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RESEARCH PAPER

# Examining the Environmental Kuznets Curve in Sweden to Assess the Nexus of Economic Sectors

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**ABSTRACT**
To support the fulfillment of Sweden's targets in term of climate change and economic growth, we need to do a distinct study to show the Environmental Kuznets Curve (EKC) pattern in different sector of the economy, as the GDP allocation, energy intensities, GHG emission, and technological development are different between sectors. This kind of study helps to figure out how the different sectors contribute to climate change and could appoint more particular and effective environment-energy policies. For this aim, we analyzed the existence of the EKC by implementing the ARDL Bound test approach in the whole and individual sectors of Sweden's economy throughout 1990-2019. Our results indicated the contribution of a particular sector on total GHG emissions per capita. Results of the whole economy confirmed the EEKC hypothesis with a turning point in 1996, in which the AFF sector, unlike industry and service, had increased GHG emissions. Disaggregated sectoral analysis showed various results. The industry sector had efficient energy improvement. Policymakers should pay attention to AFF's GHG emissions, as different sources of energy consumption had not impressive impact in both the short and long term. Also, effective fossil-related policies are necessary for the service sector due to the main contribution to transportation.

**KEYWORDS**: Energy, Environment, Greenhouse gas, Sector, Sweden.

## INTRODUCTION

Global warming is one of the world's biggest environmental challenges that have intensified after the industrial revolution due to rapid economic growth as the main goal of every economy. Environmentalist argued that Greenhouse Gas (GHG) emission from energy consumption for economic growth is the main sources of climate change and global warming. Increasing threats of GHG emission have been a crucial problem for countries to focus on energy consumption and GHG reduction. However, this reduction might put negative pressure on the development and growth of an economy but will enhance resources and also energy efficiency. With this background understanding the effects of economic growth on the environment have become an impressive ground of research to act as a reminder to member and effective response to global warming to continue to grow within limits, stay on reasonable environmental thresholds, and also implementing efficient and effective environmental policies (Duman and Kasman, 2015; Ahmad et al. 2017; Kassouri and Altintas, 2020).

North America and European countries are the most contributors to the GHG emissions in

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the world while developing countries account for a small share. So, considerable diminutions of emissions should achieve in mentioned regions, where the rapid Gross Domestic Product (GDP) growth has lead to an increasing share of energy severe industries. Based on the European Commission (2019), the European Union (EU) has registered significant advances towards most of the sustainable development goals, as well as GHG emissions. Within the EU framework, "20-20-20" climate and energy targets were implemented to reach the objective of reducing energy consumption in different sectors by 20%, increasing the share of renewable energy production to 20%, and a 20% improvement in energy efficiency in 2020 from 1990. Moreover, the EU has recently pursued new actions according to "Energy roadmap 2050" to diminishing GHG emissions to 85% or 95% below the 1990 level by 2050 (Lopez-Menendez et al., 2014; Pablo-Romero et al., 2017; Kassouri and Altintas, 2020).

According to Mazzanti et al. (2007) and Congregado et al. (2016), most of the EU energy and climate policies implemented by establishing homogenous aim between countries, while the GDP allocation, energy intensities, GHG emission, and technological development in different sectors of an economy have different behavior. For example, the industry sector's role in energy consumption, the effect of transportation on GHG emission, the contribution of the sector in the GDP, and technological development of the agriculture sector are significantly different. Hence, to support the fulfillment of the EU targets in terms of energy consumption and GHG emission, it is essential to figure out how the different sectors contribute to them to appoint more particular and effective energy policies. Various researches undertake the issue of investigating growth, energy consumption, and GHG emission at the EU level or in specific countries of the union. They have tried to estimate the extent to which countries and regions contribute to the energy and GHG emission (Bianco et al., 2019), while sectoral investigation can provide robust analysis, more informed policymaking, and prevent the heterogeneity across different sectors of an economy.

Sweden, as one of the European Union countries, is developed from an agricultural society to an industrial and service one during the last decades. This shift is called the transformational process from a product-centric business to a service-centric economy is part of the economic development of a country with or without harming the environment in the form of increased air pollution. Air pollution is argued that economic growth, urbanization,

industrialization, and trade are responsible due to increasing consumption of energy leading to rising of GHG emissions in Sweden. It's emissions account for about 0.12 percent of the global total GHG emissions. Nevertheless, Sweden is a country on the forehead of environmental economics and sustainable growth during the last years. Highest carbon tax since 1990, when can be seen as the starting point of a climate policy that has been accompanied by the Kyoto agreement in 2002 and membership in the EU-ETS from 2005, reducing by about 50 percent of national energy supply from fossil fuels, and the government's new ambitious sustainability aims for becoming fossil-free economy by 2045 are the evident samples of environmental movement and policies (Lindmark, 2019; Forsstrom and Johansson, 2020; SCB, 2020; Shahbaz et al., 2019).

According to European Statistical Office (2020), Sweden's total GDP per capita increases from 537 to 808 TKr (Thousand Kr) from 1990 to 2019 when AFF, industry, and service sectors have progressed 54%, 53%, and 63%, respectively. These considerable developments need energy so that total energy consumption per capita has distinct experience in economical sectors. AFF sector by about 42% increase in energy consumption per capita has most raise; then, industry sector has placed by 20% increase, finally, service sector shows 37% decrease energy usage per capita during the last three decade. Regarding pollutants emission, total GHG emission per capita decreases approximately 27%, in which AFF and industry sectors have intensified air pollution whereas service sector has a supportive role. The issue of increasing GHG emissions per capita in the sectors of Sweden's Economy, can use to measure environmental degradation in association with increased the GDP and energy consumption per capita because it has become serious concern in recent decades as it is the main part of global warming and also climate change. It is the main motivation for us to do an empirical analysis of Sweden’s economy. Empirically understanding the relationship between economic growth and environmental quality in the EKC hypothesis context for economic sectors of high-income countries like Sweden is more useful because they often experience enormous challenges in climate change, global warming, and the industrial revolution. Sweden’s incorporating economic sectors into the EKC context can serve as useful case studies for the countries worldwide to provide valuable examples of how environmental goals can achieve. From a policy view, it can eliminate the concern regarding establishing a production system and appropriate practices with high energy-efficient technology to preserve the environment. Moreover, it would help find appropriate environmental and energy policies to accomplish the government's future goals. So, the goal of this paper is to provide a comprehensive explanation for the relationship between economical development and environmental quality of different sectors, as well the whole economy in Sweden. In this regard, our contribution follows by the sectoral analysis of the Environmental Kuznets Curve (EKC) context, which was suggested by Kuznets (1955), to find out the relationship between the GDP, energy consumption, and GHG emissions in whole and different sectors, including (Industry, Agriculture, and Service) of Sweden economy.

Several studies have investigated the relationship between economic growth and environmental degradation, as for effective variables such as energy consumption on a region or sectoral scales. Kassouri and Altintas (2020); Pablo-Romero et al. (2017); Duman and Kasman (2015); Lopez-Menendez et al. (2014); Ozturk and Acaravci (2010); Liobikiene et al. (2019); Vehmas et al. (2007); Uddin et al. (2016); Bilgili et al. (2016); Petrovic et al. (2018); Boluk and Mert (2014) tested the EKC hypothesis to understanding the relationship among income, air pollution, energy and other relevant factors such as urbanization and technological development. Also, Gaeta et al. (2018) and Pontarollo and Munoz, who chosen specific environmental index as solid waste, land consumption, have tested the relationship among variables in the EKC context. In the other category, researchers focused on the regional scale to investigating the EKC hypothesis in which some of them were related to a specific region, country, and sectors of an economy. Bella et al. (2014); Fujili and Managi (2013); Ozdemir and Ozokcu (2017) for the OECD countries, and Sanchez-Braza and Pablo-Romero (2017) for European Union countries studied the relationship among income, air pollution, and energy consumption. On the country scale, both Pata (2018); Boluk and Mert (2015) for Turkey, Reclade and Zilio (2011) for Latin America and the Caribbean, Du et al. (2017) for Croatia, Pakrooh and Pishbahar (2020) for Iran, Morley et al. (2012) for the UK, Mutascu et al. (2013) for Romania, Zambrano-Monserrate and Fernandez (2017) for Germany, and Zambrano-Monserrate et al. (2018) for Peru analyzed the EKC hypothesis. Among all, there have been studies that authors tried to understand the relationship between economic and environmental indicators of a specific sector. Mazzanti et al. (2007) provided empirical evidence on the different results of the EKC hypothesis in the service and industry sector of Italy. Congregado et al. (2016) analyzed the existence of the EKC in the total, commercial, electrical, industrial, residential, and transportation of USA. In the same way, Madaleno et al. (2017) studied the EKC hypothesis in the economic activities of the Portuguese and Spanish industry sectors. In the other study, Tseng et al. (2020) tried to investigate the EKC hypothesis in the agriculture sector of the Malaysia.

