Energy Consumption, CO_2 Emissions and Economic Growth

Sweden's Case

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Abstract

The main purpose of this study is to examine the causal relations between energy use, CO_2 emissions and economic growth for Sweden. Vector Error Correction model with annual data from 1970 to 2016 has been used in order to determine potential causality between the variables. The empirical findings indicate that in the long-run, causality relationship between energy consumption, CO_2 emissions and economic growth cannot be rejected and it is bidirectional. This means that energy is a determining factor for economic growth in Sweden and that applying policies in order to reduce the CO_2 emissions has slowed down economic growth in Sweden. This finding is consistent with the Feedback Hypothesis. But in the short-run no causality was found between energy and economic growth. According to Granger causality test results, bidirectional causality between CO_2 emissions and energy consumption cannot be rejected in the short-run. Variables' trends show that in the period under study, energy consumption and economic growth have moved in the same direction; meaning that higher energy consumption has led to higher economic growth. At the same time, lower CO_2 emissions have been accompanied by higher economic growth. There is also short-run causality running from capital to economic growth according to VECM results. It can be suggested to the policy makers that in order to maintain economic growth and reduce environmental degradation, energy consumption should be shifted gradually from nonrenewable sources to renewable ones so to avoid decrease in economic growth and ensure lower levels of CO_2 emissions in the long-run.

Keywords: economic growth, energy consumption, CO_2 emissions, Vector Error Correction model

Contents

Introduction

Importance of Research

Energy is one of the most important production factors along with labor and capital. Throughout history, larger and larger proportions of energy have been used to create economic growth. But concerns about environmental degradation and production inefficiency leading us to an unsustainable path, were not exposed to global discussion until twentieth century. It was the United Nations Conference on the Human Environment in Stockholm in 1972 which brought up the notion of sustainable development and resulted in the creation of the United Nations Environment Program (UNEP) and the United Nations Development Program (UNDP).The link between growth and the environment has received much more attention recently because of the rapidly expanding empirical literature on the relationship between per capita income and pollution. This literature, known as the Environmental Kuznets Curve (EKC) literature, has been enormously influential (Brock and Taylor, 2004).

All over the world there are concerns about how the implementation of policies supporting environmental sustainability can affect the economy and growth. According to the environmental Kuznets curve hypothesis at higher levels of development structural change towards information-intensive industries and services coupled with increased environmental awareness enforcement of environmental regulations, better technology and higher environmental expenditures result in leveling off and gradual decline of environmental degradation (Panayotou, 1993). The concept of “decoupling” is also introduced into economics which refers to the ability of an economy to grow without corresponding increases in environmental pressure.

Sweden has been among the top-ranking countries in terms of sustainability and has set the goal of eliminating fossil energy consumption. Sweden was one of the first countries to introduce a CO_2 tax as well as an extensive environmental tax reform. According to Shmelev and Speck (2018) the technological innovation in the form of development of nuclear and hydro energy as well as higher oil prices have played a significant role in reducing CO_2 emissions in Sweden. Moreover, Sweden’s electricity imports from other countries have contributed positively towards reducing CO_2 emissions. Despite these finding, important policy questions are raised which focus on the effectiveness of environmental policy tools. Economic factors can partly explain the reason behind obstacles faced by the policy makers in influencing the decisions made by players in the economy. Therefore a key question is whether increased energy supply leads to economic growth, or whether economic growth leads to greater energy demand.

Thus the present research tries to investigate the relationship between energy and economic growth in Sweden to help improve sustainability policies. Depending on the type of relationship (causal or non-causal) and its direction in short-run and long-run, the effects of implementing different policies (targeting energy-saving and emission reduction) on economic growth could be foreseen.

Research Questions

The main question of this study is whether there exists causal relationship between energy consumption, CO_2 emissions and economic growth in Sweden and if there is such causal relationship between these variables, what is its direction. Are the answers the same for long-run and short-run?

Data

All data has been collected from World Bank database for the period 1970-2016. Constant 2010 US$ prices have been considered. Annual data is used in this study.

Method

In order to answer the research question, energy consumption and CO_2 emissions trends are studied and causality relationships between the forenamed variables are tested using Vector Error Correction Model.

Main Results

There is a long-run causality running from energy use, CO_2 emissions to economic growth. In the short-run there is causality between energy and economic growth. Accordingly policies with orientation to saving energy could have negative impact on economic growth in Sweden.

Contribution

The goal is to deliver a better understanding of energy’s role in Sweden’s economic growth and thus have a contribution in designing better sustainability policies.

Thesis structure

In the following, first “Literature Review” is presented which gives a brief report on the previous studies within the field of this study with their main results and are categorized according to the hypothesis they confirm. Afterwards, a “Theoretical Background” is stated, describing the macroeconomic theory and model which this research is built on. In the “Methodology” section, the econometric method chosen for answering the research question is introduced along with the data used for this study. The variables trends and model specification is also presented in this part. Outputs of the estimation are reported in “Empirical Findings” section accompanied by the tests for assessing the model. Overall “Conclusions” are drawn in the last section which also summarizes the thesis. “References” and “Appendix” including descriptive results of the tests are presented in the end.

Literature Review

The economics literature examining the link between growth and the environment is huge; it covers much of the theory of natural resource extraction, a significant body of theory in the 1960s and 1970s on resource depletion and growth; a large literature in the 1990s investigating the implications of endogenous growth theories; and a new and still growing literature created in the last decade examining the relationship between pollution and national income levels. The literature linking growth and pollution levels started with very early work in the 1970s by Forster (1973), Solow (1973), Stiglitz (1974), Brock (1977) and others, and culminating in the more recent work investigating the Environmental Kuznets curve such as Stokey (1998), Aghion and Howitt (1998), or Jones and Manuelli (2001). In the following first the body of literature investigating the relationship between energy consumption and economic growth is summarized along with corresponding studies. Afterwards the focus would be on the relationship between CO_2 emissions and economic growth through main studies done in this field.

Energy Consumption and Economic Growth

The empirical findings on the relationship between energy consumption and economic growth are inconsistent and suggest different policy implications. The reason for this can be found in the application of different econometric approaches: correlation analysis, regression analysis, bivariate causality, unit root tests, multivariate cointegration, panel cointegration, VECM model and the innovative accounting approach for detecting the direction of causality among variables (Chontanawat, Hunt, & Pierse, 2008).Payne (2010) claims that apart from applying various econometric approaches, possible reasons for the lack of the consensus lie in the heterogeneous climate conditions, different consumption patterns, structure and level of the economic growth of the sample country. But all the findings revolving around the relationship between energy consumption and economic growth can be categorized into four types of causal relations as the following:

1. **Growth Hypothesis**

This hypothesis points out a unidirectional causality from energy consumption to economic growth. According to this hypothesis energy consumption plays a significant role (positive or negative) in economic growth, directly or indirectly through a production process as a complement to labor and capital. In other words, energy use is either the cause or the facilitator of economic growth. The policy implication of this hypothesis suggests that the orientation to saving energy could have a negative impact on economic growth.

As an example Obradović and Lojanica (2017) examined the causal relations between energy use, CO2 emissions and economic growth for Greece and Bulgaria using "Vector Error Correction model". Their empirical findings confirm the growth hypothesis in the long run but in the short run no causality between energy and economic growth is foundfor either of the countries. Tiwari (2011) also confirms the growth hypothesis for India using Granger approach in VAR framework.

Another recent study supporting this hypothesis is done by Chen et al. (2016) who employ a panel co-integration and vector error-correction model to discuss the dynamic economy-energy-environment nexus for 188 countries for the periods of 1993–2010. Their empirical results indicate that there exist long-run relationships between economic growth, energy consumption and carbon dioxide emissions for all countries. They find that energy consumption negatively affects GDP in the world as a whole and developing countries, but not in developed countries.

2. Conservation Hypothesis

According to this hypothesis there exists a unidirectional causality from economic growth to energy. It implies that the increase in GDP leads to the increase in energy consumption and therefore the energy reduction policy will not negatively affect economic growth, since economic growth of a country does not depend on energy. This hypothesis is more prevalent among developing countries.

Among the studies confirming this hypothesis, Farhani and Ben Rajab's (2012) study of 15 MENA countries can be mentioned which covers the annual period 1973-2008. They apply panel unit root tests, panel co-integration methods and panel causality test to investigate the relationship between energy consumption, GDP and CO2 emissions and their results show that in the long run, there is a unidirectional causality running from GDP and CO_2 emissions to energy consumption.

As another example, Saidi and Hammami (2015) investigate the impact of economic growth and CO_2 emissions on energy consumption for a global panel of 58 countries using dynamic panel data model estimated by means of the Generalized Method of Moments (GMM) for the period 1990–2012. The empirical evidence indicates significant positive impact of CO_2 emissions on energy consumption. It also shows that economic growth has a positive impact on energy consumption and is statistically significant.

3. Feedback Hypothesis

This hypothesis points out bidirectional causality between energy consumption and economic growth. Accordingly, energy consumption and economic growth affect each other at the same time, and are determined together in the positive direction. In other words, changes in energy consumption have an effect on economic growth, whilst changes in economic growth impact the demand for energy. The implication of this hypothesis is that energy policies toward efficient energy consumption negatively affect economic growth and in turn, the lower economic growth leads to lower energy consumption.

Among the studies backing up this hypothesis we can mention Antonakakis et al. (2017) who examined the dynamic interrelationship in the output–energy–environment nexus by applying panel vector auto-regression (PVAR) and impulse response function analyses to data on energy consumption (and its subcomponents), carbon dioxide emissions and real GDP in 106 countries classified by different income groups over the period 1971–2011. Their results reveal that the effects of the various types of energy consumption on economic growth and emissions are heterogeneous on the various groups of countries. Moreover, causality between total economic growth and energy consumption is bidirectional, thus making a case for the feedback hypothesis. However, they do not report any statistically significant evidence that renewable energy consumption, in particular, is conducive to economic growth, a fact that weakens the argument that renewable energy consumption is able to promote growth in a more efficient and environmentally sustainable way.

Mirza and Kanwal (2017) also explored the presence of dynamic causality between economic growth, energy consumption and CO_2 emissions for Pakistan using VECM framework. The short run, long run and strong Granger causality results of this study indicate the presence of bidirectional causalities between energy consumption, economic growth and the CO2 emissions.

Adewuyi and Awodumi (2017) employ a simultaneous equation model estimated with three stage least squares (3SLS) to investigate the causality relationship in West African countries. The overall results show that a complete significant interactive relationship (feedback effects) exists among GDP, biomass consumption and carbon emission in these countries.

4. Neutrality Hypothesis

Based on this hypothesis there is no causality between the economic growth and energy consumption. According to this, energy consumption is a small share of GDP, so it does not have a significant effect on economic growth. Furthermore, saving energy policy does not have a negative effect on GDP. Among the confirmative studies, Farhani and Ben Rajab (2012) can be mentioned who showed that there is no causal link between GDP and energy consumption; and between CO2 emissions and energy consumption in the short run.

CDC Group (2016) provided a count of investigations confirming the four different energy–economic growth hypotheses in “Development Impact Evaluation” evidence review, which is presented in table 1. The counts correspond individual countries (excluding research on multiple countries).

Table 1- Energy – growth hypotheses prevalence

Hypothesis	Causal Direction	No. of Instances	% of Instances
Conservation Hypothesis	EG* → EC**	33	29
Growth Hypothesis	EC → EG	26	23
Feedback Hypothesis	EC ↔ EG	30	26
Neutrality Hypothesis	Neutral	25	22

* EG = Economic Growth; **EC = Energy Consumption;
Note: → denotes unidirectional causality, whilst ↔ denotes bidirectional causality.
Source: CDC (2016)

CO_2 Emissions and Economic Growth

In order to make a step forward in the analysis of the relation between energy and economic growth, CO_2 emission have been included as an additional variable, which has been recently drawn attention among researchers in this field. The main reason for importing this variable is that CO_2 emissions can represent the redundancy in energy inputs which in turn can be a major source of production inefficiency (Wang and Feng, 2015). The corresponding hypothesis suggests that a decrease in emissions has a certain cost, meaning that it is accompanied with a decrease in economic output, whether in the form of policies reducing CO_2 emissions directly or shifting pollutant industries to other countries and turning to imports instead of domestic production (which both are true for the case of Sweden) which affect economic growth negatively. Wang, Feng, and Zhang (2014) showed that technical progress is the key factor for energy efficiency which can explain the decrease in CO_2 emissions growth rates in developed countries.

The literature linking growth and pollution levels started with the early works in the 1970s by Forster (1973), Solow (1973), Stiglitz (1974), Brock (1977) and others, and culminating in the more recent work investigating the Environmental Kuznets curve such as Stokey (1998), Aghion and Howitt (1998), or Jones and Manuelli (2001). Environmental Kuznets curve is a popular hypothesis in this regard which has been confirmed by a large number of case studies and it focuses on the causal relationship between economic growth and environmental degradation (indexed as CO2 emissions). According to this hypothesis there is an inverted U-shape relation between environmental degradation and GDP per capita. Various forms of the environmental degradation are needed for the economic growth in the initial stages of economic development. Dinda (2004), in his review of EKC literature, points out that previous studies` results are not consistent with the negative relation between environmental degradation and economic growth in the initial stages of development. In addition, the literature does not confirm the consensus about the level of income needed for a turning point, after which the cleanness of the environment is very significant (Obradović and Lojanica, 2017).

Among the studies investigating the relationship between economic growth, energy consumption and carbon dioxide emissions Zhang and Cheng (2009), and Soytas and Sari (2009) could be mentioned which examined causality and its direction among these variables. The empirical results of both studies show that neither carbon dioxide emissions nor energy consumption lead to economic growth, which implies a carbon dioxide reduction policy as well as an energy saving policy without affecting growth. On the other hand, Ismail and Mawar (2012), Shahbaz (2012) and Shahbaz, Muhammad, and Tiwari (2012) examined the relations among energy, emissions and economic growth and their results corroborated the premise of long-run causality among variables. These studies raised some new questions considering environmental control by using energy efficient technologies.

Chapter's Summary

As it can be seen, most studies show different results for the short-run and long-run. In general, four hypotheses have been suggested for the causal relationship between energy consumption and economic growth, namely growth hypothesis (unidirectional causality from energy consumption to economic growth), conservation hypothesis (unidirectional causality from economic growth to energy), feedback hypothesis (bidirectional causality between energy consumption and economic growth) and neutrality hypothesis (no causality between the economic growth and energy consumption). Apart from applying various econometric approaches, possible reasons for the lack of the consensus lie in the heterogeneous climate conditions, different consumption patterns, structure and level of the economic growth of the sample country.

Among the hypotheses explaining the causal relationship between economic growth and environmental degradation, the Environmental Kuznets curve has been mentioned in this chapter which suggests that there is an inverted U-shape relation between environmental degradation and GDP per capita, so that eventually growth reduces the environmental impact of economic activity. The present study aims at figuring out which of the forenamed hypotheses can explain Sweden's case both in the long-run and short-run.

Theoretical Background

In this section first the energy's role as a production factor and determinant of economic growth is explained in a macroeconomic context. Moreover the factor affecting the relationship between energy and economic growth are discussed. Afterwards the link between the environment and economic growth is explained briefly summarizing the main reasons for including the environmental degradation when studying the causal relationship between economic growth and energy consumption.

Energy as a Driver of Economic Growth

One of the factors used as an input for production is energy in its various forms. According to Stern (1997), energy is an essential factor of production. All production involves the transformation or movement of matter in some way and all such transformations require energy. The classical macroeconomic growth theories primarily focus on labor and capital and do not consider the role of energy resources which are having the significant role for economic growth and production (Stern and Cleveland, 2004). But in the new growth theories, the energy factor is considered to different degrees of importance. Stern and Cleveland (ibid.) investigated on the relationship between energy consumption and economic activities using neoclassical production function and represented the following form as a general production function:

$$Y = f(A, X_1, \dots, X_n, E_1, \dots, E_P)$$

Where the Y is aggregate outputs (manufactured goods and services), the X_i are various inputs such as capital, labor, etc., the E_i are different energy inputs: coal, oil, etc. and A is the state of technology as defined by the total factor productivity indicator.It is assumed that there is a direct relation between production factors (inputs) and production level, meaning that by increasing any of the inputs, production would increase. In other words, along with economic growth, demand for production factors increase.

According to Stern and Cleveland (2004) the relationship between energy and an aggregate of output such as gross domestic product can then be affected by 1) substitution between energy and other inputs; 2) technological change - a change in A; 3) shifts in the composition of the energy input; and 4) shifts in the composition of output, which are discussed in the following.

1. Substitution between Energy and Other Inputs

There is no consensus about whether capital and energy are complements or substitutes (Berndt and Wood, 1979). But in general, capital and energy act more as substitutes in the long run and more as complements in the short run (Apostolakis, 1990). In a study using data from Germany, Frondel and Schmidt (2002) found that evidence of complementarity only occurs in cases where the cost share of energy is small. When materials are included the cost shares of capital and energy are smaller and a finding of complementarity is more likely. Similarly, Berndt and Wood (1979) found that econometric studies using the KLE specification (i.e. not including materials) and engineering studies indicate substitution, while cost functions with the KLEM specification indicate complementarity. It seems that capital and energy are at best weak substitutes and possibly are complements. The degree of complementarity likely varies across industries and the level of aggregation considered. However, if the cost share of energy is small relative to that of capital, only small percentage increases in capital will be needed for large percentage reductions in energy use (Stern and Cleveland, 2004).

2. Technological Change

The energy intensity (the quantity of energy used to produce a real currency unit of economic activity) are divided among three causes: price-driven changes in demand, income-driven changes in demand and autonomous energy efficiency improvements (AEEI) (Azar and Dowlatabadi, 1999). The autonomous energy efficiency improvementsrefer to changes in the energy/GDP ratio that are not related to changes in the relative price of energy. These non-price factors could be due to anyof the determinants of the relationship between energy and output such as structuraland technical changes. Stern(1999) suggests an indicator for energyaugmenting technical change and reformulates the productionfunction as follows:

$$Y = f(A_1X_1, \dots, A_nX_n, A_EE)$$

so that each input is multiplied by its own technology factor A_i that converts crude units of the input into “effective units”. A_E is the index of energy augmenting technical change, which holds the use of all other inputs and their augmentation indices constant.

Estimates of the trend in autonomous energy efficiency or the related energy augmentation index are mixed. This is likely because the direction of change has not been constant and varies across different sectors of the economy. Jorgensen and Wilcoxen (1993) estimated that autonomous energy efficiency is declining. Berndt et al. (1993) estimate that in US manufacturing industry between 1965 and 1987 the energy augmentation index was increasing at between 1.75% and 13.09% per annum depending on the assumptions made (Stern and Cleveland, 2004).

A number of researchers argue that energy saving innovations can end up causing even more energy to be used as the money saved is spent on other goods and services which themselves require energy in their production. This is known as the “rebound effect” (introduced by Brookes, 1990; Khazzoom, 1980). Accordingly, energy services are demanded by the producer or consumer and are produced using energy itself. An innovation that reduces the amount of energy required to produce a unit of energy services lowers the effective price of energy services. This results in an increase in demand for energy services and thus for energy (Binswanger, 2001). The lower price of energy also results in an income effect (Lovins, 1988) that increases demand for all goods in the economy and therefore for the energy required to produce them. There may also be adjustments in capital stocks that result in an even further increased long-run demand response for energy (Howarth, 1997). This adjustment in capital stocks is termed a "macro-economic feedback". Howarth (1997) argues persuasively that the rebound effect is less than the initial innovation induced reduction in energy use, so improvements in energy efficiency do, in fact, reduce total energy demand.

3. Shifts in the Composition of the Energy Input

Energy quality is the relative economic usefulness per heat equivalent unit of different fuels and electricity. One way of measuring energy quality is the marginal product of the fuel, which is the marginal increase in the quantity of a good or service produced by the use of one additional heat unit of fuel. Some fuels can be used for a larger number of activities and/or for more valuable activities. For example coal cannot be used to directly power a computer while electricity can. The marginal product of a fuel is determined in part by a complex set of attributes unique to each fuel: physical scarcity, capacity to do useful work, energy density, cleanliness, amenability to storage, safety, flexibility of use, cost of conversion, and so on. But also the marginal product is not uniquely fixed by these attributes but also varies according to what activities it is used in, how much and what form of capital, labor, and materials it is used in conjunction with, and how much energy is used in each application. Therefore, energy qualities are not fixed over time. However, it is generally believed that electricity is the highest quality type of energy followed by natural gas, oil, coal, and wood and biofuels in descending order of quality.

Schurr and Netschert (1960) were among the first to recognize the economic importance of energy quality. Noting that the composition of energy use has changed significantly over time, Schurr and Netschert argued that the general shift to higher quality fuels reduces the amount of energy required to produce a dollar’s worth of GDP. Berndt (1990) also notes the key role played by the shifting composition of energy use towards higher quality energy inputs.

4. Shifts in the Composition of Output

Typically, over the course of economic development the output mix changes. In the earlier phases of development there is a shift away from agriculture towards heavy industry, while in the later stages of development there is a shift from the more resource intensive extractive and heavy industrial sectors towards services and lighter manufacturing. Different industries have different energy intensities. It is often argued that this will result in an increase in energy used per unit of output in the early stages of economic development and a reduction in energy used per unit output in the later stages of economic development (Panayotou, 1993).

However, service industries still need large energy and resource inputs. The service being sold may be intangible but the office towers, shopping malls, warehouses, rental apartment complexes etc. where the activity is conducted are very tangible and energy is used in their functioning as well as in their construction and maintenance. Other service industries such as transport are clearly heavily resource and energy using. Furthermore, consumers use large amounts of energy and resources in commuting to work, shop etc. Therefore a complete decoupling of energy and growth as a result of shifting to the service sector seems unlikely. When the indirect energy use embodied in manufactured products and services is taken into account the US service and household sectors are not much less energy intensive than the other sectors of the economy and there is little evidence that the shift in output mix that has occurred in the last few decades has significantly lowered the energy/GDP ratio. Rather, changes in the mix of energy used are primarily responsible (Cleveland et al. 1984). There may also be a tendency for consumers to use more energy directly over time as their consumption of the services appliances, housing, transport, etc. increases. Judson et al. (1999) find that the consumer sector sees rising energy intensity over time, ceteris paribus, while the manufacturing sector sees decreasing energy intensity.

Environment and Economic Growth

Apart from energy's role in economy as a factor of production, its consumption brings about consequences which may hinder economic growth. According to many economists, the relationship between economic growth and the environment is, and may always remain, controversial. For many years, the limited natural resource base of the planet was viewed as the source of limits to growth. Recently however it has become clear that limits to growth may not only arise from nature's finite source of raw materials, but instead from nature's limited ability to act as a sink for human. As a sink, nature dissipates harmful air, water and solid pollutants, is the final resting place for millions of tons of garbage, and is the unfortunate repository for many toxic chemicals. When the environment's ability to dissipate or absorb wastes is exceeded, environmental quality falls and the policy response to this reduction in quality may in turn limit growth. Growth may be limited because reductions in environmental quality call forth more intensive clean up or abatement efforts that lower the return to investment, or growth may even be limited when humans do such damage to the ecosystem that it deteriorates beyond repair and settles on a new lower, less productive steady state (Brock and Taylor, 2004).

Among the theories explaining the relationship between CO_2 emissions and economic growth, the environmental Kuznets curve has been the most popular. It proposes that there is an inverted U-shape relation between environmental degradation and GDP per capita, so that eventually growth reduces the environmental impact of economic activity. The hypothesis here is that environmental damage first increases with GDP per capita, then declines. The reasoning behind this hypothesis is that at low levels of development both the quantity and intensity of environmental degradation is limited to the impacts of subsistence economic activity on the resource base and to limited quantities of biodegradable wastes. Accordingly, in a country at higher levels of development, structural change towards information-intensive industries and services coupled with increased environmental awareness, enforcement of environmental regulations, better technology and higher environmental expenditures, result in leveling off and gradual decline of environmental degradation (Panayotou, 1993).

Therefore including the environmental degradation when studying the causal relationship between economic growth and energy consumption seems necessary and has been confirmed by many researchers in this field.

Methodology

In this section first descriptive statistics of the data are presented and variables' trends are discussed. Then the framework of "Vector Error Correction" is explained and the model is specified for investigating the causal relations between energy use, CO_2 emissions and economic growth for Sweden.

Descriptive statistics

Four variables are chosen in this study based on the theoretical background discussed in the previous chapter. The descriptive statistics is presented in table 1. All data has been collected from World Bank database for the period of 1970-2016. GDP and capital per capita are expressed in constant 2010 US$.

The Gross Domestic Product per capita in Sweden was last recorded at 51599.87 US dollars in 2016. The GDP per Capita in Sweden is equivalent to 446 percent of the world's average. GDP per capita in Sweden averaged 28943.52 US dollars from 1970 until 2016, reaching an all-time high of 60283.25 USD in 2013. Gross Fixed Capital Formation per capita is the second variable of interest which statistics show that averaged 9164.25 US dollars from 1970 until 2016 in Sweden, reaching its peak of 14280.64 in 2016. The minimum capital formation per capita equals 5906.16 US dollars in 1978.

Regarding energy consumption, the average value for Sweden during the period 1970-2016 was 5316.83 kilograms of oil equivalent per capita, with a minimum of 4450.38 kilograms of oil equivalent in 1971 and a maximum of 5878.8 kilograms of oil equivalent in 1986. As for CO_2 emissions, Sweden's average has been 7.09 metric tons per capita. In 1970 Sweden had its highest CO_2 emissions per capita (11.49 metric tons) and its lowest in 2016 (7.09 metric tons) which shows Sweden's consistent improvement. Sweden has been among the top-ranking countries in terms of sustainability and has set the goal of eliminating fossil energy consumption. Sweden was one of the first countries to introduce a CO_2 tax as well as an extensive environmental tax reform. According to Shmelev and Speck (2018) the technological innovation in the form of development of nuclear and hydro energy as well as higher oil prices have played a significant role in reducing

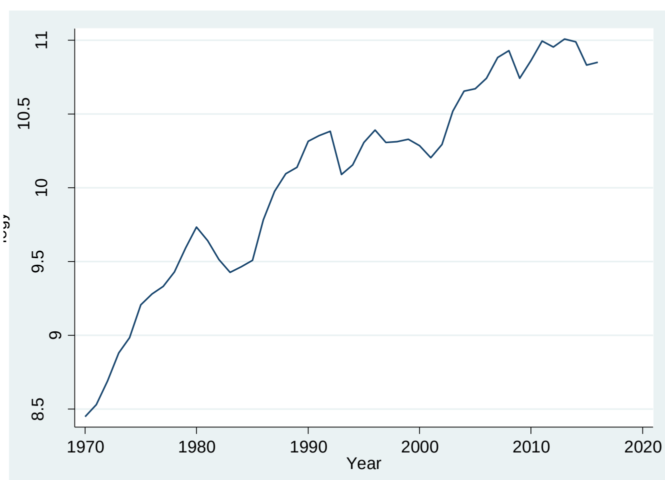
CO_2 emissions in Sweden. Moreover, Sweden's electricity imports from other countries have contributed positively towards reducing CO_2 emissions.

Table 2- Summary of descriptive statistics (1970-2016)

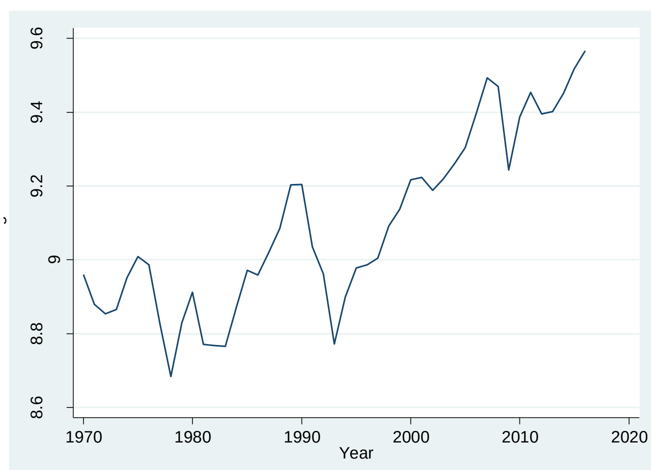
Variable	Mean	Maximum	Minimum	Standard deviation
GDP per capita	28943.52	60283.25	4669.44	16949.9
Capital per capita	9164.25	14280.64	5906.16	2276.95
Energy consumption*	5316.83	5878.8	4450.38	403.59
CO2 emissions**	7.09	11.49	4.48	1.98

* kg of oil equivalent per capita, ** metric tons per capita
(Source: Author's calculations)

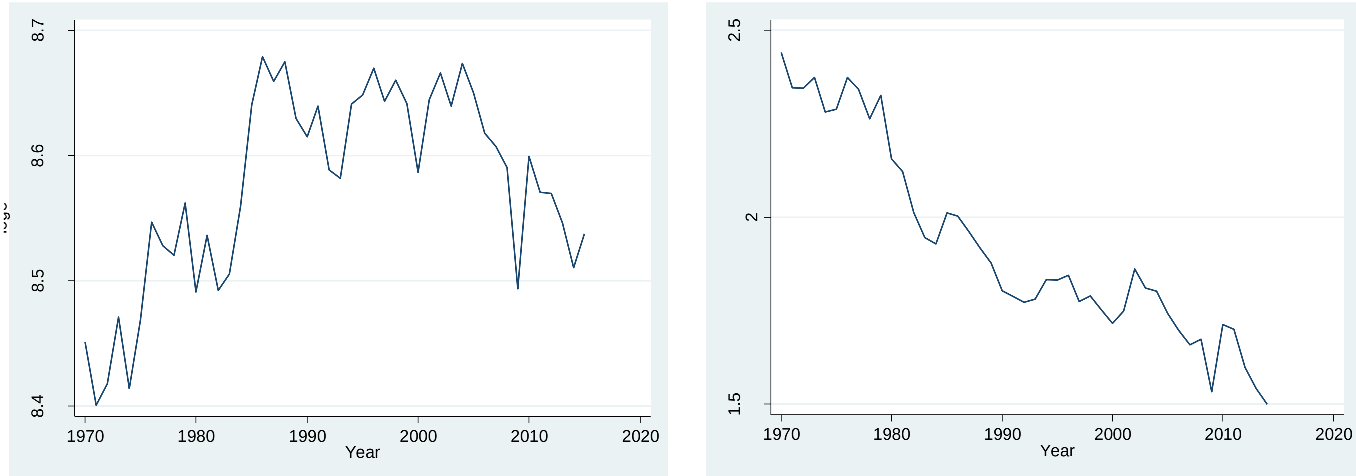
As stated in the previous chapter, the Cobb-Douglas production function is considered and the logarithmic form of variables would be applied for estimation. Their corresponding trends are presented in figure 2. As it can be observed, energy consumption and capital formation trends move in the same direction as economic growth, while CO_2 emissions trend move in the opposite direction of economic growth.



GDP



Capital formation



Energy consumption $\qquad$ CO_2 emissions

Figure 2- Selected variables' trends (Source: Author's calculations using World Bank data)

Considering the conventional production function (Y), capital stock (K) and labor (L) are the main inputs. Based on the theoretical background presented in the previous section, energy is also a factor of production. By including energy (E), the production function could be augmented and stated as below:

$$Y = f(K, E, L)$$

The Cobb-Douglas production function would be:

$$Y = K^a . E^b . L^c$$

where a, b and c are respectively output elasticity to changes in capital, labor and energy. In logarithmic form we have:

$$Log(Y) = aLog(K) + bLog(E) + cLog(L)$$

In this study, the per capita values have been chosen for estimation. The empirical equation is modeled as follows which is suggested by Obradović and Lojanica (2017):

$$Log(y) = c + aLog(k) + bLog(e) + dLog(co2) + \varepsilon_i$$

where *Log(y)* represents gross domestic product per capita, *Log(k)* represent gross fixed capital formation per capita, and *Log(e)* represents energy use per capita which are all expected to have positive impacts on the economic growth. Other than these variables, per capita greenhouse gas emissions is also included which is represented by *Log(co2)* to measure the effects of the environment on economic growth which according to theory is expected to have a negative impact on economic growth. Including *Log(co2)* provides the possibility to find out whether applying policies to reduce CO_2 emissions can affect economic growth. $\varepsilon_i$is the error term assumed to be normally distributed withzero mean and constant variance.

Model Specification

In order to determine potential causality between the variables of interest, "Vector Error Correction model (VECM)" is used which is just a special case of the VAR for variables that are stationary in their differences (i.e., I(1)). The vector autoregressive (VAR) model is a general framework used to describe the dynamic interrelationship among stationary variables. The reason for choosing VECM in this study is that the problems present in bivariate approaches due to bias of omitted variables could be overcome by using such multivariate approach (Payne, 2010). The VEC model can also take into account any cointegrating relationships among the variables. For cointegration analysis Johansen and Juselius (1990) method is used which employs VAR system to test for numbers of cointegration vectors. Its estimation procedure is based on Maximum Likelihood (ML) method. Following Johansen and Juselius (1990) VAR representation of column vector X_t is as follows:

$$X_t = Bz_t + \sum_{i=1}^{k} \Pi_i X_{t-i} + \varepsilon_t$$

Where X_t is column vector of n endogenous variables, z is a (n×1) vector of deterministic variables, ε is a (n×1) vector of white noise error terms and Π_i is a (n×n) matrix of coefficients. Since, most of the macroeconomic time series variables are nonstationary, VAR of such models are generally estimated in first-difference forms. Following Johansen and Juselius (1990), the first differencing of the equation 1 in form of VECM specification, can be specified as follows:

$$\Delta X_t = Bz_t + \sum_{i=1}^{k} \psi_i \Delta X_{t-i} + \Pi X_{t-i} + \varepsilon_t$$

