The linkage between CO₂, FDI, economic growth, and value-added: A European perspective

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Research Article

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The linkage between CO₂, FDI, economic growth, and value-added:

A European perspective

Abstract: This article aims to investigate the linkage among CO₂ emissions, Foreign Direct Investment (FDI), economic growth, Gross Value Added (GVA) of different sectors namely agriculture, service, manufacturing, and resource extensive industries including construction sectors in four European regions Eastern Europe (EE), Southern Europe (SE), Northern Europe (NE) and Western Europe (WE). This article uses the 3SLS simultaneous equation estimation during the period of 2000 to 2018. This study is the extension of seeing the challenges in policy implication in reducing CO₂ emission in technologically rich economies. This article concluded that the causality among variables CO₂ emission, economic growth, FDI, and all four sectors GVA is varied according to the regions. However, the CO₂ emission has bidirectional causality with each industrial sector's GVA.

Keywords: *CO₂ emission; Foreign Direct Investment; FDI; Gross Value added; economic growth; four-way linkage; service sector; manufacturing sector; agriculture sector; mining and natural resources; Europe; Western Europe; Northern Europe; Southern Europe; Eastern Europe.*

1 Introduction

Academic scholars and policymakers showed increasing interest in how to reduce carbon emissions without sacrificing economic growth. The severity of this issue is described in the (UNIDO, 2019) report. Industrial energy is estimated to increase annually by 1.8% and 3.1% further in the next 25 years. This increasing energy demand creates worry-ness due to limited energy resources and seeks sustainable economic growth. Growing industries always seek to improvise the value addition with the limited resource and minimizing the CO₂ emission although it is still a challenge of latest works. The developed countries such as European regions achieved some progress in reducing CO₂ emission, progress through development in technology and innovation and, improving the efficiency of energy and curbing energy use in recent years. However, achieving sustainability along with increasing production requires further effort and investigations to enable the developed economies to achieve such prospective goals.

This study is an attempt to answer the question of how do economic growth, FDI inflows, and sectoral GVAs (agriculture sector, service sector, manufacturing sector, and construction sector) lead to the environmental degradation in Eastern Europe (EE), Southern Europe (SE), Northern Europe (NE), and Western Europe (WE) regions? This research tries to identify which sectors need more attention to achieve sustainability and identify specific policies that can help to develop European region economies in their response to climate change. Concentrating on different sectors agriculture sector, manufacturing sector, service sector, and construction and mining sector. This research inspires by the fact that different sectors agriculture sector, manufacturing sector, service sector, and construction sector need different emissions mitigation actions and energy policies. All together these four sectors produce 33.5% world's greenhouse gasses (Ritchie & Roser, 2016).

Therefore, it is well important to discuss the implication of all of these sectors on environmental degradation.

This work attempts to fill this literature gap by addressing the question of whether the FDI, economic growth, and GVAs are causation of CO₂ emission over the year 2000 to 2018 in European regions. The present study is different from the previous studies in the following way. This paper uses simultaneous-equation modeling to study the four-way linkages between FDI inflows, CO₂ emissions, economic growth, with GVAs (agriculture, mining, manufacturing, and services) sectors in the European region of EE, NE, WE, and SE countries. This four-way linkage enables us to examine the interrelationship between economic growth, FDI, CO₂ emissions, and GVAs at the same time. Specifically, this study uses a model made up of 16 structural equations that allow us to examine the simultaneous influence of (i) the FDI inflows, CO₂ emissions, and GVA of agriculture, mining, manufacturing, and services on economic growth; (ii) the economic growth, CO₂ emissions, and GVA of agriculture, mining, manufacturing, and services sector on FDI inflows; and (iii) the economic growth on FDI and GVA of agriculture, mining, manufacturing, and services sector on CO₂ emissions; and (vi) the FDI, CO₂ emissions, and economic growth on GVA of agriculture, mining, manufacturing, and services. Therefore, to the best of the authors' knowledge, this is one of the first studies that simultaneously investigate GVAs of all four sectors in single research for the EE, SE, WE, and NE regions. The, disaggregated study of GVAs sector-wise is important as it can provide a precise relationship between each sector and its impact on CO₂ emission. We considered a homogeneous panel of countries based on their similarity in basic economic structure and geographical proximity, the bifurcation of four groups is according to the (Singh & Gal, 2020). The findings of this study are immensely important to the design of European Union environmental policy to achieve the pledge of a significant reduction of CO₂ emissions.

The rest of the article is organized as follows: Section 2, provides a critical review of the existing literature. Section 3, data description and explanation of variables and, research methodology of empirical estimation and estimated equations. Section 4, presents the results and discussion. Finally, section 5, discusses the concluding remarks, elaboration of policy implications, limitations, and future recommendations.

