea, Rep.	High income
Netherlands	High income
Norway	High income
Sweden	High income
China	Upper middle income
Colombia	Upper middle income
Costa Rica	Upper middle income
Ecuador	Upper middle income
Jordan	Upper middle income
Mauritius	Upper middle income
Malaysia	Upper middle income
Panama	Upper middle income
Thailand	Upper middle income
Venezuela, RB	Upper middle income
South Africa	Upper middle income
Bangladesh	Lower middle income
Bolivia	Lower middle income
Cameroon	Lower middle income
Congo, Rep.	Lower middle income
Honduras	Lower middle income
India	Lower middle income
Kenya	Lower middle income
Nigeria	Lower middle income
Philippines	Lower middle income

Table A. 33. Country classification according to the income level. *Source*: World Bank, https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups