# THESISES OF THE DOCTORAL (PhD) DISSERTATION

## ENVIRONMENT, GROWTH, FINANCE.
## AN EMPIRICAL ANALYSIS OF THE ENVIRONMENTAL KUZNETS CURVE HYPOTHESIS


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# 1. RESEARCH BACKGROUND, GOALS AND HYPOTHESES

The choice of my research subject goes back to 2011. At that time, I started to study the pro-environmental behavior and the consumer habits of the future generations and how important the protection of the environment is in economic decision-making. The questionnaires filled in by young university students showed an increase in consumer preferences, pro-environmental behavior and that several areas and consumer decisions affect the condition of the natural environment. A long-term investment or even an instant purchase might be definitive elements for the sustainability chances of the future generations, whether they will have the chance to enjoy the consumer goods and the natural resources as much as the generations of our time do.

During my PhD studies, I was doing an in-depth study of the effects of financial development on pollutant emission, which can be measured with econometric methods. I was also studying the effects of such macroeconomic processes which cannot be ignored in relation of the environment and growth, e.g. energy, finance and urbanization. The methodology of this thesis is based on the study of the Environmental Kuznets Curve (EKC) hypothesis, which can promote the exploration of the correlations between economic growth and pollution. This hypothesis is able to show the relationship between the per capita national income and an environmental indicator, which is mostly the CO2 emissions.

The environmental Kuznets curve hypothesis states that every economy has an optimal level reaching the income turning point in which rising economic growth takes place with declining CO2 emissions. The inverse U-shaped relationship to be represented in this way, higher income can reduce CO2 emissions in the long run. With an increase in national per capita income, more intensive energy production in the new production phase will lead to higher CO2 emissions due to the overuse of obsolete technology, and a higher income level will reduce the environmental impact as the economy grows due to technological and efficiency improvements.

The results of the environmental Kuznets curve hypothesis may show a new angle on the relationship between a country’s development stage, the income level and the long-term decisions related to pollutant emission (mostly CO2). Every nation aims to get beyond the turning point of the environmental Kuznets curve hypothesis because when this turning point is reached, the economic growth brings improvement in the natural environment. The study of growth and environment helps to devise the short-term and long-term energy strategies and harmonize the economic and environmental measures.

The goal of this thesis is to confirm the relationship between economic growth and pollutant emission for the longest available time interval by modeling the Hungarian environmental Kuznets curve. To accomplish this, all of the involved macroeconomic processes for the period between 1982 and 2016 should be identified. This thesis is the first one to examine the realization of the environmental Kuznets curve exclusively in Hungary. Understanding the relationship between economic growth and CO2 emissions may help to get more accurate forecasts by revealing the cause-effect relationships of the variables. The factors of the Hungarian environmental Kuznets curve include not only growth, pollution but, uniquely, the role of electricity consumption, financial development and urbanization has also been defined. The thesis emphasizes the peculiarities of urbanization in Hungary which is an innovation both methodologically and professionally. Unlike in the international literature, the impact of urbanization is measured another way.

In this thesis, the environmental Kuznets curve reveals (1) whether the attainment of the economic growth goals have brought the improvement or the degradation of the environmental conditions in Hungary during the past decades and (2) whether the turning point propelling the economy into a more mature stage may be reached. Since every economy operates in a complex system, the impacts of other social-economic and environmental processes may not be ignored in this case. Therefore, by taking the recommendations of the literature into account, the author performed an expanded test of the hypothesis by measuring (3) the use of electricity, as the most widely used indicator, in relation to financing, (4) the role of financial development in the sustainability of towns and cities and (5) the function of urbanization in the trends of CO2 emissions during the past decades. The following specific goals have been linked to the five general goals:

- to compare the effects of the pollutant emission factors and the extent of these effects;
- to examine how the shocks occurring in the factors of pollutant emission (economic growth, electricity consumption, urbanization and financial development) affect pollutant emission;

- to study the relationship between electricity consumption and economic growth to prove the environmental Kuznets curve hypothesis;
- to identify the factors affecting the cause-effect relationship between electricity consumption, $CO_2$ emissions and economic growth;
- to measure the role of financial development in pollution;
- to identify the role of urbanization in pollutant emission.

In this thesis, the following hypotheses have been stated in a line with the strategic and general goals of the thesis:

H1a: In case of Hungary, the environmental Kuznets curve has been proven, the relationship between $CO_2$ emissions and economic growth is an inverted U-shape.

H1b: Taking macroeconomic processes into account in the analysis, the environmental Kuznets curve has been proven, the relationship between $CO_2$ emissions and economic growth is an inverted U-shape in case of Hungary.

H2: Economic growth is currently happening alongside a decreasing level of $CO_2$ emissions.

H3: In Hungary, there is a causality relationship between economic growth and $CO_2$ emissions. The direction of causality is from economic growth to $CO_2$ emissions.

H4: Economic growth and financial development play the most significant role in $CO_2$ emissions.

H5: Electricity consumption can be used as an indicator of development, therefore, not only economic growth but electricity consumption also has a significant impact on pollutant emission.

H6: The decreasing electricity consumption might forecast a decline in economic growth.

H7: Urbanization, that is, the growth of the number of towns and cities, decreases the per capita $CO_2$ emissions.

H8: It is empirically proven that the role of financial development increases $CO_2$ emissions due to the growing number of lending opportunities and stock exchange opportunities.

## 2. DATA AND APPLIED METHODS

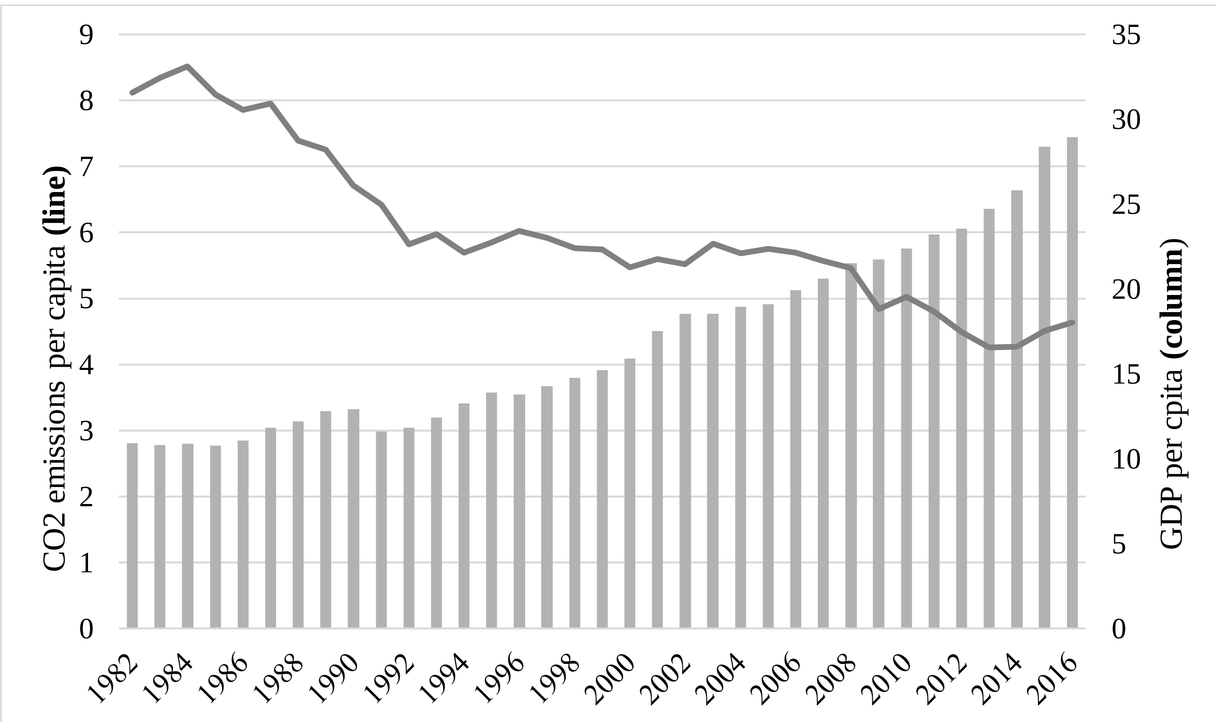
During my research I carried out secondary research, the processing of the database and the examination of the theses were done using modern time series econometric methods.

The subject of the analysis is the testing of the environmental Kuznets curve hypothesis for Hungary and the effect of the curve's macro-processes in the period of 1982-2016. The hypothesis of the Kuznets curve in the environment states that the economy is in an optimal "state" with the occurrence of an income turning point in which increasing production takes place with declining emissions. The question is when will the economy reach this turning point when will the two processes split (decoupling), as this will create a certain level of economic growth for environmentally friendly production when natural environment can be improved and environmental goals can be met by economic growth.

*Figure 1* shows that the decoupling of economic growth (GDP / capita) and CO2 emissions (tons /capita) may have taken place in Hungary in the 1990s, but an econometric analysis is needed to test the environmental Kuznets curve hypothesis.

**Figure 1**

**Per capita CO2 emissions and per capita GDP in Hungary between 1982 and 2016**




* 1,000 USD at 2011 exchange rates

*Source: Own editing based on World Bank (2018) and GGDC (2018)*

There were big ups and downs in the development of the Hungarian economy. Beginning in the 1980s, the oil crisis caused a slowdown in growth, and then production declined due to the loss of foreign markets. More than a third of GDP was still generated by industry at the time, and now a structural transformation has taken place: two-thirds of GDP is accounted for by the service sector. With the decline of the industry, energy production has fallen and there has been a noticeable change in the volume of greenhouse gas emissions: the fall in CO2 emissions, which is responsible for 70% of greenhouse gases since 2000, has also been driven by fossil fuels (*Figure 1*).

The time series data used as input to the analysis come from several domestic and international sources to provide sufficiently long-term data set for the analysis *(Table 1).*

**Table 1**

**Databases and sources used for analysis**

| **Variable** | **Unit** | **Source** |
| --- | --- | --- |
| Carbon-dioxide emission (CO2) per capita | tons | World Bank (2018) |
| Economic growth per capita | 1,000 USD (at the 2011 exchange rate) | GGDC* (2018) |
| Electricity consumption per capita | 1,000 kWh | MEKH** (2018) |
| Urbanization | number of cities | KSH*** (2016) |
| Financial development (index) | range of 0-1 | IMF (2020) |

* *Penn World Table from Groningen Growth and Development Centre*

** *The Hungarian Energy and Public Utility Regulatory Authority*

** *Hungarian Central Statistical Office*

In this thesis, I assume lately effects due to the time required to respond in the impact of economic growth, electricity consumption, urbanization, and financial development on the CO2 emissions. The impact of economic variables is rarely immediate because it takes time for consumers, producers and other actors in the economy to react to change, so it is recommended to formulate time-series econometric models with delays in such cases. Since both economic growth and its quadratic and cubic forms are included in the environmental Kuznets curve models, I chose the ARDL modeling framework, which has the advantage of estimating the problems arising from multicollinearity with delayed effects.

The basis of the environmental Kuznets curve, the relationship between CO2 emissions and economic growth, can be described by regressions, which can be gradually expanded with a quadratic and then cubic term of economic growth to explore the shape of the curve. The specifications examined in the dissertation are the following for the basic model:

$$CO2_t = f(GDP_t) \tag{1}$$

$$CO2_t = f(GDP_{t,} GDP_t^2) \tag{2}$$

$$CO2_t = f(GDP_{t,} GDP_t^2, GDP_t^3) \tag{3}$$

where $CO2_t$ is the CO2 emissions, $GDP_t$ is the economic growth, $GDP_t^2$ is the quadratic economic growth and $GDP_t^3$ is the cubic economic growth. All variables are per capita form. Since many macro-processes may play a role in the development of CO2 emissions, I tested the environmental Kuznets hypothesis in an extended model framework, so that in addition to the linear, quadratic and cubic terms of economic growth, electricity consumption, urbanization and financial development were included:

$$CO2_t = f(GDP_t, GDP_t^2, GDP_t^3, \mathrm{E}C_t, URB_t, FD_t) \tag{4}$$

where $CO2_t$ is the CO2 emissions, $GDP_t$ is the economic growth with level, quadratic and cubic form, $\mathrm{E}C_t$ is the electricity consumption, $URB_t$ is the urbanization and $FD_t$ is the financial development. I converted the data to a value per capita and their natural logarithm:

$$lnCO2_t = \beta_0 + \beta_1 \ln GDP_t + \beta_2 \ln GDP_t^2 + \beta_3 lnGDP_t^3 + \beta_4 \ln \mathrm{E}C_t + \beta_5 lnURB_t + \beta_6 lnFD_t + \varepsilon \mathrm{t} \tag{5}$$

where $\beta_0$ is the intercept, $\beta_1 \ldots \beta_6$ is the coefficients of the explanatory variables, $\varepsilon_t$ is the error term with normal distribution.

The shape of the environmental Kuznets curve can be determined from the signs of the $\beta$parameters and the significance of the coefficient (Table 2). If combined significant fulfillment of two inequalities $\beta_1 > 0$ and $\beta_2 < 0$, means the inverse U-shape of the environmental Kuznets curve. The environmental impact of the income shock can be tested by including the cubic shape of economic growth. For example, if the cubic term of economic growth $\beta_3 > 0$, the curve assumes an N-shape, and all opposite values of the betas result in the inverse N-shape. If $\beta_1 = \beta_2$, there is no link between income and environmental degradation and CO2 emissions are independent of economic growth.

**Table 2**

**The shape of the environmental Kuznets curve**

| **Inverted U-shape** | **U-shape** | **N-shape** | **Inverted N-shape** | **Monotonously increasing** | **Monotonously decreasing** | **No linkage** |
|---|---|---|---|---|---|---|
| $\boldsymbol{\beta_1 > 0}$<br>$\boldsymbol{\beta_2 < 0}$<br>$\boldsymbol{\beta_3 = 0}$ | $\beta_1 < 0$<br>$\beta_2 > 0$<br>$\beta_3 = 0$ | $\beta_1 > 0$<br>$\beta_2 < 0$<br>$\beta_3 > 0$ | $\beta_1 < 0$<br>$\beta_2 > 0$<br>$\beta_3 < 0$ | $\beta_1 > 0$<br>$\beta_2 = \beta_3 = 0$ | $\beta_1 < 0$<br>$\beta_2 = \beta_3 = 0$ | $\beta_1 = \beta_2 = \beta_3$<br>$= 0$ |

*Source: Own compilation*

The explanation of the inverted U-shape of the environmental Kuznets curve is already well known. The correlation is more pronounced in developed countries, although only two-thirds of the Member States in the European Union have managed to cross the income point. The simple U-shape is the case to avoid when economic recovery increases CO2 emissions, typical of developing countries, countries where agriculture is dominant, or industrial technology is outdated.

The N-shape, after a full examination of the hypothesis, gives a picture of the separation after the cubic models: although economic growth has reached its target and pollution has decreased, due to an economic shock, CO2 emissions and income together increase in the second stage. The re-intensification of pollution between the initial and second stages of the economy can be explained by a slowdown in technological development and a halt in the spread of innovation, but in such a case the relaxation of pollution regulations and rules may also play a role, but in such a case, the relaxation of pollution regulations and rules may also contribute, while the inverse N-shape is the favorable response of emissions to a shock effect.

Due to the properties of the studied time series (mixed stationarity properties, structural breaks, lags), traditional econometric modeling cannot be used, so I chose the ARDL modeling framework. I checked the applicability conditions of the ARDL model, so (1) the normality of the error terms of the time series and (2) the stationarity properties of the time series. Then, unit root testing was performed the augmented Dickey-Fuller (ADF) unit root test and I expanded the checking using the Zivot-Andrews structural-break unit root test

(ZA). The pre-results revealed the applicability of the ARDL model structure. The ARDL bounds test has several econometrics advantages over other cointegration tests. It is applicable when variables have mixed stationarity properties and suitable for small sample size data providing better estimates for small sample data.

ARDL bounds testing approach was used to find out the relationships (cointegration) between the examined variables. After founding evidence for cointegration between variables, the next step is estimating the long-run coefficient of the ARDL model. Having obtained the value of the long-run coefficient, the cointegrating vector of the ARDL model is reparametrized to form an error correction mechanism (ECM). The reparametrized result provides short-run dynamics (i.e. traditional ARDL) and the long-run relationship of the variables of a single model. A negative and significant value of the error correction term (ECT) is expected to support long-run relationship.

Diagnostic tests indicate the robustness of the estimated coefficients. Serial independence and normal distribution of error terms are both crucial assumptions in the ARDL Bounds testing methodology. This study employed the Breusch–Godfrey Serial Correlation LM test for testing serial independence, White test for testing heteroscedasticity, and the Jarque–Bera test for checking normality of the error terms in the model equations. The stability of the model can be deduced from the long-run results based on the cumulative sum of recursive residuals (CUSUM) and cumulative sum of recursive residuals of squares (CUSUMQ) in the graphical representation of the figures.

The conventional Granger causality test based on ECM cannot eliminate bias and spurious results because most economic time series do not have the same stationarity properties.Toda and Yamamoto developed a test to reveal Granger causality regardless of the stationarity properties of the variables. However, a shortcoming both causality tests is that they do not show the relative strength of the causal effects. The result of the variance decomposition revealed the contribution of the macro-processes to CO2 emissions, namely how much of the variance in a given variable could be explained by another variable. The generalized impulse response functions express the dynamic responses of a variable to shocks caused by its own and other variables, the moving of the volatility of each variable and the effect on other variables.

## 3. THE MOST SIGNIFICANT CONCLUSIONS OF THE THESIS

The goal of this thesis is to test the environmental Kuznets curve hypothesis and to determine the shape of the curve. Six models have been created to test the environmental Kuznets curve hypothesis. Basically, these models can be divided into two groups: in the first group, only the time series of the classic environmental Kuznets curve hypothesis (economic growth and CO2 emissions) were involved. The basic model can be used to examine the shape of the curve but it does not take the emission impacts of other, non-income-related macroeconomic processes into account. The second group, which includes expanded models, tests a more reasonable, extended form of the hypothesis by adding indicators recommended by the literature: electricity consumption, urbanization and financial development.

The following theses have been formed from the strategic and general goals:

> ***H1a. The EKC hypothesis has been proven in case of Hungary, the relationship between CO2 emissions and economic growth is an inverted U-shape.***
>
> ***H1b: Taking macroeconomic processes into account in the analysis, the environmental Kuznets curve has been proven, the relationship between CO2 emissions and economic growth is an inverted U-shape in case of Hungary.***

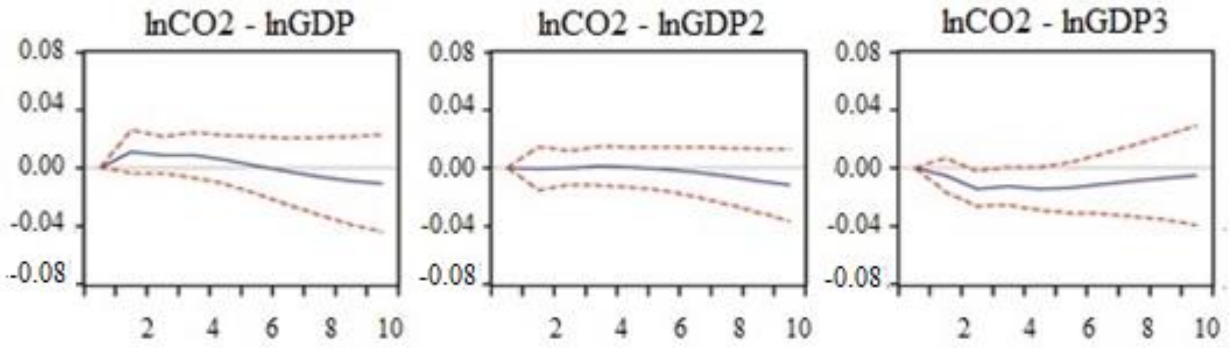
This hypothesis has been partly proven. Although, the existence of the environmental Kuznets U-shape curve hypothesis was proved for Hungary, but extending the calculation of point 3 of the curve, an inverted N-shaped environmental Kuznets curve was confirmed for Hungary.

The results confirm that the processes of economic growth and CO2 emissions are closely related and there is a causality relationship between them. The quadratic model proved an inverted U-shaped relationship between economic growth, its squared value and CO2 emissions. However, the explanatory power is quite weak and all the other macroeconomic processes were omitted. The examination of a common model became reasonable by including the cubed value of economic growth. However, the validating tests of the model fell short. The cubed model including electricity consumption, urbanization and financial development proved to be valid and the significance of the negative, positive and negative value of economic growth resulted in an inverted N-shaped environmental Kuznets curve.

The conclusions for Hungary about the shape and the existence of the environmental Kuznets curve, the inverse N-shape, are also confirmed by a higher-level econometric method, the shape of the impulse response functions. The impulse response function is an alternative to the variance decomposition showing how long and to what extent the dependent variable (here: CO2 emissions) responds to the shock in the independent variable (here: economic growth) (*Figure 2*).

**Figure 2**

**Impulse response functions for CO2 emissions representing the inverted N-shaped environmental Kuznets curve**




*Source: Own calculation*

*Figure 2* shows that the response of CO2 emissions to economic growth is declining. After a peaking period at the beginning of the period, the curve begins to decline, which may suggest that, over time, for example, technological innovations and efficiency improvements will bring about a reduction in CO2 emissions. The function of quadratic economic growth is stagnated, while that of cubic economic growth is declining to declining by the end of the period. If we look at the three impulse responses representing their square and cubic members of economic growth, the first and last descending stages may represent the inverted N-shaped environmental Kuznets curve phenomenon.

> ***H2. Economic growth is currently happening without increased environmental pressure, that is, with a decreasing level of CO2 emissions.***

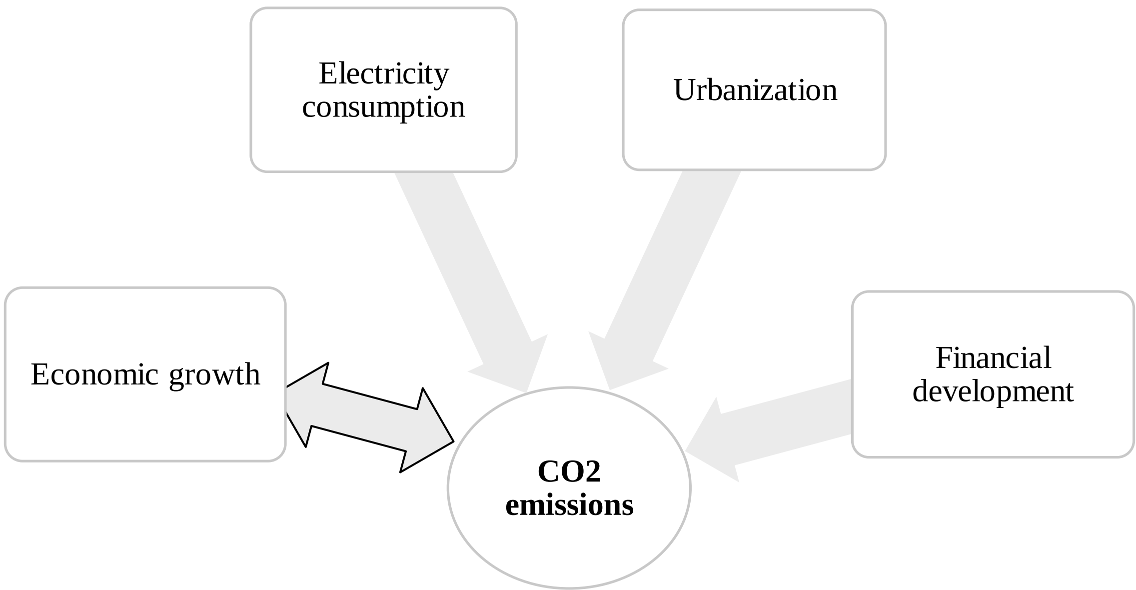
This hypothesis has been proven. According to the calculations, economic growth does not threaten the condition of the environment. The expanded cubed ARDL model shows that Hungary has passed the income level above which economic growth does not worsen the condition of the environment but improves it. A new upward trend in the income level would not change this either as suggested by the inverted U-shaped curve. However, it is known that the examined macroeconomic processes increase $CO_2$ emissions and if we want the inverted U-shaped environmental Kuznets curve to remain valid in the long term, the factors affecting $CO_2$ emissions and the relationships between them must be taken into account when the climate and energy policy goals are set.

***H3. In Hungary there is a causality relationship between economic growth and $CO_2$ emissions. The direction of causality is from economic growth to $CO_2$ emissions.***

This hypothesis has been partly proven. The causality relationships were estimated with the Toda-Yamamoto method and with the use of the Wald statistics. The result shows that the causality relationship between economic growth and $CO_2$ emissions have been proven *(Figure 3).*

**Figure 3**

**Causal relationships among the examined macro-processes ***




* ⇔ two-way causal relationship; ⇐ one-way causal relationship

*Source: Own calculation*

There is a two-way relationship between these two examined variables, that is, each process has a definite impact on the other one. We might have a better forecast regarding either economic growth or $CO_2$ emissions if the past data of the other process is used in the estimates. This same statement is valid for both the short term and the long term, there is a two-way relationship between economic growth and $CO_2$ emissions. Therefore, it is necessary to harmonize the growth and environmental policies if (1) the preservation and improvement of the environment is important while economic growth is withheld and if (2) economic growth and development is important without the decay of the environment.

***H4. Economic growth and financial development play the most important role in $CO_2$ emissions.***

This hypothesis has been partly proven. Almost half of the variances of $CO_2$ emissions can be explained with earlier processes of the variable itself. Economic growth contributes to $CO_2$ emissions above all, electricity consumption is the second factor. The contribution of urbanization and financial development is at a rather low level compared to the previously mentioned factors. Regarding the extent of the impacts of the variables, the results are consistent with the regressive results of the ARDL models.

Based on the above-mentioned results, the achievement of the emission goals should be planned through the processes which are in a causality relationship with $CO_2$ emissions.

Financial development has a relatively small impact on $CO_2$ emissions. However, it is important to note that if the impact of financial development is slight compared to the other factors, it is significant in all of the valid models.

***H5. Electricity consumption is a good indicator of development, therefore, not only economic growth but electricity consumption also has a significant impact on pollutant emission.***

This hypothesis has been proven. Economic growth can be found in all of the models and this factor has a significant role in all three valid models. The impact of this factor is not unambiguous because it has a plus and a minus sign but these values remain always significant making the models valid for testing the environmental hypothesis and confirming that economic growth has a significant role in emission. A 1% change in electricity consumption has a significant impact on $CO_2$ emissions. If electricity consumption increases by 1%, the long-term increase of $CO_2$ emissions is 0.9%, while the short-term increase is 0.8% at a 5% significant level ceteris paribus.

This result implies that the energy efficiency is not at a high level in Hungary yet. If welfare is accompanied by the increase of electricity consumption, it is an increased burden to the natural environment. For the time being, the efficacy of the energy-efficiency programs and the campaigns promoting the environmentally conscious behavior cannot be confirmed either in the short term or the long term. The data currently show that the decrease of $CO_2$ emissions can only occur if energy consumption decreases. The specific electricity consumption might be reduced with the purchase of modern and new machines and equipment but the bouncing effect may make the protection of the environment more difficult.

***H6. The decrease of electricity consumption might predict the decline of economic growth.***

This hypothesis has not been proven. The processes showing the cause-effect relationship promote the forecast mutually. Since electricity consumption and economic growth are in a causality relationship and the direction is from electricity consumption to economic growth, these processes are not only correlated but they also move together and a change in either of them has an impact on the other one. This means that if electricity consumption is taken into account in the forecast of economic growth, we can get more accurate results rather than just estimating from earlier data.

If there is a decline in economic growth, a decline occurs in electricity consumption too. In fact, the question is whether it is possible to grow by using less electricity. The result of the causality test shows that the answer is negative.

***H7. Urbanization, that is, the growing number of towns and cities reduces the per capita $CO_2$ emissions.***

This hypothesis has not been proven. It is proven that the expansion of urbanization affects $CO_2$ emissions but urbanization cannot reduce the emission rate in any of the cases. The result shows that the growing number of towns and cities increases $CO_2$ emissions both in the short and the long term. The extent of the impact is similar in case of the short and the long term but it is significantly smaller than the impact of economic growth and electricity consumption. The coefficient of urbanization is significant only in the long term, the short-term impact cannot be considered to be general.

Based on these results, the results found in the literature can be refuted since this thesis failed to prove that urbanization would have a positive impact on emission in a medium-developed country like Hungary. The economies of scale can explain that the more people live in a town or a city, the less the per capita energy consumption is and this can be seen in the emission data too. Typically, these indicators increase together with the expansion of towns and cities in the less developed regions.

***H8. It can be empirically proven that the role of financial development, with the expansion of lending opportunities and stock exchange opportunities, increases CO2 emissions.***

This hypothesis has been partly proven. Financial development increases CO2 emissions only in the short term, in the long term CO2 emissions are reduced. The impact is significant in both cases. The explanation for this result may be this: in the short term, the accessibility of the financial system or the expansion of the lending opportunities may have a shocking impact on CO2 emissions either for the households or the whole economy. As the financial services become more widespread, more and more people take advantage of the opportunities and they buy new and modern energy-efficient machines or invest in green portfolios which have long-term positive impacts. In this thesis, the beneficial impact of financial development could be proven. The expansion of financial products and the better accessibility of financial services may contribute to a wider availability of products and services which may be favorable to the preservation and improvement of the environment.

This thesis has answered several questions, however, the results should be treated with the consideration of the limits of the environmental Kuznets curve and the conclusions must be drawn. This model, as emphasized in the chapter on methodology, is sensitive to delays as well as to the period of the analysis and its length and the good fit of the parameters may be caused by mathematical evidence.

## 4. THE NEW AND NOVEL RESULTS OF THE THESIS

This thesis has determined the factors which affect CO2 emissions, those factors which contributed to the increase of the concentration of CO2 in the atmosphere in Hungary between 1982 and 2016. The relationships between these factors and the cause-effect impacts, especially the correlation between economic growth and CO2 emissions, show that the environmental Kuznets curve hypothesis has been proven. The analysis has revealed the role, contribution and the relative extent of economic growth, electricity consumption, urbanization and financial development in CO2 emissions.

This thesis contributes to the literature with the following new and novel results:

1. **The testing of the environmental Kuznets curve hypothesis using the ARDL model provides reliable results**. By increasing the number of delays, the model properly handles the auto-correction in a model where the variables have a mixed order of integration.

2. **In Hungary, the environmental Kuznets curve has an inverted N-shape** between economic growth and CO2 emissions in the long term. The short-term curve has an inverted U-shape.

3. **All the macro-process** – economic growth, electricity consumption, urbanization and financial development – **have a significant role and causal relationship** for the inverted N-shape of the environmental Kuznets curve.

4. **Based on the macro-process, better forecast can be prepared for the future CO2 emissions** if the past data of economic growth, electricity consumption. urbanization and financial development are also taken into account.

5. **There is a two-way relationship between economic growth and $CO_2$ emissions in Hungary.** Thus, the growth and environmental policies need to be harmonized if (1) it is important to preserve and improve the environment without slowing down the growth and if (2) it is important to boost the economy without the decay of the environment.

6. Responding to an income shock, **CO2 emissions get back to a balanced state after 4 or 5 years.**

7. $CO_2$ emissions are increased by electricity consumption and urbanization. Out of the macroeconomic processes, **only financial development can decrease the emission**. Thus, the role of the green finances should be emphasized in the research and financing practices.
8. **Electricity consumption is the only macroeconomic process where the pollutant emission will not decline in the long term** if the consumption increases. Therefore, the energy and environmental policies have to find an emission-reducing way of electricity consumption in decision-making and practical implementation. This is necessary if we want to maintain the long-term beneficial impacts of the inverted N-shaped environmental Kuznets curve.
9. **In Hungary, the change in the number of towns and cities is the proper indicator to measure urbanization** rather than the rate of the urban population within the total population, which is applied in the literature.

I do hope that all of the above listed results will help us to know more about the linking points of the environmental-income processes in Hungary and the regulation will be more efficient and it can be applied in a more expedient way to harmonize the economic and environmental goals on the way to a (more) sustainable future.

## 5. THE PRACTICAL IMPLEMENTATION OF THE RESULTS

The environmental Kuznets curve is one of the most important empirical results of environmental economics. The result coming from the proof of the environmental Kuznets curve hypothesis revealed that in Hungary the long-term relationship between economic growth and CO2 emissions do not show an inverted U-shaped curve for the period of 1982 to 2016 but it is an inverted N-shaped curve. This means that the CO2 emissions started to decrease at an early stage but as it reached the first income turning point, it started to increase until the second turning point and then it started to decrease again. The increase in CO2 emissions is temporary in the long term.

In order to move on a course which supports growth and focuses on the environment, an economy should reach the mature stage, it should grow up to be able to increase production and well-being by taking the environmental goods into account. The goal of the economies is to realize the environmental Kuznets curve as soon as possible since the inverted U-shape of the curve also implies that the growth is expensive and the expenses are paid by the destruction of the environment.

The Hungarian results of the environmental Kuznets curve may throw new light on the relationship between the country's development stage and national income level in relation to the long-term decisions related to CO2 emissions. With the use of the environmental Kuznets curve, we obtain new information on the interaction or the cause-effect correlation of the macroeconomic processes. The environmental Kuznets curve did not only reveal the impact of national income and economic growth on pollutant emission, but the expansion of the curve with the growth-pollution model also helped to identify the impacts of other macroeconomic processes involved in pollution.

We obtained more information about the energy efficiency measures, the impacts of urbanization the consequences of urban expansion on emission. We also got some information about the environment-degrading or environment-improving role of financial development, which is an important factor in investment and development and measures mainly the accessibility of bank loans. In other words, the environmental Kuznets curve hypothesis identified all the macroeconomic process impacts which might directly or indirectly affect the condition of the natural environment. For instance, it turned out that it is worth paying more attention to the technical solutions which use energy-saving and energy-efficient electricity in order to reduce $CO_2$ emissions since the increase of living standards is a factor that increases $CO_2$ emissions.

This thesis measured the impacts of an important but less widespread factor: the development level of financial systems. The literature does not show a clear result in relation to the impacts of expanding bank loan opportunities, the expanding stock exchange role and the expansion of green financial portfolios. The economy-boosting impacts of financial development might encourage not only investments but it might also increase the living standards as it encourages overconsumption. According to the results, financial development has a favorable impact on $CO_2$ emissions, unlike electricity consumption and urbanization, financial development decreases $CO_2$ emissions in the long term.

This thesis revealed and analyzed such macroeconomic correlations which might help to harmonize the sustainability goals of the policies in the various sectors. The results coming from the cause-effect correlations of the macroeconomic processes may improve the predictions since the proof of the causality relationship, we can have more accurate forecasts for a time series the changes of the related variables are also taken into account. For example, one important conclusion is that a better forecast can be made regarding the future changes of $CO_2$ emissions if the past data of economy growth, electricity consumption, urbanization and financial development are also taken into account.

The conclusions of this thesis suggest that Hungary has to find a way to reduce emission in electricity consumption and urbanization through the various energy and environmental policies in order to maintain the favorable impacts of the inverted N-shaped Kuznets curve in the long term. Hungary has reached a level of economic growth which gives a chance to improve the condition of the natural environment and this is supported by the level of financial development as well. It is only up to us now whether we will make use of this opportunity well.

# 6. PUBLICATIONS WRITTEN IN THE SUBJECT OF THE THESIS

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**List of publications related to the dissertation**

Articles, studies (9)

1. **Németh-Durkó, E.**, Hegedűs, A.: Climate Change in the Capital Markets: A Study of Actively Managed Green Bond Funds.
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7. **Németh-Durkó, E.**, Huzsvai, L., Csipkés, M.: A magyarországi községekben élő háztartások villamosenergia fogyasztásának modellezése.
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13. **Németh-Durkó, E.**, Petróczy, D. G.: Reálopció: Napelem telepítés.
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