where $\psi_i = -\sum_{i=1}^{k-1} \Pi_i$, $\Pi = -\sum_{i=1}^{k} \Pi_i - I$. Assuming that Π has reduced rank $0 < r < K$ so that it can be expressed as $\Pi = \alpha\beta'$, where α and β are both $K \times r$ matrices of rank r. β is a matrix containing the cointegrating vectors. This equation differs from standard first-difference version of a VAR model only by the presence of term ΠX_{t-i} in it. This term contains the information about the long run equilibrium relationship amongst the variable in X_t. Where, ΔX_t are all I(0) endogenous variables, Δ indicates the first difference operator, ψ_i is a (n×n) coefficient matrix and Π_i is a (n×n) matrix whose rank determines the number of cointegrating relationships. The Johansen and Juselius (1990) cointegration test is to estimate the rank of the Π matrix (r) from an unrestricted VAR and to test whether we can reject the restrictions implied by the reduced rank of Π. And if the rank of Π is reduced, even if all variables are individually I(1), the level-based long-run component would be stationary. For example with 4 variables and two integrating vectors ignoring Bz_t and setting $\Pi = \alpha\beta$ the equations can be rewritten as:

$$\Delta \mathrm{X}_{1\mathrm{t}} = \alpha_{11}(\beta_{11}X_{1t-1} + \beta_{12}X_{2t-1}\beta_{13}X_{3t-1}\beta_{14}X_{4t-1}) + \alpha_{12}(\beta_{21}X_{1t-1} + \beta_{22}X_{2t-1}\beta_{23}X_{3t-1}\beta_{24}X_{4t-1}) + \gamma_{11}\Delta X_{1t-1} + \gamma_{12}\Delta X_{2t-1} + \gamma_{13}\Delta y_{3t-1} + \gamma_{14}\Delta y_{4t-1}$$

$$\Delta \mathrm{X}_{2\mathrm{t}} = \alpha_{21}(\beta_{11}X_{1t-1} + \beta_{12}X_{2t-1}\beta_{13}X_{3t-1}\beta_{14}X_{4t-1}) + \alpha_{22}(\beta_{21}X_{1t-1} + \beta_{22}X_{2t-1}\beta_{23}X_{3t-1}\beta_{24}X_{4t-1}) + \gamma_{11}\Delta X_{1t-1} + \gamma_{12}\Delta X_{2t-1} + \gamma_{13}\Delta y_{3t-1} + \gamma_{14}\Delta y_{4t-1}$$

$$\Delta \mathrm{X}_{3\mathrm{t}} = \alpha_{31}(\beta_{11}X_{1t-1} + \beta_{12}X_{2t-1}\beta_{13}X_{3t-1}\beta_{14}X_{4t-1}) + \alpha_{32}(\beta_{21}X_{1t-1} + \beta_{22}X_{2t-1}\beta_{23}X_{3t-1}\beta_{24}X_{4t-1}) + \gamma_{11}\Delta X_{1t-1} + \gamma_{12}\Delta X_{2t-1} + \gamma_{13}\Delta y_{3t-1} + \gamma_{14}\Delta y_{4t-1}$$

$$\Delta \mathrm{X}_{4\mathrm{t}} = \alpha_{41}(\beta_{11}X_{1t-1} + \beta_{12}X_{2t-1}\beta_{13}X_{3t-1}\beta_{14}X_{4t-1}) + \alpha_{42}(\beta_{21}X_{1t-1} + \beta_{22}X_{2t-1}\beta_{23}X_{3t-1}\beta_{24}X_{4t-1}) + \gamma_{11}\Delta X_{1t-1} + \gamma_{12}\Delta X_{2t-1} + \gamma_{13}\Delta y_{3t-1} + \gamma_{14}\Delta y_{4t-1}$$

Considering the four chosen variables (economic growth, capital formation, energy consumption and CO_2 emissions) and i lags, the matrix specification is as follows:

$$\begin{pmatrix} \Delta\log(y)_t \\ \Delta\log(k)_t \\ \Delta log(e)_t \\ \Delta\log(co2)_t \end{pmatrix} = \psi_1 \begin{pmatrix} \Delta\log(y)_{t-1} \\ \Delta\log(k)_{t-1} \\ \Delta log(e)_{t-1} \\ \Delta\log(co2)_{t-1} \end{pmatrix} + \cdots + \psi_i \begin{pmatrix} \Delta\log(y)_{t-i} \\ \Delta\log(k)_{t-i} \\ \Delta log(e)_{t-i} \\ \Delta\log(co2)_{t-i} \end{pmatrix} + \Pi \begin{pmatrix} \log(y)_{t-i} \\ \log(k)_{t-i} \\ log(e)_{t-i} \\ \log(co2)_{t-i} \end{pmatrix} + \varepsilon_t$$

In the next chapter, the model and required tests are applied on the data for the chosen variables and the results would be discussed afterwards.

Empirical Findings

This section reports the estimation outcomes and required tests before and after estimation. These include Dickey-Fuller test for unit root, Johansen's cointegration test (as a prerequisite for applying Vector Error Correction model), Lagrange multiplier test for checking autocorrelation and Jarque- Bera's test for verifying normal distribution of residuals. All calculations have been done in STATA software. The results are discussed at the end of the chapter.

Unit Root Test

The first step in time-series analysis is to determine whether the levels of the data are stationary which is also a precondition for using Johansen's cointegration test. Therefore Dickey-Fuller test for unit root is run. The results are presented in table 3.

Table 3- Dickey-Fuller test results for unit root

Variable	t-statistic	Critical value (5%)	Variable	t-statistic	Critical value (5%)
log(y)	-2.552	-2.941	D*.log(y)	-4.340	-1.950
log(e)	-2.045	-3.520	D.log(e)	-8.828	-3.524
log(co2)	-2.640	-3.524	D.log(co2)	-7.630	-3.528
log(k)	-2.877	-3.516	D.log(k)	-5.868	-3.520

* D. shows the first difference of variables.
Source: Author's calculations

Null hypothesis in this test is that the variable is not stationary or has unit root. If the t-statistic is less than critical value, null hypothesis is rejected. Comparing the t-statistics and critical values for all four variables shows that they are all non-stationary but their first difference is stationary. In other words, variables are integrated of same order.

Cointegration Test

After checking for stationarity of variables, the Johansen's test for integration is run. Johansen`s approach allows determination of causal relations among variables. The null hypothesis for this test is that "there is no co-integration among variables". If the critical value is more than the trace statistic, we can reject the null hypothesis, meaning that "there is co-integration among variables". Comparing the corresponding values for trace statistic and critical value for rank 0 (63.13 and 47.21), we can reject the null hypothesis. But for rank 2, we cannot reject the null hypothesis which means that our chosen variables are co-integrated and have long-run association. For rank 2 the trace statistic (13.77) is less than the critical value (15.41) which means that three co-integrating equations exist. These findings are presented in table 4.

Table 4- Johansen's test for co-integration

Maximum rank	**Trace statistics**	**5% critical value**	**Maximum eigenvalue statistics**	**5% critical value**
0	63.1368	47.21	28.5563	27.07
1	34.5805	29.68	20.8104	20.97
2	13.7701*	15.41	12.4821	14.07
3	1.2879	3.76	1.2879	3.76

Source: Author's calculations

VECM Estimation

Based on the obtained result from unit root and cointegration tests, the time series of variables of interest (growth in GDP per capita, growth in capital formation per capita, growth in energy use per capita and growth in CO2 emissions per capita) are not stationary in their levels but are in their differences and the variables are cointegrated. Therefore we can run the "Vector Error Correction Model (VECM)". Four models are run accordingly. In each model one of the variables (economic growth, energy consumption, CO2 emissions and capital) are the target variable. The results are reported in table 5.