According to the aim of the study, we would like to focus on the literature review of Sweden's EKC hypothesis to find out how EKC hypothesis has examined for Sweden during the last decades. This survey will help us in identify the advantages, disadvantages, differences, similarities of studies. For this aim, the following table presented to show up the studies in regard to EKC hypothesis of Sweden’s economy. Surveys on studies clarify the following points. Primary, the advantage of reviews is in examining the relationship between income, air pollution, and different kind of energy consumption along time that helps policymakers to implement effective policies. Second, studies disadvantage is that the EKC hypothesis examined alongside other European Union countries; it means that studies are based on regional and aggregated data scale. It may be unreasonable because it does hide more informative details; for instance, the panel models imply that all countries have the same turning point, which is not true in the real world. Third, the present study’s similarity with the literature studies is in investigating the relationship between income, air pollution, and different kind of energy consumption. Forth, the examination of the EKC hypothesis by sectors is critical in the literature because of the several reasons to be interested in the observation of the income, air pollution, and energy consumption by sectors of Sweden’s economy. Despite several studies that have tried to testing the EKC hypothesis, the presented paper examines the theory in Sweden’s economy that can highlight different behaviors across time by sectors.

**Table 1.** Summary of studies about the EKC theory in Sweden

| Author(s) | Aim | Indicators | Region and Periods | Econometric Technique | Results |
|---|---|---|---|---|---|
| Vehmas et al. (2007) | EKC | GDP, Material Intensity | 1980-2000 EU includes Sweden | Data Analysis | Results present different relationships among variables in different countries. Overall, the trend is a weak de-linking of material intensities from the GDP. |
| Fujii and Managi (2013) | EKC | GDP, $CO_2$, Energy | 1970-2005 OECD includes Sweden | Panel Data Procedures and Factor decomposition Analysis | Results reveal an N-shaped relationship between the GDP and $CO_2$ in the paper, pulp, printing, wood, construction industries. Oil and coal have increased the GDP in the steel and construction industries. Metallic, minerals, machinery, transport equipment industries tend to increase emission from oil and electricity with the GDP. |
| Pablo-Romero et al. (2014) | EKC | GDP, $CO_2$, Energy | 1996-2010 EU includes Sweden | Panel Data Procedures | Results confirm the existence of an EKC relationship, but this relationship had the different shape. Sweden has monotonic decreasing trend, in which renewable energy has a significant effect. |
| Bella et al. (2014) | EKC | GDP, $CO_2$, Energy | 1965-2006 OECD includes Sweden | Panel Data Procedures | The result indicates an inverted-U-shaped relationship between the GDP and $CO_2$. Both emissions and electricity consumption are bound to decrease in the long run. |
| Duman and Kasman (2015) | EKC | GDP, $CO_2$, Energy, Trade, and Urbanization | 1992-2010 EU includes Sweden | Panel Data Procedures | There is an inverted U-shaped relationship between $CO_2$ and the GDP. Also, the mentioned indicators could play an essential role in the adjustment process. |

**Table 1.**

| Author(s) | Aim | Indicators | Region and Periods | Econometric Technique | Results |
|---|---|---|---|---|---|
| Bilgili et al. (2016) | EKC | GDP, $CO_2$, Energy | 1977-2010 EU includes Sweden | Panel Data Procedures | Results confirm the existence of an EKC relationship between the GDP, $CO_2$ emissions, and renewable energy consumption. Moreover, renewable energy has a negative impact on $CO_2$ emission. |
| Uddin et al. (2016) | EKC | GDP, $CO_2$, Energy, Technology | 1980-2010 EU includes Sweden | Panel ARDL | There is an inverted-U-shaped relationship between $CO_2$ and the GDP in the long run. Biomass energy significantly link to $CO_2$ emissions, and technological innovation significantly reduces $CO_2$ emission. |
| Pablo-Romero et al. (2017) | EKC | GVA and Energy | 1995-2009 EU includes Sweden | Panel Data Procedures | The EKC hypothesis dose not approves for this sector, and energy elasticity concerning the GVA have decreased during the time. |
| Vlontzos et al. (2017) | EKC | GDP, GHG, Energy | 1999-2012 EU includes Sweden | Panel data Procedures and the DEA Model | There is an N-shaped relationship between the GDP and energy efficiency. While there is an inverted-U-shape relationship between GHG and the GDP. |
| Petrovic et al. (2018) | EKC | GDP and GHG | 2000-2014 EU includes Sweden | Correlation Analysis and Panel Data Procedures | An inverse-U-shaped relationship exists between transport GHG emission and the GDP. Also, the change of economic structure has influenced the transport GHG emissions. |
| Bese (2018) | EKC | GDP, $CO_2$, Energy, | 1960-2014 Sweden | ARDL-Bound, Causality Test | EKC hypothesis dose not confirm for Sweden, and the energy consumption is the only significant factor in GHG emissions. |
| Urban and Nordensvard (2018) | EKC | GDP, $CO_2$, Energy | 1960-2015 Nordic Countries | Data Analysis | For Sweden, there is an inverted-U-shaped relationship between the GDP and $CO_2$, and a monotonic increasing trend for the GDP and energy consumption. |
| Shahbaz et al. (2019) | EKC | GDP, $CO_2$ | 1850-2005 Sweden | MARS | Results indicate an inverted-U-shaped relationship between the GDP and $CO_2$ with a turning point in 1970. |
| Liobikiene et al. (2019) | EKC | GDP, GHG, Energy | 1995-2005 EU includes Sweden | Panel Data Procedures | There is an inverted-U-shaped relation between the GDP and GHG. By concerning renewable energy, the monotonic decreasing relationship approve among the GDP, GHG, and energy. |
| Kassouri and Altintas (2020) | EKC | GDP, $CO_2$, Energy | 1990-2014 EU includes Sweden | Panel Data Procedures | There is an inverted-U-shaped relationship between the GDP, and $CO_2$. Renewable energy is an environmentally friendly source, while fossil fuels contribute to environmental degradation. |

This study organized into the following sections. The Second section relates to the theory about EKC and the methodology part in which the models and the data analysis are followed.

The next sections conclude empirical results, discussion, and also the implications of the findings.

## MATERIAL AND METHODS

### *THEORY*

Historically, there are various ideas in economic theory that related to environment and natural resources scarcity. But over the years, ideas have been transformed from natural resources scarcity into sustainability, and necessity of economic growth to succeed in dealing with environmental issues. Significant reports and clubs, like "Club of Rome", "Conference on the Environment in Stockholm", and "Earth Summit groundwork in Brazil", have emerged concerning the process of economic growth and environmental degradation. In line with this, sustainability of economic development purposed at a specific level of consumption per capita that has to be sustained for future generations which contains three environmental, economic, and sociopolitical sustainability parts. The relationship between environmental degradation and economic growth has been a debate between growth supporters and environmentalists, finally, Grossman and Kruger (1991), based on Kuznets (1955) income inequalities hypothesis, find out the inverse U-shaped curve for the relationship between income and environmental degradation, which is called Environmental Kuznets Curve (EKC). According to the fundamental philosophy of the EKC-theory, economic growth will support the environment in the long term, although it would have a destructive role in the short-time. To more, in the early stage of growth, due to limitation in activities, economic faces with abundant of resources stock and finite pollution. Further development along with industrialization occurs a considerable depletion of resources and pollution accumulate. During this stage, there would be a positive relationship between economic growth and environmental degradation per capita. Finally, further economic growth along with improved services and technology, reduce environmental degradation (Zervas and Kaika, 2013; Pakrooh and Pishbahar, 2020). This is an important concept relevant to find out the energy transition (as a main resource) and understanding how economic development relates to environmental degradation, on both an aggregate and per capita basis.

Most of the studies test EKC theory by using the following general polynomial regression model as Eq(1). This estimation allows us to measure the impact of economic development on environmental degradation.

$$
\begin{aligned}
&Y = f(x, x^2, z)\\
&Y_{it} = \alpha_i + \beta_1 x_{it} + \beta_2 x_{it}^2 + \beta_3 z_{it} + e_{it}\\
&i = 1, 2, \ldots.., N \quad Sectors\\
&t = 1, 2, \ldots.., T \quad Year\\
&x^* = -\frac{\beta_1}{2\beta_2}
\end{aligned}
\qquad (1)
$$

where, $Y$ is the environmental degradation as the dependent variable, $x$ refers to the independent variable of economic development, $z$ indicates other variables such as energy consumption, urbanization and etc., α is the constant term of the model, $\beta_i$ are estimated coefficients, $e$ is an error term, and $x^*$ is the turning point. The estimated model may be one of the following cases in Table (1) (Dinda, 2004).

**Table 2.** EKC patterns according to estimated coefficients

| Pattern | Inverted U-shaped | U-shaped | Monotonically Increasing | Monotonically decreasing | Level |
|---|---|---|---|---|---|
| Coefficients | $\beta_1 > 0$ <br> $\beta_2 < 0$ | $\beta_1 < 0$ <br> $\beta_2 > 0$ | $\beta_1 > 0$ <br> $\beta_2 = 0$ | $\beta_1 < 0$ <br> $\beta_2 = 0$ | $\beta_1 = \beta_2 = 0$ |

*ESTIMATION PROCEDURE*

The estimation procedure is applied by four key econometrics steps. The primary step was to test unit-root by implementing the ordinary and breakpoint unit-root tests. The second step is model specification and searches the existence of co-integration by the ARDL bound test. The third step is the diagnostic and stability tests to find the normal residual by Shapiro Wilk test, homocedasticity by Breuusch-Godfrey, first order, and serial autocorrelation by Durbin-Watson and Breusch-Godfrey, Ramsey–regression equation specification error test for functional form test, and also the CUSUM and the CUSUMQ stability tests. Then, in the fourth step, it is necessary to report the direction of the causality between variables by Granger Causality test.

*UNIT-ROOT TEST*

To avoid spurious regression, it is necessary to control the variables stationary level by appropriate unit-root tests to using the OLS. Several tests have suggested regarding time series unit-root. For this study, the Dickey-Fuller (ADF) and the Philips-Peron (PP) unit-root tests chosen for controlling the stationary level concerning structural breaks in time series, also Zivot-Andrews test employed to report the structural break years. Furthermore, each variable’s stationary status, could provide the choice of the appropriate method for the following econometrics steps (Tseng et al. 2020).

*MODEL SPECIFICATION AND ARDL-BOUND APPROACH*

According to the aim, the general EKC model, in which the quadratic effect of the GDP on GHG emissions is supposed to examine the hypothetical EKC. Also, energy consumption may have an impact on GHG emissions; consequently, the multivariate framework is as Eq(2), in which the GHG emission per capita is dependent variable, the GDP and energy consumption per capita are independent variables, and t indicates the time span (1990-2019).

$$GHG_t = f(GDP_t, GDP_t^2, E_t) \quad (2)$$

The study aims to investigate the EKC hypothesis for Sweden. The AFF, industry, and service are the three sectors that present the components of Sweden’s GDP, as well as energy consumption. Given the considerable contributions of these three sectors to the whole economy, the assumption that each sector may impact on GHG emissions of the nation is reasonable. Hence, the econometric specification by taking the natural logarithms of variables, to obtain a meaningful interpretation, for total and sectors of Sweden’s economy is as the Table (3). To avoid multicollinearity problem and understand the impact of energy from different sources on air quality, sectoral models specified in three sub-models, in which the first model includes only GHG emissions and the GDP terms, the second model has fossil energy consumption, and the last one specified with renewable and electricity energies.

**Table 3.** Econometric specification of Sweden's economy

| Equation | Variables | Econometric Model |
|---|---|---|
| Total | GDP, GHG, Energy | $\ln GHG_t = \alpha_0 + \alpha_1 \ln GDP_{1,t} + \alpha_2 \ln GDP_{2,t} + \alpha_3 \ln GDP_{3,t} + \alpha_4 \ln GDP^2{}_{1,t} + \alpha_5 \ln GDP^2{}_{2,t} + \alpha_6 \ln GDP^2{}_{3,t} + \alpha_7 \ln E_{1,t} + \alpha_8 \ln E_{2,t} + \alpha_9 \ln E_{3,t} + u_t$ |
| AFF | GDP, GHG | $\ln GHG_{1,t} = \beta_0 + \beta_1 \ln GDP_{1,t} + \beta_2 \ln GDP^2{}_{1,t} + \psi_t$ |
| | GDP, GHG, Fossil Energy | $\ln GHG_{1,t} = \gamma_0 + \gamma_1 \ln GDP_{1,t} + \gamma_2 \ln GDP^2{}_{1,t} + \gamma_3 \ln F_{1,t} + \xi_t$ |
| | GDP, GHG, Renewable and Electricity Energy | $\ln GHG_{1,t} = \lambda_0 + \lambda_1 \ln GDP_{1,t} + \lambda_2 \ln GDP^2{}_{1,t} + \lambda_3 \ln R_{1,t} + \lambda_4 \ln e_{1,t} + \vartheta_t$ |
| Industry | GDP, GHG | $\ln GHG_{2,t} = \delta_0 + \delta_1 \ln GDP_{2,t} + \delta_2 \ln GDP^2{}_{2,t} + \zeta_t$ |
| | GDP, GHG, Fossil Energy | $\ln GHG_{2,t} = \phi_0 + \phi_1 \ln GDP_{2,t} + \phi_2 \ln GDP^2{}_{2,t} + \phi_3 \ln F_{2,t} + \upsilon_t$ |
| | GDP, GHG, Renewable and Electricity Energy | $\ln GHG_{2,t} = \mu_0 + \mu_1 \ln GDP_{2,t} + \mu_2 \ln GDP^2{}_{2,t} + \mu_3 \ln R_{2,t} + \mu_4 \ln e_{2,t} + \sigma_t$ |
| Service | GDP, GHG | $\ln GHG_{3,t} = \pi_0 + \pi_1 \ln GDP_{3,t} + \pi_2 \ln GDP^2{}_{3,t} + \kappa_t$ |
| | GDP, GHG, Fossil Energy | $\ln GHG_{3,t} = \rho_0 + \rho_1 \ln GDP_{3,t} + \rho_2 \ln GDP^2{}_{3,t} + \rho_3 \ln F_{3,t} + \nu_t$ |
| | GDP, GHG, Renewable and Electricity Energy | $\ln GHG_{3,t} = \theta_0 + \theta_1 \ln GDP_{3,t} + \theta_2 \ln GDP^2{}_{3,t} + \theta_3 \ln R_{3,t} + \theta_4 \ln e_{3,t} + \tau_t$ |

GHG emissions per capita as an environmental quality indicator, the GDP per capita is the income indicator, E represents the per capita total energy consumption, F, R, and e are refers to per capita fossil, renewable, and electricity consumption by sectors. T is the time span, 1,2,3 signs refer to the AFF, industry, and service sectors. α, β, $\gamma$,λ, δ, ϕ, μ, π, ρ, θ relate to coefficients, and u, ψ, ξ, ϑ, ς, υ, σ, κ, ν, τ are error terms of econometric models.

The current study has considered the ARDL procedure, which is introduced by Pesaran and Smith (1995), and Pesaran et al. (2001), as a flexible and dynamic econometric method. Four advantages of ARDL-Bound test method are as follow. Primary, the assumption of stationary at first level I(1) is not necessary for all variables. It means that variables can either take zero I(0) or first integration order I(1). Second, bound tests provide a clear result on the co-integration status. So, the method does not need any further test to evaluate the co-integration status between variables. Third, the method is able to estimate the long and short-term specification to provide robust results. Fourth, the method is also appropriate for a small sample size (Zambrano-Monserrate et al. 2018; Menegaki, 2019). The optimal lag order of the model can select by applying the AIC (Akaike Information Criterion) or SCB (Schwartz-Bayesian Criterion) which is appropriate to select lag length concerning preserve freedom degree as it can suggest the minimum of lag to model.

To use the ARDL bound approach, it is necessary to characterize ARDL equations. For instance, Eq (3) indicates the ARDL model for the AFF sector, in which $\beta_1$ to $\beta_3$ are the coefficients for long-term and $\beta_4$ to $\beta_6$ are the coefficients of short-term. The ARDL Bound test is applied to test the co-integration. The computed F-statistic is compared to the critical values by Nayaran (2005) to realize the co-integration existence. When the computed value is rather than the critical value of upper bound I(I), we accept the alternative hypothesis, as Eq (5), that co-integration exists between the variables. If the computed value is less than the critical value of lower bound I(0), we reject the alternative hypothesis, as Eq (4), that the co-integration existence between the variables. Also, if the calculated value is between the critical value of upper and lower bound, conclusion will be inconclusive (Abu, 2016). After the co-integration examination, the estimation for the long term offered as Eq(6). Finally, the short-term coefficients in Eq (7) are estimated by the ECM, error correction model, with the ARDL model in Eq(8). The negative ECM coefficient represents the adjustment speed; it means that how long the short-term shocks adjust to their long-term values (Tseng et al.

2020). On the other mean, this coefficient shows how fast the variables return to their equilibrium level in the long-term from the short-term (Zambrano-Monserrate et al. 2018).

$$\Delta \ln GHG_{1,t} = \beta_0 + \sum_{p=1}^{P_1} \beta_1 \Delta \ln GHG_{1,t-p} + \sum_{p=1}^{P_2} \beta_2 \Delta \ln GDP_{1,t-p} + \sum_{p=1}^{P_3} \beta_3 \Delta (\ln GDP_{1,t-p})^2 + \beta_4 \ln GHG_{1,t-1} + \beta_5 \ln GDP_{1,t-1} + \beta_6 \ln (GDP_{1,t-1})^2 + \psi_t \tag{3}$$

$$H_0 : \beta_4 = \beta_5 = \beta_6 = 0 \tag{4}$$

$$H_a : \beta_4 \neq \beta_5 \neq \beta_6 \neq 0 \tag{5}$$

$$\Delta \ln GHG_{1,t} = \beta_0 + \sum_{p=1}^{P_1} \beta_1 \Delta \ln GHG_{1,t-p} + \sum_{p=1}^{P_2} \beta_2 \Delta \ln GDP_{1,t-p} + \sum_{p=1}^{P_3} \beta_3 \Delta (\ln GDP_{1,t-p})^2 + \psi_t \tag{6}$$

$$\Delta \ln GHG_{1,t} = \beta_0 + \beta_4 \ln GHG_{1,t-1} + \beta_5 \ln GDP_{1,t-1} + \beta_6 \ln (GDP_{1,t-1})^2 + \psi_t \tag{7}$$

$$\Delta \ln GHG_{1,t} = \beta_0 + \sum_{p=1}^{P_1} \beta_1 \Delta \ln GHG_{1,t-p} + \sum_{p=1}^{P_2} \beta_2 \Delta \ln GDP_{1,t-p} + \sum_{p=1}^{P_3} \beta_3 \Delta (\ln GDP_{1,t-p})^2 + \beta_4 ETC_{1,t-1} + \psi_t \tag{8}$$

**Table 4.** ARDL equations by applying ECM

| Equation | Variables | Econometric Model |
|---|---|---|
| Total | GDP, GHG, Energy | $\Delta \ln GHG_t = \alpha_0 + \sum_{p=1}^{P_1} \alpha_1 \Delta \ln GHG_{t-p} + \sum_{p=0}^{P_2} \alpha_2 \Delta \ln GDP_{1,t-p} + \sum_{p=0}^{P_3} \alpha_3 \Delta \ln GDP_{2,t-p} + \sum_{p=0}^{P_4} \alpha_4 \ln GDP_{3,t-p} + \sum_{p=0}^{P_5} \alpha_5 \Delta \ln (GDP_{1,t-p})^2 + \sum_{p=0}^{P_6} \alpha_6 \Delta \ln (GDP_{2,t-p})^2 + \sum_{p=0}^{P_6} \alpha_7 \Delta \ln (GDP_{3,t-p})^2 + \sum_{p=0}^{P_7} \alpha_8 \Delta \ln E_{1,t-p} + \sum_{p=0}^{P_8} \alpha_9 \ln E_{2,t-p} + \sum_{p=0}^{P_9} \alpha_{10} \ln E_{3,t-p} + \alpha_{11} ETC_{t-1} + u_t$ |
| AFF | GDP, GHG | $\Delta \ln GHG_{1,t} = \beta_0 + \sum_{p=1}^{P_1} \beta_1 \Delta \ln GHG_{1,t-p} + \sum_{p=1}^{P_2} \beta_2 \Delta \ln GDP_{1,t-p} + \sum_{p=1}^{P_3} \beta_3 \Delta (\ln GDP_{1,t-p})^2 + \beta_4 ETC_{1,t-1} + \psi_t$ |
| | GDP, GHG, Fossil | $\Delta \ln GHG_{1,t} = \gamma_0 + \sum_{p=1}^{P_1} \gamma_1 \Delta \ln GHG_{1,t-p} + \sum_{p=0}^{P_2} \gamma_2 \Delta \ln GDP_{1,t-p} + \sum_{p=0}^{P_3} \gamma_3 \Delta (\ln GDP_{1,t-p})^2 + \sum_{p=0}^{P_4} \gamma_4 \Delta \ln F_{1,t-p} + \gamma_5 ETC_{1,t-1} + \xi_t$ |
| | GDP, GHG, Renewable and Electricity | $\Delta \ln GHG_{1,t} = \lambda_0 + \sum_{p=1}^{P_1} \lambda_1 \Delta \ln GHG_{1,t-p} + \sum_{p=1}^{P_2} \lambda_2 \Delta \ln GDP_{1,t-p} + \sum_{p=0}^{P_3} \lambda_3 \Delta (\ln GDP_{1,t-p})^2 + \sum_{p=0}^{P_4} \lambda_4 \Delta \ln R_{1,t-p} + \sum_{p=0}^{P_5} \lambda_5 \Delta \ln e_{1,t-p} + \lambda_6 ETC_{1,t-1} + \vartheta_t$ |
| Industry | GDP, GHG | $\Delta \ln GHG_{2,t} = \delta_0 + \sum_{p=1}^{P_1} \delta_1 \Delta \ln GHG_{2,t-p} + \sum_{p=0}^{P_2} \delta_2 \Delta \ln GDP_{2,t-p} + \sum_{p=0}^{P_3} \delta_3 \Delta (\ln GDP_{2,t-p})^2 + \delta_4 ETC_{2,t-1} + \zeta_t$ |
| | GDP, GHG, Fossil Energy | $\Delta \ln GHG_{2,t} = \phi_0 + \sum_{p=1}^{P_1} \phi_1 \Delta \ln GHG_{2,t-p} + \sum_{p=0}^{P_2} \phi_2 \Delta \ln GDP_{2,t-p} + \sum_{p=0}^{P_3} \phi_3 \Delta (\ln GDP_{2,t-p})^2 + \sum_{p=0}^{P_4} \phi_4 \Delta \ln F_{2,t-p} + \phi_5 ETC_{2,t-1} + \upsilon_t$ |
| | GDP, GHG, Renewable and Electricity | $\Delta \ln GHG_{2,t} = \mu_0 + \sum_{p=1}^{P_1} \mu_1 \Delta \ln GHG_{2,t-p} + \sum_{p=0}^{P_2} \mu_2 \Delta \ln GDP_{2,t-p} + \sum_{p=0}^{P_3} \mu_3 \Delta (\ln GDP_{2,t-p})^2 + \sum_{p=0}^{P_4} \mu_4 \Delta \ln R_{2,t-p} + \sum_{p=0}^{P_5} \mu_5 \Delta \ln e_{2,t-p} + \mu_6 ETC_{2,t-1} + \sigma_t$ |
| Service | GDP, GHG | $\Delta \ln GHG_{3,t} = \pi_0 + \sum_{p=1}^{P_1} \pi_1 \Delta \ln GHG_{3,t-p} + \sum_{p=0}^{P_2} \pi_2 \Delta \ln GDP_{3,t-p} + \sum_{p=0}^{P_3} \pi_3 \Delta (\ln GDP_{3,t-p})^2 + \pi_4 ETC_{3,t-1} + \kappa_t$ |
| | GDP, GHG, Fossil | $\Delta \ln GHG_{3,t} = \rho_0 + \sum_{p=1}^{P_1} \rho_1 \Delta \ln GHG_{3,t-p} + \sum_{p=0}^{P_2} \rho_2 \Delta \ln GDP_{3,t-p} + \sum_{p=0}^{P_3} \rho_3 \Delta \mathrm{l}(\mathrm{n}\, GDP_{3,t-p})^2 + \sum_{p=0}^{P_4} \rho_4 \Delta \ln F_{3,t-p} + \rho_5 ETC_{3,t-1} + \nu_t$ |
| | GDP, GHG, Renewable and Electricity | $\Delta \ln GHG_{3,t} = \theta_0 + \sum_{p=1}^{P_1} \theta_1 \Delta \ln GHG_{3,t-p} + \sum_{p=0}^{P_2} \theta_2 \Delta \ln GDP_{3,t-p} + \sum_{p=0}^{P_3} \theta_3 \Delta (\ln GDP_{3,t-p})^2 + \sum_{p=0}^{P_4} \theta_4 \Delta \ln R_{3,t-p} + \sum_{p=0}^{P_5} \theta_5 \Delta \ln e_{3,t-p} + \theta_6 ETC_{t-1} + \tau_t$ |

*GRANGER CASUALITY TEST*

The co-integration test of the ARDL bound test approach can not present the direction of the causality among variables; hence, Granger (1969) causality test employed to take the relationship status. The VECM, Vector Error Correction Model, can be characterized by Eq(8) as follow.

$$(1-L)\begin{bmatrix}\ln GHG_t\\ \ln GDP_t\\ \ln(GDP_t)^2\end{bmatrix}=\begin{bmatrix}\alpha_1\\ \alpha_2\\ \alpha_3\end{bmatrix}+\sum_{p=1}^{P}(1-L)\begin{bmatrix}c_{11i}\ c_{12i}\ c_{13i}\\ c_{21i}\ c_{22i}\ c_{23i}\\ c_{31i}\ c_{32i}\ c_{33i}\end{bmatrix}\begin{bmatrix}\ln GHG_{t-1}\\ \ln GDP_{t-1}\\ \ln(GDP_{t-1})^2\end{bmatrix}+\begin{bmatrix}\beta_1\\ \beta_2\\ \beta_3\end{bmatrix}[ETC_{t-1}]+\begin{bmatrix}u_{1,t}\\ u_{2,t}\\ u_{3,t}\end{bmatrix} \quad (9)$$

$\Delta = (1-L)$ is the first difference operator, and L refers to the lag operator, which has selected according to the SCB criteria. To have the short term causality, c coefficients, in Eq(9), must estimate and test as a joint null hypothesis as Eq(10). According to the significant value of the F-test, the null hypothesis can either accept or reject to reveal the existence of causality from independent variables to the dependent variable. Moreover, long-term Granger causality can test by β coefficients; they should be negative and highly significant to assume that there is a long-term Granger causality from independent variables to the dependent variable.

$$\begin{aligned}&H_0: c_{11i}=c_{12i}=c_{13i}=c_{21i}=c_{22i}=c_{23i}=c_{31i}=c_{32i}=c_{33i}=0 \rightarrow \textit{no Short term Granger Causality}\\&H_a: c_{11i}\neq c_{12i}\neq c_{13i}\neq c_{21i}\neq c_{22i}\neq c_{23i}\neq c_{31i}\neq c_{32i}\neq c_{33i}\neq 0 \rightarrow \textit{Short term Granger Causality}\end{aligned} \quad (10)$$

*DIAGNOSTIC AND STABILITY TEST*

To have a better estimation, the important steps after estimation are to ensure that models have un-bias, effective, stable parameters, and the error terms should have a normal distribution, a constant mean, as well as variance, no autocorrelation in the first and higher order, and homoscedasticity. Additionally, an appropriate functional form is the other important consideration after estimation. Therefore, to support these issues, the Shapiro-Wilk, Durbin-Watson, Breusch-Godfrey, Ramsey-RESET, CUSUM, CUSUMQ tests is applied to ensure that the estimated parameters and models are valuable to interpretation.