2 Literature

The relation between CO₂ emission, FDI, GDP per capita, and GVAs has been widely investigated in the last two decades through the various empirical and theoretical literature. But the relationship between CO₂ emission and sectoral GVAs has been a subject of debate and gained importance in the last decade. The literature on CO₂ emission, FDI, economic growth, and industrial sector is classified into three groups. Some studies examine the individual countries (Agboola & Bekun, 2019; Alamdarlo, 2016; Asom & Ijirshar, 2016; Prastiyo et al., 2020; Rauf et al., 2018; Samargandi, 2017). Other research focused on income groups (Jebli et al., 2020; Zhang et al., 2019). While some other studies focused on geographic regions (Alam, 2015; Ceylan & Özkan, 2013; Kołodziejczak, 2020). Finally, some studies presented the overview (Friesenbichler, 2016; H. Liu & Fan, 2017; Murshed et al., 2020).

2.1 FDI and environmental pollution

The research on the linkage between FDI and environmental pollution is classified into three categories. First, support the pollution haven hypothesis, to avoid costly environmental compliance in their home country from pollution-intensive sectors firms relocate to the weak environmental regulation host country. Therefore, firms significantly increase the overall level of pollution to achieve the desired production. The pollution heaven hypothesis generally exists in the low- and middle-income countries, pollution haven hypothesis exists in the short-run these income group countries in long-run low- and middle-income countries have pollution heaven hypothesis. The reason is that in the beginning foreign multinational corporation tend to improve the efficiency in the limited use of resources to tackle the environmental pollution problem in the host country's domestic enterprises, whereas, on the other hand, they promote the development of the host countries' environmental protection technology via knowledge diffusion, technology spillover, transfer of funds and other ways. The transnational corporations' (TNCs)' investment boost the technological progress and host country's economic development and helps the host country's domestic enterprises to reduce its environmental issues.

Shao, (2018) investigate the effect of FDI on carbon intensity using GMM estimation of the different income levels of the country group using panel data of 188 countries during 1990-2013. Their result supported the pollution halo hypothesis in high-income countries, so, these country groups have to focus on the quality of FDI instead of the amount of FDI inflow. Thus the FDI-invested companies should focus on the introduction of high-tech content while formulating a strict environmental access system and preventing resource-intensive and pollution-intensive investment through modifying the catalog of attracting FDI and adjusting relative preferential policies. Marques & Caetano, (2020) investigated the relation between FDI and environmental emission in the panel of 21 countries divided on high-income level and low-income level group for a period from 2001 to 2017 using Panel Autoregressive Distributed Lag (ARDL) methodology. They argue that regulation, innovation, and efficiency are important to understand the consequences of FDI inflow. High-income countries were found to benefit from FDI, as it reduced CO₂ emissions, both in the short- and long run, thereby supporting the Pollution Halo Hypothesis. Pollution halo effect in long run multinational transfer environment-friendly technology and maintain universal environmental standards in the host country thus it improves environmental quality.

However, there is a structural difference in high-income countries' economies and the pollution regulation, most of the studies used the single group of higher-income groups. This study fills the gap and contributes to the literature gap by investigating the FDI and environmental emission in a different group of developed economies, where they have basic similar economic structure and geographical proximity.

2.2 Economic growth and environmental pollution

Acaravci & Ozturk, (2010) used the autoregressive distributed lag (ARDL) method to find the causal relationship between CO₂ emission, economic growth, and energy consumption in the European region. The results show the long-run relation between GDP per capita and CO₂

emission in Switzerland, Portugal, Italy, Iceland, Greece, Germany, and Denmark. However no long-run relation in Sweden, Norway, Luxemburg, Motherland, UK, France, Belgium, Finland Austria. Manta et al., (2020) estimated the nexus among CO₂ emission, economic growth, energy use, and financial development in Central and Eastern European Countries (CEEC) using VECM and Granger causality over the period of 2000 to 2017. The result shows that in the long run energy emission and CO₂ emission have no impact on economic growth while in the short run increasing financial development increases the CO₂ emission and leads to enhanced economic growth. So, the European Union has to promote financial development which will help the countries to reduce the CO₂ emission, focus on the implementation of renewable and lower emission options. Kasperowicz, (2015) examines the relation between CO₂ emission and economic growth in 18 European member countries using Error Correction Model (ECM) estimation and finds the negative long-run relation because technological advancement for the production facility, in the long run, reducing the CO₂ emission in Europe. However, for short period increasing economic growth increases the CO₂ emission because the fast production system extensively needs energy.

2.3 Value-added in different sectors and environmental emission

Jebli et al., (2020) investigate the relationship between services value-added, industrial value-added, renewable energy consumption, economic growth, and CO₂ emission worldwide in four-panel groups of countries lower income, lower middle income, upper middle income, and high-income countries using GMM and Granger Causality test. Their results indicated that industries value-added and economic growth has a positive and significant impact on CO₂ emission in the lower-middle-income countries while economic growth has a negative impact, similarly, upper-middle-income countries economic growth have a negative impact while industries have a positive impact on CO₂ emission and finally upper-middle-income countries economic growth have positive and significant while services value-added have a negative impact on CO₂ emission. Further, they suggested that eco-friendly project uses of natural resources like wind, water, solar, hydrogen, and nuclear energy countries have to promote and raise the productivity to minimize the carbon emission, another solution is carbon taxation and subsidizing the ecofriendly project investment rely investors on efficient energy sources.

H. Liu & Fan, (2017) presented value-added accounting (production-based and consumption-based) system based on CO₂ emission, Main objective of the study investigated the accountability of CO₂ emission originating through human activity, within the boundary of the economic benefits principle. The study was based on bilateral trade of industrial production and variables of CO₂ emission such as CO₂ emission from transport, CO₂ emission from the manufacturing industry and construction, CO₂ emission from electricity and heat production and, CO₂ emission from other sectors. Further, they used these variables to analyze the 3-panel groups based on income level; high-income, low-income, and middle-income group countries. They promote the CO₂ emission-based accounting system based on “consumption” high consumption of good more responsibility and to reduced CO₂ emission advanced country should have to help developing nation by technology transfer to achieve a reduction of CO₂ emission target.

Alam, (2015) examines the value-added influence on GDP in the service sector, agriculture sector, and manufacturing sectors in South Asian countries. Results show that value addition in the

agriculture sector negatively influences the CO₂ emission while the service and manufacturing sector positively contributing to CO₂ emission. Therefore, the research suggested dependency on the services sector is not the solution to reduce CO₂ emission.

Similarly, Samargandi, (2017) analyses the KEC curve on Saudi-Arabia by considering the technology, sectors value addition in GDP, and volume of production, through the ARDL method. The result shows that the economic growth nurture the CO₂ emission and, value-added growth in industrial and service sector foster the CO₂ emission. However, the value addition in the agriculture sector reduces the CO₂ emission, also, technological advancement help to reduces the CO₂ emission without sacrificing the economic growth.

Rauf et al., (2018) use the ARDL method to find the linkage between industrial value-added, agriculture value-added, service value-added, economic growth, urbanization, financial development, and CO₂ emission in China from 1968 to 2016 and, their result shows in the long run and short run industrial, agriculture and services sector value-added have a negative relation with CO₂ emission in China. They recommended that increases carbon taxes, strong laws, and a greenhouse-based economy can is the solution to reduce CO₂ emission. While Xiaoqing & Jianlan, (2011) find positive relation for the period of 2000 to 2005 and long-term negative relation, between CO₂ emission and industrial value-added from 2006 to 2009. They used the cointegration test to investigate the linkage between CO₂ emission and industrial value-added and, recommended that reform in industrial structure can help to curve down the CO₂ emission.

Through the empirical literature, we observed the relation of CO₂ emission with FDI, economic growth and, service value-added, agriculture value-added, and manufacturing value-added in different regions. In the primary outlook of investigation, empirical literature verified the association among CO₂ emission, FDI, economic growth, and different sectors' value-added in different regions of the world economies. This relation varies for a short-run and long-run period. In addition, the overall results indicate that the GVAs is one of the most important factors to impact CO₂ emission.

Although the sectoral study of GVAs is important for the European Union 2030 pollution reduction goal, little attention has been paid to how the economic growth, FDI, and GVAs of the service sector, manufacturing sector, construction, and natural resources, and, agriculture sectors lead to CO₂ emission. Additionally, the author observed that the previous studies conducted on the relation between CO₂ emission and value-added are dissociated. Therefore, those studies cannot provide efficient policy-oriented and objective-based results and a gap exists in terms of policy guidelines. This study contributes to empirical literature and constitutes a debate on how economic growth, FDI, and GVA in the service sector, manufacturing sector, construction, and natural resources and, agriculture sectors in four-panel (EE, SE, NE, and WE) European regions affect the CO₂ emission. This study is the extension of seeing the challenges in policy implication in reducing CO₂ emission in technologically rich economies.

[Insert Table 1]

3 Methodology and data description

Factors like urbanization, inflation, labor, tax, and advancement in technology have a significant effect on CO₂ emission. According to L. Liu et al., (2011) increases population expanded urbanization and contribute to an increase in CO₂ emission. Al-mulali et al., (2012) hold that in a world overview study, 84% of the countries have a positive correlation between urbanization and CO₂ emission. Another aspect of determinants labor participation has an important effect on CO₂ emission. Wei et al., (2018) find labor supply is proportional to the population size and overestimate the CO₂ emission in key aging regions Europe, Russia, United States, and Japan while it underestimates in India. Further Ghazouani et al., (2020) noticed that important factors like an increase in tax influence the CO₂ emission, therefore, in Northern European nations government policies on taxation have a significant impact on CO₂ emission. European nations after 1991 started to implement the taxation policy related to curve CO₂ emission. However, the influx of CO₂ pollutant is still persistent and need more innovative reforms and advanced technologies. According to Niu et al., (2011) technology significantly contributes to conduct the clean production development mechanism and reduce CO₂ emission. So, in essence, to investigate the relationships that exist between CO₂ emission, FDI, labor (L), tax (TA), inflation (I), urbanization (U), information and communication technology (ICT), GDPPC (Gross Domestic Product Per Capita) and GVAs in different sectors this paper expressed through following equations. The CO₂ emission function is described by their exogenous variables and present through the following expression (Abdouli et al., 2018; Kahouli, 2018):

$$CO2_i = f(FDI_i, U_i, GDPPC_i, L_i, TA_i, I_i, ICT_i, GVAs_i) \text{ ----- (1)}$$

Where $i=1, \dots, N$, $CO2_i$ is the damage of environment due to CO₂ emission, FDI_i is the net inflow of FDI, $GDPPC_i$ is the GDP per capita, I_i is the inflation, L_i labor force participation rate from 15 to 64 age group, U_i is urbanization, TA_i taxes on income profit and gain, ICT_i is information and communication technology proxy from the number of inhabitants using internet and $GVAs_i$ is the value-added sectors of manufacturing, construction and mining, services and, agriculture and fishing.

The log liner form of the equation can be (1) is written as:

$$\ln(CO2)_i = \beta_0 + \beta_1 \ln(FDI)_i + \beta_2 \ln(U)_i + \beta_3 \ln(GDPPC)_i + \beta_4 \ln(L)_i + \beta_5 \ln(TA)_i + \beta_6 \ln(I)_i + \beta_7 \ln(ICT)_i + \beta_8 \ln(GVAs)_i + \varepsilon_{it} \text{ ----- (2)}$$

The subscript $i=1, \dots, N$ denotes the country (the sample of the study is 102 countries), and $t = 1, \dots, T$ time period from 2000 to 2018, β_0 is constant, β_1 to β_8 are the parameters to be estimated

Since this empirical study considers panel data, Eq. (2) can be written in time frame as follow:

$$\ln(CO2)_{it} = \beta_0 + \beta_1 \ln(FDI)_{it} + \beta_2 \ln(U)_{it} + \beta_3 \ln(GDPPC)_{it} + \beta_4 \ln(L)_{it} + \beta_5 \ln(TA)_{it} + \beta_6 \ln(I)_{it} + \beta_7 \ln(ICT)_{it} + \beta_8 \ln(GVAs)_{it} + \varepsilon_{it} \text{ ----- (2)}$$

Where $i = 1, \dots, N$ and $t = 1, \dots, T$ denote country. The four ways linkage among CO₂, FDI inflow, economic growth and values added are explained by the following simultaneous equations (Jebli et al., 2020).

$$\ln(\text{CO2})_{it} = \beta_0 + \beta_1 \ln \text{FDI}_{it} + \beta_2 \ln(\text{U})_{it} + \beta_3 \ln(\text{GDPPC})_{it} + \beta_4 \ln(\text{L})_{it} + \beta_5 \ln(\text{TA})_{it} + \beta_6 \ln(\text{I})_{it} + \beta_7 \ln(\text{ICT})_{it} + \beta_8 \ln(\text{GVAs})_{it} + \varepsilon_{it} \quad (3)$$

$$\ln(\text{FDI})_{it} = \beta_0 + \beta_1 \ln \text{CO2}_{it} + \beta_2 \ln(\text{U})_{it} + \beta_3 \ln(\text{GDPPC})_{it} + \beta_4 \ln(\text{L})_{it} + \beta_5 \ln(\text{TA})_{it} + \beta_6 \ln(\text{I})_{it} + \beta_7 \ln(\text{ICT})_{it} + \beta_8 \ln(\text{GVAs})_{it} + \varepsilon_{it} \quad (4)$$