Table 5- VECM results

Dependent variable		**Independent variables**				**Error Correction Term**
		Economic growth	Energy consumption	CO_2 emissions	Capital	
1	Economic growth	-	0.8329 (0.243)	-0.4523 (0.388)	-0.4904 (0.049*)	-0.2803 (0.001**)
2	Energy consumption	0.0127 (0.853)	-	-0.0131 (0.940)	0.0637 (0.419)	-0.1918 (0.067*)

3	CO_2 emissions	-0.0415 (0.720)	-0.9711 (0.006**)	-	-0.1103 (0.405)	-0.1609 (0.027*)
4	Capital	-0.2518 (0.182)	0.9022 (0.163)	-0.7055 (0.138)	-	0.0799 (0.655)

* significance level at 5%, ** significance level at 1%
Source: Author's calculations

Based on the error correction terms (which shows speed of adjustment towards equilibrium) it can be decided whether there is long-run causality between the variables. For all 3 target variables the error correction term is negative and significant statistically (prob.<0.05) which confirms the existence of long-run causality. For the first equation where economic growth is the target value, the error correction (-0.2803) and probability (0.001) show that there is long-run causality running from energy use, CO_2 emissions and capital to economic growth. The significance of other coefficients show if they can individually explain the target variable and designate the existence of short-run causality. For the first equation, the only variable showing short-run causality with economic growth is capital with the probability of 0.049.

The second equation with energy consumption as the dependent variable, shows a negative and significant error correction term (-0.1918) which points out long-run causality running from economic growth, CO_2 emissions and capital to energy consumption. This equation indicates no short-run causality among variables.

Considering CO_2 emissions as the target variable in the third equation, the error correction term (-0.1609) is both negative and significant (prob. 0.027) indicating long-run causality running from economic growth, energy consumption and capital to CO_2 emissions. There is also short-run causality running from energy consumption to CO_2 emissions, indicated by the significance of estimated coefficient (0.006).

The fourth equation does not show any long-run or short-run causality running from either of the variables to capital as the statistical significance of the estimated coefficients are not high enough.

Post-estimation Tests

Checking for serial correlation between residuals, Lagrange-multiplier test is used. For this test the null hypothesis is that there is no autocorrelation. Based on the probabilities for 3 lag orders which are all higher than 0.05, we cannot reject the null hypothesis. Therefore the model does not have serial correlation. The results are reported in table 6.

Table 6- Lagrange-multiplier test result

Lag	chi2	df	Prob.
1	16.2440	16	0.4361
2	13.8883	16	0.6070
3	13.6408	16	0.6255

H0: no autocorrelation at lag order
Source: Author's calculations

In order to check whether residuals are normally distributed, Jarque-Bera test has been used. The null hypothesis for this test is that residuals are normally distributed. The probabilities corresponding to all equations are higher than 0.05 which means that the null hypothesis cannot be rejected. Therefore the residuals in this model do not have any problem regarding to normal distribution of the residuals. The results of this test are presented in table 7.

Table 7- Jarque-Bera test result

Equation	chi2	df	Prob.
Economic growth	1.580	2	0.4538
Energy use	0.155	2	0.9256
CO_2 emissions	1.153	2	0.5618
Capital	0.994	2	0.6083
ALL	3.882	8	0.8676

H0: residuals are normally distributed
Source: Author's calculations

As a supplementary way of checking short-run causality, post-estimation linear hypothesis (Granger causality) test is used for each variable. Based on this test it can be decided whether each individual variable has any influence on the target variable in the short-run. The null hypothesis is that the chosen variable has zero influence on the target variable. Based on the probability value, the null hypothesis is tested. The results (which are reported in table 8) indicate that the only short-run causal relationship exists between CO_2 emissions and energy consumption and it is bidirectional. The values in the table are the corresponding chi2 values and the probabilities (Prob > chi2) are written in brackets.

Table 8- Granger causality test results

Target variable	**Independent variable**		
	Economic growth	Energy consumption	CO_2 emissions
Economic growth	-	1.74 (0.4181)	2.84 (0.2412)
Energy consumption	0.22 (0.8951)	-	7.98 (0.0185*)
CO_2 emissions	2.06 (0.3569)	7.65 (0.0219*)	-

H0: the independent variable has no influence on the target variable.
Source: Author's calculation

Chapter's summary

Using Dickey-Fuller test for unit root it was shown that all four variables are non-stationary but their first difference is stationary. Moreover according to Johansen's cointegration test results the chosen variables are co-integrated and have long-run association. Therefore "Vector Error Correction Model (VECM)" could be applied in order to investigate the causal relationship among the variables. Judging from the trace statistic from Johansen's cointegration test, there are three co-integrating equations (maximum rank 2). The VECM results show that for all 3 target variables (energy consumption, CO_2 emissions and economic growth) the error correction term is negative and statistically significant which confirms the existence of long-run causality. Judging from Lagrange-multiplier test result the model does not have serial correlation. The residuals in the model do not have any problem regarding normal distribution of the residuals which is confirmed by Jarque-Bera test.

The empirical findings indicate that in the long-run, causality relationship between energy consumption and economic growth is bidirectional. This means that energy is a determining factor for economic growth in Sweden and the decoupling of economic growth and energy use has not yet happened for Sweden. On the other hand, higher economic growth has also lead to higher levels of energy consumption. This finding is consistent with the Feedback Hypothesis. But in the short-run no causality is found between energy consumption and economic growth. In the long-run there is also a long-run causality running from CO_2 emissions to economic growth which shows that applying policies in order to reduce the CO_2 emissions has slowed down economic growth in Sweden. As discussed in the previous chapters, a decrease in emissions has a certain cost and is accompanied with a decrease in economic output; whether it is in the form of policies reducing CO_2 emissions directly or shifting pollutant industries to other countries and turning to imports instead of domestic production, which both are true for the case of Sweden and the empirical results of this study support this hypothesis.

According to Granger causality test results, bidirectional causality between CO_2 emissions and energy consumption cannot be rejected in the short-run, confirming that redundancy in energy inputs is a source of production inefficiency in Sweden (higher CO_2 emissions cause higher level of energy consumption) and although clean-energy policies are enforced, improvements can still be made to reduce CO_2 emissions.

Conclusions

This study investigates the causal relationship between energy consumption, CO_2 emissions and economic growth. Nowadays concerns about environmental degradation and production inefficiency leading us to an unsustainable path have been exposed to global discussion more than ever. Sweden has been among the top-ranking countries in terms of sustainability and has set the goal of eliminating fossil energy consumption.

The empirical findings on the relationship between energy consumption and economic growth are inconsistent and suggest different policy implications. But there are four main categories of findings in this regard: the growth hypothesis (causal unidirectional relationship from energy consumption to economic growth), the conservation hypothesis (causal unidirectional relationship from economic growth to energy consumption), the feedback hypothesis (bidirectional causality) and the neutrality hypothesis (no causality). Each of these hypotheses recommends different policies in order to move towards and maintain sustainability.