*DATA COLLECTION*

According to the aim of the study, we employed annual total and sectoral data from 1990-2019 of GHG emissions (in Thousand Tone), GDP (in the constant local currency, Million Kr), total energy consumption (Tone of oil equivalent), fossil energy consumption (Tone of oil equivalent), renewable energy consumption (Tone of oil equivalent), electricity energy consumption (Tone of oil equivalent), population (million), and the CPI. These data collected from the World Bank, European Statistical Office (Eurostat), and Statistics Sweden (SCB). All data converted to per capita which was more appropriate for representing the real economic development and environmental quality. Also, they transformed to natural logarithms level because of the difference of variables unit. As Tseng et al. (2020), this transformation has many advantages in minimizing autocorrelation, heteroscedasticity, and sharpness of data. Furthermore, it can help to present reliable outcomes. Summary of variables in the natural logarithm form presented in the Table (5).

**Table 5.** Summary of variables

| Variable | Description |
|---|---|
| Lg2 | AFF GDP |
| Lg3 | Industry GDP |
| Lg4 | Service GDP |
| Lg6 | AFF $GDP^2$ |
| Lg7 | Industry $GDP^2$ |
| Lg8 | Service $GDP^2$ |
| Le1 | Total energy consumption in AFF |
| Le2 | Total energy consumption in industry |
| Le3 | Total energy consumption in service |
| Le4 | Fossil energy consumption in the AFF |
| Le5 | Renewable energy consumption in the AFF |
| Le6 | Electricity energy consumption in the AFF |
| Le7 | Fossil energy consumption in the industry |
| Le8 | Renewable energy consumption in the industry |
| Le9 | Electricity energy consumption in the industry |
| Le10 | Fossil energy consumption in the service |
| Le11 | Renewable energy consumption in the service |
| Le12 | Electricity energy consumption in the service |
| Lp1 | Total GHG emission |
| Lp2 | GHG emission in the AFF |
| Lp3 | GHG in the industry |
| Lp4 | GHG in the service |

## *DATA ANALYSIS*

This part of the study dedicates to Sweden's economical development and environmental progress analysis according to the collected data. Following figures are presented to explain the sectoral GDP, energy consumption and GHG emissions per capita. Figure (1) describes the fixed price GDP per capita that has an increasing trend before 2008 when experiences a downfall due to Global Financial Crisis (GFC), then shows stable trend for the rest of years. All sectors have an increasing trend, which is considerable in service and industry sectors so that most of the time, industry has been dominated one. This figure is evident evidence for the transformational process from AFF to an industrial and service society in Sweden where they are prevalent contributor of the total GDP per capita during the last three decades. From environmental perspective, according to Figure (2), the total GHG emission per capita has been decreasing over the time when the AFF have sharply increasing behavior unlike service sector, and the industry sector has stable trend. These trends are due to Sweden's environmental movements that have intensified during the last six years for both industry and service activities whereas there are no robust policies and legislations regarding AFF. As the AFF sector has crucial role in developed and developing countries; so, reducing GHG emissions is necessary for sustainable development.

Economic growth without the use of energy is imperfect process; it means that energy use has a fundamental role for an economy, which is highlight in high-income economies, as well as Sweden. Therefore, considering energy consumption, as one of the GHG emissions factors, in growth investigations is critically important in climate policy development. Because it can provides critical information for policymakers on the design and evaluation of policy instruments aimed at achieving further the mitigation of the GHG emission associated with energy use (Shahbaz et al. 2019). The following figures show the status of energy consumption per capita in Sweden's total and economic sectors. According to figures (3-a:f), fossil energy consumption takes the first place in Sweden's economy, as well as AFF and service sectors during 1990-2019. The industry sector, due to prevalent sector in whole economy, is the most contributor sector in energy consumption, which uses more renewable energy and electricity. It seems that investment in new energy-efficient technologies in Sweden's industry sector has played a considerable role in energy and environmental objectives. The service sector, due to transportation activities, uses a high amount of fossil fuels, so this sector may responsible for around the most share of GHG emission per capita, as presented in Figure (2). Also, AFF sector, in terms of production and one of the main GDP contributors, has an unfavorable fossil energy share in energy mix. This sector consists of forestry, fisheries, livestock, and crops; currently so that contribute an estimated 97% of total Methane emissions.