$$\ln(\text{GDPPC})_{it} = \beta_0 + \beta_1 \ln \text{FDI}_{it} + \beta_2 \ln(\text{U})_{it} + \beta_3 \ln(\text{CO2})_{it} + \beta_4 \ln(\text{L})_{it} + \beta_5 \ln(\text{TA})_{it} + \beta_6 \ln(\text{I})_{it} + \beta_7 \ln(\text{ICT})_{it} + \beta_8 \ln(\text{GVAs})_{it} + \varepsilon_{it} \quad (5)$$

$$\ln(\text{GVAs})_{it} = \beta_0 + \beta_1 \ln \text{FDI}_{it} + \beta_2 \ln(\text{U})_{it} + \beta_3 \ln(\text{GDPPC})_{it} + \beta_4 \ln(\text{L})_{it} + \beta_5 \ln(\text{TA})_{it} + \beta_6 \ln(\text{I})_{it} + \beta_7 \ln(\text{ICT})_{it} + \beta_8 \ln(\text{CO2})_{it} + \varepsilon_{it} \quad (6)$$

Equation 3 to 6 is the common equation for gross value added, where the term GVAs represent the four sectors value-added. So, by changing the GVAs value from AGVA (gross value added of agriculture), CGVA (gross value added of industry involved in construction and mining sector), MGVA (gross value added of the manufacturing sector), and SGVA (gross value added of services sector) one by one in equation 3 to 6, simultaneous equation of each sector can be obtained. Variable description and terms explanation is given in Table-3. This research uses annual data of the period 2000 to 2018 for 21 European countries, data converted into panel form and grouped into four groups, EE, SE, NE, WE. The data is extracted from World Development Indicators (WDI) and takes a log to make analysis and results in interpretation more viable. A sampling of regions and bifurcation in four panel-group of countries are mentioned in Table 2 and variable description is presented in Table 3. Further, descriptive statics is presented in Table 4. The simultaneous equation approach is used for the econometric estimation and the 3SLS estimation is used for the empirical estimation. Analyze the relationships among the variable is problematic due to the error correlation between variables. Therefore, testing the relation through 3SLS is fulfill our objective requirement because it estimates all parameters in the equation at once and allows correlation between the error terms across the various equations in the number of included equations to be analyzed. So, the 3SLS method is more robust because it addresses the correlation between error and endogeneity, this method is time-tested and used by various researchers (Adewuyi & Awodumi, 2017; Bakhsh et al., 2017; Bui, 2020; Kahouli, 2018; Mahmoudian et al., 2020). The endogeneity problem is resolved by using a set of instrumental variables. It could be obvious that the endogeneity between the GVAs could occur so, while we considered one GVA for a single sector the other three GVA are considered as endogenous variables. All other right-hand-side variables are considered explanatory instrumental and exogenous to the system. The LLC unit root test is used in this article to test the stationarity of the variables, shown in Table 5. All variables reject the null hypothesis and accept the alternate hypothesis of the unit root test, which implies all variables used in this article are stationary at the first difference.

Insert Table [3,4,5] here

4 Results and discussion

The four-panel group we use in this article is characterized by a similar economic structure, similar transformation of external factors, and similar economic development based on the (Economou, 2019; Sayari et al., 2018; Singh & Gal, 2020). The author empirically tested the relation among

CO₂, FDI, GDP per capita, and GVAs of four industrial sectors in EE, NE, SE, and WE regions are presented in Table 10, 11, 12, and 13. In this article, there are four models created for each GVA for each region EE, SE, NE, and WE. The performance of the models, significance, and their R², Chi2, and Root Mean Square Value (RMSE) value is reported in Tables 6, 7, 8, and 9. Where R² values indicating the model fitted along the regression line and RMSE indicating the accuracy of the model, explaining the occurrence of error and absolute measure of fit. The Chi2 value indicating the significance of relationships among the four dependent variables here the null hypothesis is no relation between the dependent variables. In model summary tables all models are significant with $p < 0.5$, so the null hypothesis is rejected and accepts the alternate hypothesis. It implies the relation among the variables CO₂ emission, FDI inflow, GDPPC, and GVAs is significant, we can proceed with models.