In order to study the case of Sweden, Vector Error Correction model is applied on annual data for the period 1970- 2016. Using Johansen's test, it is confirmed that the variables of interest (economic growth, energy consumption, CO_2 emissions and capital formation) are cointegrated and therefore the multivariate approach of Vector Error Correction model is suitable for investigating causality relationships between them. This model is preferred to other approaches addressing this subject, as the bias of omitted variables does not affect the results of this model.

The empirical findings indicate that in the long-run we cannot reject the existence of a bidirectional causality between energy consumption, CO_2 emissions and economic growth. This means that energy is a determining factor for economic growth in Sweden and policies restraining energy consumption could slow down economic growth in the long-run. This finding confirms the Feedback hypothesis. But in the short-run there is no causality between energy and economic growth. According to Granger causality test results, in the short-run there is bidirectional causality between CO_2 emissions and energy consumption. Variables' trends show that in the period under study, energy consumption and economic growth have moved in the same direction; meaning that higher energy consumption has led to higher economic growth. At the same time, lower CO_2

emissions have been accompanied by higher economic growth showing that there is still room for improvement despite all successful efforts made to reduce environmental degradation. There is also short-run causality running from capital to economic growth which is expected.

Finally it can be suggested to the policy makers in Sweden that in order to maintain economic growth and reduce environmental degradation, energy consumption should be shifted gradually from nonrenewable sources to renewable ones so to avoid decrease in economic growth and ensure lower levels of CO_2 emissions in the long-run.

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Appendix

Table 7- Johansen tests for cointegration

Trend: constant Number of obs = 42

Sample: 1973- 2014 Lags = 3

Maximum rank	**parms**	**LL**	**eigenvalue**	**Trace statistic**	**5% critical value**
0	36	253.07659	.	63.1368	47.21
1	43	267.35476	0.49334	34.5805	29.68
2	48	277.75996	0.39073	13.7701*	15.41
3	51	284.00103	0.25710	1.2879	3.76
4	52	284.64499	0.03020		
Maximum rank	**parms**	**LL**	**eigenvalue**	**max statistic**	**5% critical value**
0	36	253.07659	.	28.5563	27.07
1	43	267.35476	0.49334	20.8104	20.97
2	48	277.75996	0.39073	12.4821	14.07
3	51	284.00103	0.25710	1.2879	3.76
4	52	284.64499	0.03020		

Table 8- VECM results

	Coef.	**Std. Err.**	**z**	**P>|z|**	**[95% Conf. Interval]**
D_logy					
_ce1					
L1.	-.2802605	.0842245	-3.33	0.001	-.4453376 -.1151835
_ce2					
L1.	.5653808	.1976678	2.86	0.004	.177959 .9528026
logy					
LD.	.0030214	.2083946	0.01	0.988	-.4054245 .4114674
L2D.	-.1228361	.194316	-0.63	0.527	-.5036884 .2580163
logk					
LD.	-.1202972	.2383358	-0.50	0.614	-.5874268 .3468323
L2D.	-.4904201	.2495769	-1.97	0.049	-.9795819 -.0012584
loge					
LD.	.8329714	.7141136	1.17	0.243	-.5666655 2.232608

L2D.	-.3077967	.6319949	-0.49	0.626	-1.546484 .9308906
logco2					
LD.	-.4523509	.5245223	-0.86	0.388	-1.480396 .5756939
L2D.	.6670851	.4518525	1.48	0.140	-.2185296 1.5527
_cons	.0016242	.0285391	0.06	0.955	-.0543114 .0575597

	Coef.	**Std. Err.**	**z**	**P>|z|**	**[95% Conf. Interval]**
D_loge					
_ce1					
L1.	-.0839949	.0278665	-3.01	0.003	-.1386122 -.0293776
_ce2					
L1.	-.0390032	.0654003	-0.60	0.551	-.1671854 .0891791
logy					
LD.	.0127405	.0689494	0.18	0.853	-.1223978 .1478787
L2D.	-.030097	.0642913	-0.47	0.640	-.1561057 .0959117
logk					
LD.	.0637426	.0788557	0.81	0.419	-.0908117 .218297
L2D.	.0325086	.0825749	0.39	0.694	-.1293353 .1943525
loge					
LD.	-.1539564	.2362714	-0.65	0.515	-.6170398 .3091269
L2D.	-.5294326	.2091016	-2.53	0.011	-.9392643 -.1196009
logco2					
LD.	-.0131257	.1735433	-0.08	0.940	-.3532642 .3270129
L2D.	.4222564	.1494998	2.82	0.005	.1292422 .7152706
_cons	.0094178	.0094424	1.00	0.319	-.009089 .0279246

	Coef.	**Std. Err.**	**z**	**P>|z|**	**[95% Conf. Interval]**
D_logco2					
_ce1					
L1.	-.1242066	.0468379	-2.65	0.008	-.2160071 -.0324061
_ce2					
L1.	.1013286	.1099245	0.92	0.357	-.1141194 .3167767
logy					
LD.	-.041572	.1158897	-0.36	0.720	-.2687117 .1855677
L2D.	-.1324206	.1080605	-1.23	0.220	-.3442153 .0793741
logk					
LD.	-.1103092	.1325402	-0.83	0.405	-.3700832 .1494649
L2D.	-.0149084	.1387915	-0.11	0.914	-.2869348 .2571179

loge					
LD.	-.0788685	.3971236	-0.20	0.843	-.8572165 .6994795
L2D.	-.9711302	.3514569	-2.76	0.006	-1.659973 -.2822873
logco2					
LD.	-.1029081	.2916906	-0.35	0.724	-.6746111 .4687949
L2D.	.5774011	.2512784	2.30	0.022	.0849045 1.069898
_cons	-.013653	.0158708	-0.86	0.390	-.0447592 .0174532

	Coef.	**Std. Err.**	**z**	**P>|z|**	**[95% Conf. Interval]**
D_logk					
_ce1					
L1.	-.0431641	.0763023	-0.57	0.572	-.1927138 .1063856
_ce2					
L1.	.0799318	.1790749	0.45	0.655	-.2710486 .4309122
logy					
LD.	-.2517961	.1887928	-1.33	0.182	-.6218231 .1182309
L2D.	.0207793	.1760384	0.12	0.906	-.3242496 .3658082
logk					
LD.	.3132487	.2159176	1.45	0.147	-.109942 .7364394
L2D.	-.4409409	.2261014	-1.95	0.051	-.8840915 .0022096
loge					
LD.	.9021851	.6469432	1.39	0.163	-.3658002 2.17017
L2D.	-.416416	.5725487	-0.73	0.467	-1.538591 .7057588
logco2					
LD.	-.7054703	.4751851	-1.48	0.138	-1.636816 .2258753
L2D.	.3719615	.4093507	0.91	0.364	-.4303512 1.174274
_cons	.010415	.0258547	0.40	0.687	-.0402592 .0610892