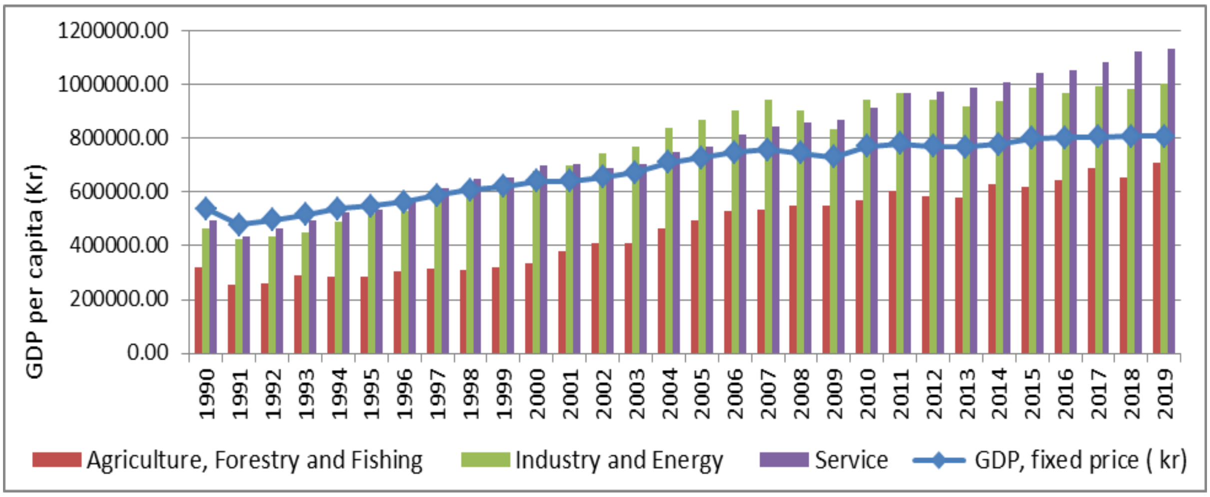


**Fig. 1.** GDP per capita by the economic sector in Sweden during (1990-2019).Sources: Statistics Sweden (2020).

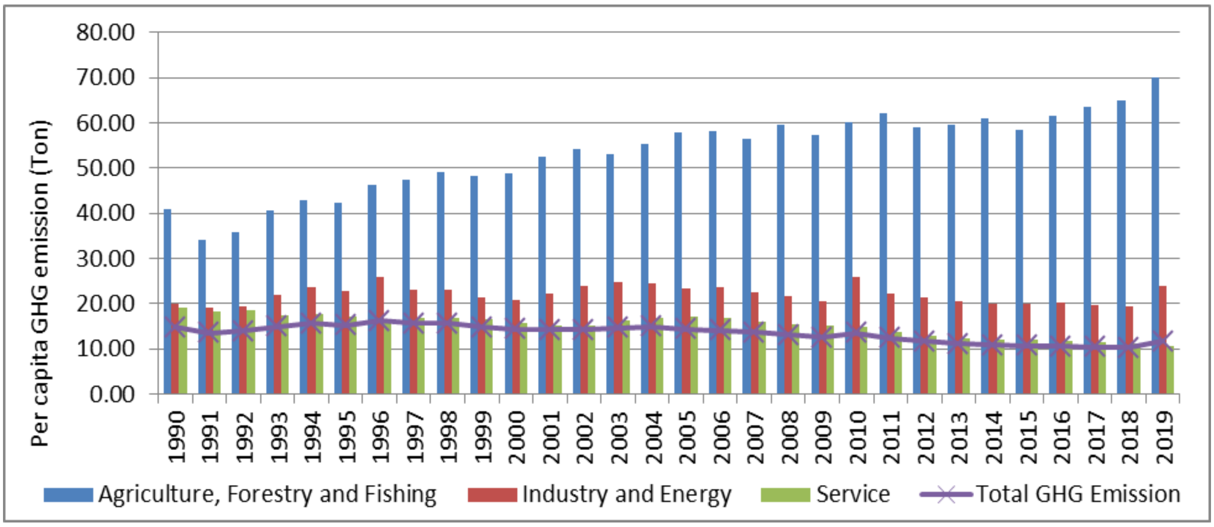


**Fig. 2.** GHG emissions per capita by the economic sector in Sweden during (1990-2019). Sources: Eurostat (1990-2019).

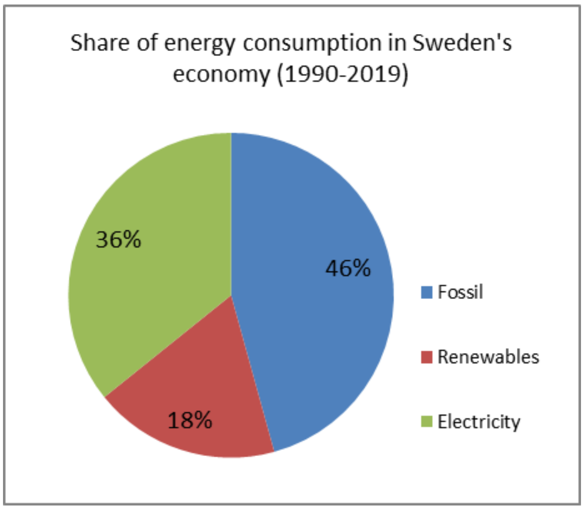


**Fig. 3.a** Per capita share of energy consumption in Sweden's economy (1990-2019).

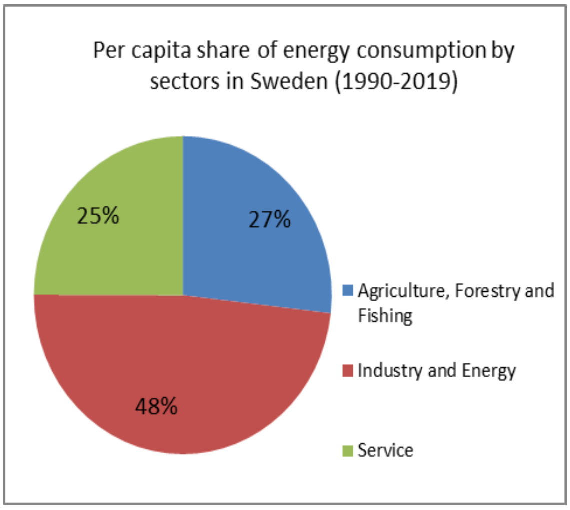


**Fig. 3.b** Per capita share of energy consumption by sectors in Sweden (1990-2019).

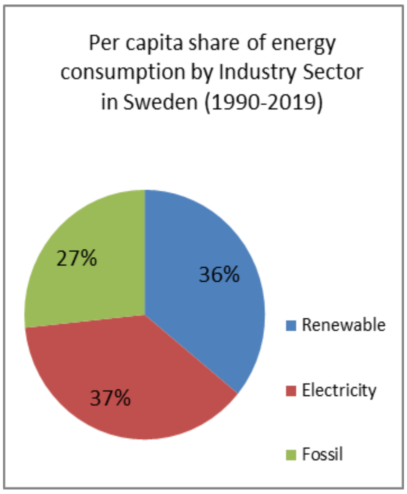


**Fig. 3.c** Per capita share of energy consumption by industry sector in Sweden (1990-2019).

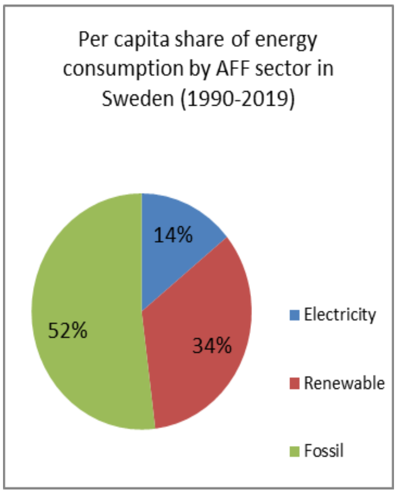


**Fig. 3.d** Per capita share of energy consumption by AFF sector in Sweden (1990-2019).

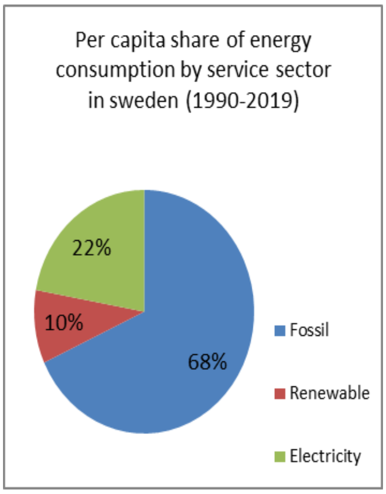


**Fig. 3.f** Per capita share of energy consumption by service sector in Sweden (1990-2019).

## RESULTS & DISCUSSION

In the primary stage of the result analysis, stationary level of variables concerning structural point checked by different tests as the Table (A) in Appendix; because, for ARDL model, an integration of variables should be either I(0) or I(1), or both but not I(2). According to the result of the ADF and the PP stationary tests, we found that the variables were stationary at I(1). In the following, the Zivot-Andrews test revealed the year that variables had a structural break. Also, the optimum lag length of each variable was determined based on the BIC criteria as it selected minimum lag.

The result from disaggregated model estimation was important since it supplements the total estimation analysis; also it provided evidence of each sector on total GHG emissions. So, the observed results could thus differ from the aggregated analysis. To proceed, ARDL model was carried out for total and different sectors of Sweden's economy. The results of the total model in Table (6) revealed that the F-statistic of bound test rejected the null hypothesis in relation to no level relationship. There were long-term co-integration association among total

GHG per capita, GDP per capita of individual sectors, and total energy consumption per capita by sectors. Before the interpretation of the estimated coefficients, it was necessary to consider the presence of Granger Causality between variables of each equation. In the total model, there was causality from the GDP, $GDP^2$, and total consumption per capita of AFF, industry, and service to total GHG emissions per capita, the exception of the $GDP^2$ of AFF sector. The results of the coefficient in the long-term revealed the effect of GDP and energy consumption per capita of the AFF, industry, and service on total GHG emission per capita. In this regard, a one percent increases in the GDP of the AFF sector, increased air pollution by about 9.06 %, while the industry and service sector decreased GHG emissions by about 0.34% and 1.70%, respectively. Also, an increase in energy consumption by AFF and service sector, the total GHG emission led to increasing by about 0.15% and 0.35%. In contrast, the industry sector supported the environment by decreasing the total GHG emissions, that is, industry activities were more efficient from an environmental point of view. About short-term coefficients, GDP of industry and service was one of the environmental degradation factors during the last three decades. The long-term coefficients of the GDP for industry and service sectors were lower than short-term estimation, which proposed that the GDP had a greater impact on emissions in the short-term. In terms of the Energy Environmental Kuznets Curve (EEKC) hypothesis, the coefficient of industry income in the long-term was negative, which these results confirmed the existence of the EEKC hypothesis in Sweden's economy. This analysis by individual economic sectors highlighted the total EEKC pattern was impressed by different economic activities. A significant and negative sign of the ETC coefficient indicated the adjustment speed of the economy that the equilibrium experiences a shock. The discrepancy from the short-term was corrected by 100% toward the long-term equilibrium. On other mean, the speed of transformation between shocks and the trend was modified in less than a year. Finally, the outcomes of post-estimation tests, including Durbin-Watson, Breusch-Godfrey, and Shapiro-Wilk, indicated that no autocorrelation in the first and high orders, no heteroscedasticity, no-normality in residuals. The RESET-Ramsey test confirmed the appropriate functional form for the model. For stability of coefficient, the CUSUM and CUSUMQ tests results showed a stable trend within the bounds of significant level, that was explain the model's stability.

To sum up, it was urgent that Sweden have designed policies, concerning energy and environment that provided unclear effects on total economy. Industry could support the environment by improved technology and implemented energy policies. This could be an effective sector to reduce GHG emissions. About service sector, it was clear that the sector had paradoxical effects on the economy. Further economic growth through service activities, like IT services was followed by environmental reservation; however fossil energy policies needed more evolutions. Further economic growth by AFF activities reduced environmental quality, because of lacking specific energy policies.

Results of sub-models highlighted the effect of individual sectors on Sweden's economy, including AFF, industry, and service. Because it allowed us to observe the differentiated potential of each sector and understand the driving factors of GHG emission at the sectoral level. For this aim, a summary of the estimated ARDL models of the individual sector concerning different kind of energy consumption presented in the Tables (7, 8, and 9).

**Table 6.** Results of the ARDL(1,1,1,1,1,1,0,0,1,0,0) model for total economy

| Element | Variable | Coefficient | St. error | t-statistic | Causality (From X to Y) |
|---|---|---|---|---|---|
| LR | Lg2 | 9.06* | 4.94 | 1.83 | 4.45* |
| | Lg3 | -0.34* | 0.18 | -1.87 | 4.87* |
| | Le4 | -1.70*** | 0.58 | -2.89 | 4.72* |
| | Lg6 | 0.10** | 0.03 | 2.74 | 4.08 |
| | Lg7 | -0.52* | 0.29 | -1.82 | 4.49* |
| | Lg8 | 0.007 | 0.009 | 0.81 | 10.99*** |
| | Le1 | 0.15*** | 0.04 | 3.09 | 6.01** |
| | Le2 | -0.40* | 0.22 | -1.83 | 6.52** |
| | Le3 | 0.35*** | 0.10 | 3.43 | 6.38** |
| SR | D.lg2 | 1.47 | 3.64 | 0.41 | |
| | D.lg3 | 0.51*** | 0.17 | 2.97 | |
| | D.lg4 | 1.45*** | 0.44 | 3.28 | |
| | D.lg6 | -0.10*** | 0.03 | -3.10 | |
| | D.lg7 | -0.08 | 0.21 | -0.38 | |
| | D.le3 | -0.05 | 0.20 | -0.29 | |
| | Cons | -28.73 | 26.81 | -1.07 | |
| ADJ | ETC | -1.00*** | 0.17 | -6.34 | |
| Adj-$\mathbf{R}^2$ | | | 88% | | |
| LL | | | 92.02 | | |
| Bound Test | | | F=9.76*** | | |
| Diagnostic | Normality | | -0.31 | | |
| | DW | | 2.04 | | |
| | BG | | 2.83 | | |
| | BG(het) | | 0.88 | | |
| | Ramsey | | 2.85 | | |
| Stability | CUSUM | | Stable | | |
| | CUSUMQ | | Stable | | |

Notes: ***, **, and * represent 1%, 5% and 10% of significance levels respectively.