Insert summary Table [6,7,8,9] here

Addressing the relation between CO₂ emission and value-added in agriculture and its condition regional differences is a noticeable factor. Therefore, Table 9, presents the empirical estimation of the agriculture sector in EE, NE, and WE European regions where we find the four-way linkage while in the SE region relationship of CO₂ with other variables is insignificant so, the three-way linkage is noticed. The significance of AGVA models in Table 9 is in line with the (Ceylan & Özkan, 2013; Kulyk & Augustowski, 2020). It is well known that the energy sector plays important role in economic development. The FDI investment can contribute an important role to reduce CO₂ emissions and enhances the agriculture-related industries' production by technology transfer and positively increases the country's economic growth. Long et al., (2018) revealed that technology advancement and innovation negatively affect CO₂ emission and FDI brings new technology and innovation. So, it is possible to reduce the greenhouse emission and increase production through technology advancement and structural changes in the production system and, grow in a sustainable development way. It is also the condition that in long run the opposite relation could be expected, where enhancement in production will not be associate with greenhouse emission. Optimal changes in policy at the individual country level are beneficial not economically but also socially such as the association between academia and agriculture. Labor is the most important factor that contributes to the four-way linkage of GVA-A. The positive approach of labor training is a necessary condition for the adaptation and implementation of new technology. Similar to the argument Pishgar-Komleh et al., (2012); Mobtaker et al., (2013) reported that advanced machinery and trained labor increase production and save the energy consumption in the production system which reduces the CO₂ emission. The rationalization of employment in agriculture in Europe supports sustainability and economic development.

The relation between FDI and CO₂ emission is positive in EE and WE region, negative in the NE region, and has no significance in the SE region. The results of the negative and positive association between FDI and CO₂ emission are in line with the (Huang et al., 2019; Shao, 2018). According to Pazienza, (2015) suggestion, the sign between FDI on CO₂ emission is dependent on the productivity specialization of the country and the country's competitive advantage. The insignificance of FDI and CO₂ emission in the SE region is understood by the isolated phenomena, it implies other sectors have a greater impact compared to agriculture, which means these

phenomena are influenced by the other factors (Atici, 2012; Demena & Afesorgbor, 2020; Wang et al., 2020). Further, the increase of FDI inflow by 1% tends to raise the CO₂ emission 3.23% in EE and 5% increase tends to 0.43% in WE, while in NE this association is negative so the increase of FDI inflow by 0.1% decrease the CO₂ emission -1.37%. Therefore, in the NE region, FDI inflow sufficiently brings technological advancement and innovation to reduce CO₂ emission.

Further GDP per capita has a significant relation with all variables FDI, CO₂, and GVA-A, except, FDI inflow and economic growth in the SE region. This insignificant result is consistent with (Alvarado et al., 2017). Another side, the relation between GDP per capita and CO₂ emission has a negative association in all regions because in the long-run development of new technology to reduce CO₂ emission production system produces the same product with a lower level of carbon emission while, in the short-run GDP and CO₂ emission is positive because the rapid increase in production can be achieved due to large intensive energy used compared to previous consumption of energy with lower production, capacity increase CO₂ emission increase (Kasperowicz, 2015).

Insert Table [9] here

The empirical estimation for SGVA sector industries is shown in Table 10. The EE region countries' service sector are more positively contribute to CO₂ emission compare to the other three European panel groups, which have an almost similar effect on carbon emission because according to Kołodziejczak, (2020) less affluent countries in Europe, a greater number of workforces related to the agriculture while in high affluent countries a smaller number of workforces related to the agriculture sector, so the high GVA is generated through the secondary sectors (industry) and tertiary sectors (service).

The SGVA sector industries have a 0.1% significance level and positive relation with CO₂ emission in all four regions of Europe, this result is similar to the (Jebli et al., 2020; Murshed et al., 2020). The relation between CO₂ emission and FDI inflow has 0.1% significant relation in SE region it implies 0.1% increase in FDI inflow CO₂ emission rise 4.01%, significant and negative relation in NE region 1% increase in FDI inflow CO₂ emission decreases 1.059% and insignificant relation in EE and WE region. While GDP per capita has 0.1% significant and negative association with CO₂ emission in all four European regions this result is similar to the (Kasperowicz, 2015). Because adaptation of low carbon technologies takes time to reach the same production level with lesser CO₂ emission. Further SGVA and CO₂ emission results are highly significant, thus every 0.1% rise in service sectors GVA tends to 1.276% rise of CO₂ emission in EE region while in SE, NE, and WE regions it increases approximately 0.9% (one point decimal place).