Based on the Table (7), evidence from the estimated first equation indicated that there was the long-term co-integration association among GHG emissions and the GDP in the AFF sector. Granger causality test confirmed the directional relation from income to GHG emissions, in which an increase in the GDP intensified GHG emissions by about 0.79%. In terms of the EKC hypothesis, the result provided a monotonic increasing pattern between economic development and environmental degradation. Post- estimation tests presented the valuable coefficient and model for interpretation. Furthermore, the discrepancy from the short-term was corrected by 19% toward the long-term equilibrium. In the second estimated equation, the bound test confirmed the long-term relationship, and the causality test indicated the casual relationship from both income and fossil energy consumption to GHG emissions. Further investigation revealed that fossil energy consumption had an only the short-term impact on environmental degradation so that by about 0.80% of GHG emission increase was due to an one percent increase at income level. These results, confirmed a monotonic increasing pattern for income and environmental degradation concerning fossil energy consumption. The discrepancy from the short-term was corrected by 23% toward the long-term equilibrium. Finally, the last equation confirmed a monotonic increasing relationship between economical development and environmental degradation regarding renewable and electricity energy consumption. The bound test result showed the long-term co-integration association, and the causality test confirmed causal relationship from the GDP, renewable, and electricity consumption to GHG emission per capita, while renewable and electricity consumption were not significant in the both short and long-term. The short-term coefficient of the GDP was lower than the long-term estimation, economic development in the AFF sector had a greater impact on environment quality in the long-term. The speed of transformation between shocks and the trend was modified in less than a year. Also, post estimation tests provided fit functional model, normal residuals, efficient, unbias, and the stable coefficient for analysis. As a result, it was clear that, AFF activities with or without energy consumption had a negative effect on environment quality. Therefore, energy policies for further economic growth would support the environment for a short time. On the other mean, the sector needed policies concerning non-energy sources to minimize Methane and Nitrogen dioxide emissions.

**Table 7.** Results of the ARDL model for the AFF sector

| Equation | Element | Variable | Coefficient | St. error | t-statistic | Causality (From X to Y) |
|---|---|---|---|---|---|---|
| GHG, GDP ARDL(1,1,1) | LR | Lg2 | 0.79* | 0.33 | 2.38 | 10.66*** |
| | | Lg6 | -0.08 | 0.10 | -0.85 | 3.87 |
| | SR | D.lg6 | -11.77*** | 2.95 | -3.99 | |
| | | Cons | -12.02*** | 4.42 | -2.72 | |
| | ADJ | ETC | -0.19* | 0.11 | -1.75 | |
| | Adj-R² | | | 69% | | |
| | LL | | | 60.31 | | |
| | Bound Test | | | F=5.08** | | |
| | Diagnostic | Normality | | 1.04 | | |
| | | DW | | 2.03 | | |
| | | BG | | 1.17 | | |
| | | BG(het) | | 1.79 | | |
| | | Ramsey | | 1.31 | | |
| | Stability | CUSUM | | Stable | | |
| | | CUSUMQ | | Stable | | |
| GHG,GDP and Fossil Energy ARDL(1,1,0,1) | LR | Lg2 | 0.80*** | 0.28 | 2.88 | 9.63** |
| | | Lg6 | -0.04 | 0.06 | -0.74 | 1.43 |
| | | Le4 | -0.14 | 0.19 | -0.74 | 10.15*** |
| | SR | D.lg1 | 0.33** | 0.13 | 2.45 | |
| | | D.le4 | 0.10** | 0.04 | 2.28 | |
| | | Cons | 2.11*** | 0.51 | 4.08 | |
| | ADJ | ETC | -0.23** | 0.1710 | -2.32 | |
| | Adj-R² | | | 60% | | |
| | LL | | | 73.75 | | |
| | Bound Test | | | F=5.57*** | | |
| | Diagnostic | Normality | | -2.76 | | |
| | | DW | | 2.04 | | |
| | | BG | | 1.57 | | |
| | | BG(het) | | 0.65 | | |
| | | Ramsey | | 0.37 | | |
| | Stability | CUSUM | | Stable | | |
| | | CUSUMQ | | Stable | | |
| GHG,GDP, Renewable, Electricity Energy ARDL(1,1,0,0,0) | LR | Lg2 | 0.82** | 0.37 | 2.17 | 19.02*** |
| | | Lg6 | -0.11 | 0.12 | -0.92 | 1.35 |
| | | Le5 | 0.07 | 0.21 | 0.33 | 16.59*** |
| | | Le6 | 0.11 | 0.22 | 0.54 | 25.27*** |
| | SR | D.lg2 | 0.61*** | 0.09 | 6.49 | |
| | | Cons | 2.26*** | 0.62 | 3.65 | |
| | ADJ | ETC | -0.19* | 0.10 | -1.68 | |
| | Adj-R² | | | 68% | | |
| | LL | | | 60.84 | | |
| | Bound Test | | | F=3.55* | | |
| | Diagnostic | Normality | | 1.08 | | |
| | | DW | | 2.06 | | |
| | | BG | | 1.02 | | |
| | | BG(het) | | 1.22 | | |
| | | Ramsey | | 1.17 | | |
| | Stability | CUSUM | | Stable | | |
| | | CUSUMQ | | Stable | | |

**Table 8.** Results of the ARDL model for the industry sector

| Equation | Element | Variable | Coefficient | St. error | t-statistic | Causality (From X to Y) |
|---|---|---|---|---|---|---|
| GHG, GDP ARDL(1,0,0) | LR | Lg3 | 0.52* | 0.28 | 1.83 | 19.80*** |
| | | Lg7 | -0.009** | -2.33 | -2.33 | 20.03*** |
| | SR | Cons | 3.35 | 2.38 | 1.41 | |
| | ADJ | ETC | -0.63*** | 0.20 | -3.12 | |
| | Adj-$R^2$ | | 33% | | | |
| | LL | | 33.02 | | | |
| | Bound Test | | F=3.38* | | | |
| | Diagnostic | Normality | 1.12 | | | |
| | | DW | 1.98 | | | |
| | | BG | 0.007 | | | |
| | | BG(het) | 1.89 | | | |
| | | Ramsey | 0.54 | | | |
| | Stability | CUSUM | Stable | | | |
| | | CUSUMQ | Stable | | | |
| GHG,GDP and Fossil Energy ARDL(1,1,0,1) | LR | Lg3 | 0.41* | 0.23 | 1.76 | 15.77*** |
| | | Lg7 | -0.07** | 0.06 | -3.48 | 13.45*** |
| | | Le7 | 0.99*** | 0.19 | 5.18 | 14.24*** |
| | SR | D.lg7 | -0.02** | 0.12 | -2.21 | |
| | | Cons | 0.61 | 1.41 | 0.43 | |
| | ADJ | ETC | -0.86*** | 0.14 | -6.10 | |
| | Adj-$R^2$ | | 62% | | | |
| | LL | | 49.46 | | | |
| | Bound Test | | F=12.08*** | | | |
| | Diagnostic | Normality | 0.05 | | | |
| | | DW | 1.80 | | | |
| | | BG | 0.23 | | | |
| | | BG(het) | 1.27 | | | |
| | | Ramsey | 1.67 | | | |
| | Stability | CUSUM | Stable | | | |
| | | CUSUMQ | Stable | | | |
| GHG,GDP, Renewable, Electricity Energy ARDL(1,1,0,0,0) | LR | Lg3 | -1.12* | 0.64 | -1.75 | 63.93*** |
| | | Lg7 | 0.01 | 0.02 | 0.60 | 29.12*** |
| | | Le8 | -0.47* | 0.26 | -1.82 | 23.87*** |
| | | Le9 | 1.54* | 0.91 | 1.70 | 14.14*** |
| | SR | D.lg3 | 0.67** | 0.31 | 2.13 | |
| | | Cons | 4.59 | 3.17 | 1.45 | |
| | ADJ | ETC | -0.19* | 0.10 | -1.68 | |
| | Adj-$R^2$ | | 55% | | | |
| | LL | | 40.21 | | | |
| | Bound Test | | F=4.04* | | | |
| | Diagnostic | Normality | 0.05 | | | |
| | | DW | 2.26 | | | |
| | | BG | 1.39 | | | |
| | | BG(het) | 0.81 | | | |
| | | Ramsey | 1.27 | | | |
| | Stability | CUSUM | Stable | | | |
| | | CUSUMQ | Stable | | | |

Table (8) representing the results of industry equations, which was estimated by the ARDL bound test approach. Primary, all estimated equations rejected the null hypothesis of the bound test and confirmed the co-integration association among variables. Additionally, the Granger causality test revealed the causal relationship from independent variables, including the GDP, $GDP^2$, and energy consumption of different sources, to GHG emissions per capita in the industry sector. According to the post-estimation results, all the coefficients were interpretable because of normal residual, no heteroscedasticity, no first and serial autocorrelation, stability during the period, and fit functional model. The negative ETC coefficients in the first, second, and third equations signified that the discrepancy from the short-term corrected by 63%, 86%, 19%, and toward the long-term equilibrium, respectively. In terms of the EKC hypothesis, the evidence of the first equation provided the EKC pattern with the turning point in 1996, in which an increase in the GDP per capita, enhanced by 0.52% of GHG emissions per capita. The second and third models presented the different patterns. With the fossil energy consumption, there was the Energy Environmental Kuznets Curve (EEKC) pattern, in which an increase in fossil energy consumption per capita diminished environmental quality by 0.99% rise in GHG emissions. At the beginning of time, the industry sector destroyed the environment by increasing fossil activities while experienced environmental support by further consumption. Also, a 0.41% increase in GHG emissions was related to a rise in industry income. Moreover, the third model presented the monotonic decreasing pattern concerning renewable and electricity consumption, which reflected the supportive role of renewable energy in the industry, whereas electricity consumption intensified by about 1.54% of GHG emission due to an increase in consumption. Besides, economic development reduced by 1.12% of GHG emissions in the industry sector. A remarkable result was that the industry sector of Sweden's economy had a supportive role on environmental quality; however, the effect of fossil energy was significant. In the early stage of economic growth, activities had reduced the air quality due to increase in fossil energy consumption. Further growth along with renewable energy policies could improve the environment.

The last table was belonging to the service sector. Based on the Table (9), there were co-integration associations among the GDP,$GDP^2$, GHG, and different types of energy consumption as the F-statistic was greater than the critical value in all equations. Granger Causality reported the direction of relationship from independent variables to GHG emissions per capita in the service sector, the exception of the $GDP^2$ in the second and third equation. A significant and negative sign of the ETC coefficient in all equation indicated the adjustment speed of the economy, the rate of transformation between shocks and the trend modified in less than a year. According to the first equation, there was an EKC pattern between the GDP and GHG emissions, in which economic development increased by about 1.09% of GHG emissions before 1996, then had a supportive role in environmental quality. In the following equations, a monotonic increasing pattern confirmed for the second equation since both income development, and fossil energy consumption had a destructive impact in environment. Fossil energy consumption due to transportation service had a ruinous impact on environmental quality in which 0.53% and 0.35% rise of GHG emissions related to an increase in fossil energy consumption by service activities in the long-term, and the short-term, respectively. Regarding renewable and electricity consumption, environmental quality and economic development of the service sector had a monotonic decreasing pattern. Based on the reported evidence, renewable energy diminished GHG emissions by about 2.13% due to an increase in consumption, while electricity consumption in service activities implied a destructive role in environmental quality. Also, income development had a supportive role in the environment during the last three decades.

As a result, service sector like industry mostly had a supportive effect on air quality. It seems that service activities that engaged with fossil resources, like transportation, had a destructive role on environment, and it needs policies to minimize the Carbon emissions.

**Table 9.** Results of the ARDL model for the service sector

| Equation | Element | Variable | Coefficient | St. error | t-statistic | Causality (From X to Y) |
|---|---|---|---|---|---|---|
| GHG, GDP ARDL(1,1,0) | LR | Lg4 | 2.09* | 1.12 | 1.87 | 8.17** |
| | | Lg8 | -0.05*** | 0.01 | -2.91 | 5.28* |
| | SR | D.lg4 | 0.33** | 0.15 | 2.15 | |
| | | Cons | -0.08 | 1.41 | -0.06 | |
| | ADJ | ETC | -0.19** | 0.08 | -2.16 | |
| | Adj-$R^2$ | | | 30% | | |
| | LL | | | 61.13 | | |
| | Bound Test | | | F=4.64* | | |
| | Diagnostic | Normality | | 0.72 | | |
| | | DW | | 1.86 | | |
| | | BG | | 1.88 | | |
| | | BG(het) | | 0.98 | | |
| | | Ramsey | | 0.24 | | |
| | Stability | CUSUM | | Stable | | |
| | | CUSUMQ | | Stable | | |
| GHG,GDP and Fossil Energy ARDL(1,0,0,1) | LR | Lg4 | 2.02* | 1.13 | 1.79 | 9.63** |
| | | Lg8 | -0.03 | 0.062 | -1.29 | 1.43 |
| | | Le10 | 0.53* | 0.30 | 1.79 | 10.15*** |
| | SR | D.le10 | 0.35** | 0.16 | 2.12 | |
| | | Cons | -1.31 | 1.31 | -1.0 | |
| | ADJ | ETC | -0.21** | 0.10 | -2.04 | |
| | Adj-$R^2$ | | | 45% | | |
| | LL | | | 64.46 | | |
| | Bound Test | | | F=3.77* | | |
| | Diagnostic | Normality | | -0.38 | | |
| | | DW | | 2.01 | | |
| | | BG | | 1.60 | | |
| | | BG(het) | | 0.27 | | |
| | | Ramsey | | 0.86 | | |
| | Stability | CUSUM | | Stable | | |
| | | CUSUMQ | | Stable | | |
| GHG,GDP, Renewable, Electricity Energy ARDL(1,1,1,5,2) | LR | Lg4 | -5.16*** | 0.58 | -8.83 | 15.15*** |
| | | Lg8 | -0.02 | 0.03 | -0.66 | 7.70** |
| | | Le11 | -2.13*** | 0.28 | -7.40 | 5.80* |
| | | Le12 | 2.60*** | 0.73 | 3.55 | 5.87* |
| | SR | D.lg4 | 1.0*** | 0.32 | 3.10 | |
| | | D.lg8 | -0.02** | 0.01 | -2.19 | |
| | | D.l4.le11 | -0.17*** | 0.04 | -4.01 | |
| | | D.l.le12 | 0.51*** | 0.17 | 2.92 | |
| | | Cons | 29.25*** | 5.02 | 5.82 | |
| | ADJ | ETC | -0.33*** | 0.04 | -6.87 | |
| | Adj-$R^2$ | | | 90% | | |
| | LL | | | 88.45 | | |
| | Bound Test | | | F=18.67*** | | |
| | Diagnostic | Normality | | 0.78 | | |
| | | DW | | 1.98 | | |
| | | BG | | 0.00 | | |
| | | BG(het) | | 0.84 | | |
| | | Ramsey | | 1.85 | | |
| | Stability | CUSUM | | Stable | | |
| | | CUSUMQ | | Stable | | |

## COCLUSION

This paper analyzed the relationship between economic development, environmental quality, and energy consumption from different sources at the national and sectoral level in Sweden. For this aim, ARDL bound approach test employed in this paper as a new comprehensive and dynamic technique to test the co-integration, and estimate both short and long-term relationships. In Table (10), estimated models provided interesting empirical results on both the EEKC and the EKC hypothesis from 1990 to 2019. The empirical evidence suggested that sectoral analysis highlighted the different behavior of the individual sector, as well as the contribution of each sector to the whole economy.

According to the results of the total model, the GDP of the AFF sector had a destructive role in Sweden’s air quality, while industry and service GDP, as a major share of the total GDP, revealed a supportive role in the environment concerning total energy consumption. Regarding energy consumption, industry unlike service and AFF sectors had a supportive effect on environmental quality, because it has 48% share of total energy consumption in the whole economy, in which 37% of this consumption supplied from renewable resources. Also, the efficiency of fossil-related activities was one of the other supportive factors.

About the AFF sector, different kinds of energy consumption had no impressive effect on GHG emissions in the long-term; policymakers needed to promote reduction policies concerning both Methane and Nitrous Oxide from soil and livestock activities by the focus on organic farming and new livestock production system. Evidence of the industry model highlighted the supportive role of this sector with or without different types of energy consumption. It seems that Sweden’s industry shifted away from severs to lower energy-intensive production, and also there were significant energy efficiency improvements in this sector during the last years. Therefore, policymakers needed to implement efficient fossil and electricity consumption policies to reduce GHG emissions. The services sector needed more attention concerning environmental stabilization. Transportation services were responsible for around 68% of fossil energy consumption, which had the both short and the long-term effects on GHG emissions. This kind of energy didn’t show the turning point over the period; fossil energy consumption in the service sector needed efficient policies. Finally, sectoral analysis in the EKC context presented the disaggregated results could reveal differences across different sectors, which was more informative for policymakers to achieve energy-climate aims.

It was for sure that researches will have some limitations and it is normal. However, it is critically important for us to be striving to minimize the range of scope of limitations throughout the research process. The limitations of the study were time period, and, lack of previous sectoral research studies on the topic. Future studies need to develop the research database, examine the potential each sector on environment quality, and implement dynamic methods.

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## CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

## LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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