Insert Table [10] here

Regarding the MGVA panel, estimation results in Table 11 indicating that all four European regions manufacturing sectors are the highly significant and positive contributors of CO₂ emission. It is also noticeable that comparing to all four European regions EE has a high coefficient value for every 0.1% rise of GVA of manufacturing sectors, CO₂ value increases 1.42%. This result is similar to the (Jebli et al., 2020). Although it is admissible that the manufacturing value-added is the most impactful driver of CO₂ emission, up-gradation of technology through innovations, industries can improve the efficiency of the production system and reduces the carbon emission

(Li et al., 2019). Although CO₂ emission increases rapidly due to cheaper polluting resources Central and Eastern European (CEE) countries have had high CO₂ emission per capita since 1980 this carbon emission is continuously decreasing. However, compared to other technologically advanced European regions such as WE countries CO₂ emission per capita is still high in CEE countries (Atici, 2009). Thus, the CEE regions need FDI which brings innovation and technology advancement therefore, FDI inflow can play an important role to address this issue, based on previous empirical literature. In this research results, a 1% rise of FDI inflow tends to increase the 4.04% of CO₂ emission in EE regions. Another step of reducing the CO₂ emission can be to increase the GDP per capita, the results show the significant and negative association between GDP per capita and CO₂ emission in EE, WE, and NE region increase in per capita income decreases the carbon emission this significant result is supported by the (Alvarado et al., 2017; Kasperowicz, 2015). Therefore every 0.1% increase of GDP per capita reduces the CO₂ emission 1.56%, 1.12%, and 1.62% in EE, NE, and WE regions respectively. Further MGVA has a significant relation with all variables FDI, CO₂, and GDP per capita except, FDI inflow and MGVA in EE regions.

Insert Table [11] here

Results related to the CGVA are shown in Table 12, representing the resource extensive industries including construction, mining, electricity, water, and gas. The Table 12 results demonstrate that GAV-C has a 0.1% significant and positive impact on CO₂ emission in all four panel-group EE, SE, NE, and WE regions. This result is similar to the (Murshed et al., 2020). However, the impact of CGVA on CO₂ emission is very less in all European countries possibly because the European region is a group of advanced developed countries where construction and mining are very rare compare to developing nations where construction is at peak. Further FDI has a significant and positive impact on CO₂ in EE, SE, and WE region and a negative impact in the NE region concerning CGVA. Every 5% rise of FDI inflow tends to increase CO₂ emission 4.44%, 1% rise in FDI inflow tends to increase CO₂ emission 10.04% in SE and 0.85 % in WE. The significance of the model of CGVA is supported by (Alcántara & Padilla, 2006; Murshed et al., 2020; Zhang et al., 2019). We observed the four-way linkage in terms of CGVA which is significant with variables CO₂, FDI inflow, and GDP per capita in all regions except the relation between FDI inflow in EE regions. Furthermore, we observed the heterogeneity in the relation between the GDP per capita and FDI inflow; insignificant relation in EE regions, significant but negative relation in SE regions, insignificant relation in NE regions, and a significant and positive association in WE regions. This result is similar to the (Bačić et al., 2004; Bermejo Carbonell & Werner, 2018; Simionescu, 2016). The insignificant effect of economic growth on FDI inflow strives to be positive by developing a strong domestic financial system- FDI is more beneficial to advanced economies (Hermes & Lensink, 2003).

Insert Table [12] here

The summary, depiction of relationship and causality of the variable is reported in Figure 1 and 2. Where arrows end indicating the direction of the causality.

Insert Figure [1 and 2]

5 Conclusion

This study analyses the four-way linkage among CO₂ emission, FDI inflow, GDP per capita, and value-added in four sectors AGVA, SGVA, MGVA, and CGVA in four European regions EE, WE, SE, and NE over the period of 2000 to 2018 and data have been used from the WDI database. To do this simultaneous equation approach has been used with the 3SLS estimation technique.

The result of panel groups EE, NE, SE, and WE regions shows that the CO₂ emission has bidirectional causality with each industrial sector AGVA, SGVA, MGVA, and CGVA. Therefore, this article finds homogeneity in the relation between CO₂ and GAVs of industrial sectors.

There is a bidirectional relation between CO₂ emission and economic growth in EE, SE, NE, and WE regions for industrial sector GVA-A, SGVA, and CGVA, while there is no association between CO₂ emission and economic growth when we considered the manufacturing GVA in SE region.

The relation between CO₂ emission and FDI we find the heterogeneous results. In the scenario of the GVA agriculture sector EE, NE, and WE region countries have bidirectional causality while SE region result shows no relation. For the case of the services sector, GVA bidirectional causality in NE and SE regions while no relation in EE and WE regions. Further manufacturing sector GVA there is bidirectional relation in EE, NE, and WE regions and no relation for SE region. Furthermore, with consideration of CGVA sectors, we find bidirectional relations in all sub-group EE, SE, NE, and WE regions. In the European region, it is well known that better policy, management, and advanced technology may play a critical role to curve CO₂ emissions. Hence, in that case through FDI we can achieve zero or negative effects on CO₂ emission.

Therefore, there is heterogeneity in the literature to make uniform consciousness about the CO₂ and FDI relations. Adaptation of better policy, management, and advanced technology may play a critical role to curve CO₂ emissions. Hence, in that case through FDI we can achieve zero or negative effects on CO₂ emission.

The result of the relation between FDI inflow and economic growth is also heterogeneous. There is no relation between FDI and economic growth in EE, SE, NE, and WE region for the case of sector GVA. In the case of GVA of agriculture sector EE, NE, and WE bidirectional relation while no causality in SE region.

The results of this article help the policymakers to understand and grasp the complexity of the relation among the CO₂ emission, FDI inflow, economic growth, and GVA of different sectors in the European region. Therefore, the findings of this study have potential importance for policymaking to tackle the CO₂ emission in different industrial sectors. This article concluded that the causality among this research variable depends on the regions, indicating that it is impossible to create universal policy and recommendations for European regions. Therefore, to make pollution free economic development decision-makers (such as European Union) have to draft policies that should have to consider regional factors and coherent with industrial sectors which will help to reduce the CO₂ emission without sacrificing the economic growth because in our results factors like labor, urbanization, taxes, and internet and telecommunication variable

influence CO2 emission influence heterogeneously according to the regions and industry-specific in Europe. Along with its merits, this article has some limitations. This article panel-groups are limited to the group of countries and didn't focus on country-specific; it leads the future research. Finally, it will be interesting to find out these relations at the country level.

Discloser statement

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Figure-1, Relation summary of AGVAand SGVA.

Figure 2, relation summary of MGVA and CGVA.

Table 1 summary of the literature review of CO2 emission and value added

Author	Region	Methodology	Period	Scope
(Zhang et al., 2019)	Global/income level classification	Environmental Kuznets curve and various	1960-2014	CO2 is directly related to income level, higher-income higher EKC curve, significant relation between manufacturing and construction directly related to CO2 emission
(Jebli et al., 2020)	Global/income level classification	GMM and Granger causality	1990-2015	Negative relation between CO2 emission and, manufacturing and service sector industries value-added in higher-income countries, this relation is positive in low-income industries
(Asom & Ijirshar, 2016)	Nigeria	Augmented Dickey-Fuller, Johansen co-integration, unit root, error correction	1981-2015	agriculture value-added have a positive and insignificant effect on economic growth in the short and long run
(Rauf et al., 2018)	China	ARDL	1968-2016	Agriculture, services, and manufacturing value-added have a significant and positive relation with CO2 emission
(Kołodziejczak, 2020)	Europe	Comparative analysis	2000-2008	Positive association between employment and value added of different sectors
(H. Liu & Fan, 2017)	Multi country	Comparative analysis	2000-2010	Positive promotion of value-added based accounting of CO2
(Alam, 2015)	South Asia	Environmental Kuznets curve and various	1972-2010	Negative and significant association between agriculture value added and CO2 emission, positive and significant association between services sectors value added and CO2 emission
(Ceylan & Özkan, 2013)	Europe	Comparative analysis	1995-2007 and 2002-2007	positive relation between agriculture value added and economic growth
(Murshed et al., 2020)	OPEC	Environmental Kuznets curve and various	1992-2015	Positive association between CO2 emission and construction and services value added
(Agboola & Bekun, 2019)	Nigeria	Environmental Kuznets curve and various	1981-2014	Positive association between CO2 emission and FDI and agriculture value added
(Prastiyo et al., 2020)	Indonesia	Environmental Kuznets curve and various	1970-2015	Bidirectional causality between CO2 emission and, manufacturing, agriculture and urbanization
(Samargandi, 2017)	Saudi Arabia	Environmental Kuznets curve, ARDL	1970-2014	Value addition in services and manufacturing sectors positively causes CO2 emission, technology and innovation help to reduce CO2 emission with enhancement of economic growth
(Alamdarlo, 2016)	Iran	Environmental Kuznets curve and various	2001-2013	Direct relation among water consumption, agriculture value added and CO2 emission
(Friesenbichler, 2016)	Eastern Europe and Central Asia	3SLS	2010-2013	Positive and direct association between labor value added and innovation in manufacturing and services industry

Source: author.

Table 2 panel bifurcations

Panel	Countries
Northern Europe	Denmark, Finland, Ireland, Norway, Sweden, United Kingdom
Southern Europe	Greece, Italy, Portugal, Slovenia, Spain,
Western Europe	Austria, Belgium, France, Germany, Netherlands
Eastern Europe	Czech Republic, Hungary, Poland, Romania, Ukraine

Source: author

Table-3, variable description

Variable	Definition	Unit of measurement	Source
CO2 emission	damage to the environment due to CO2 emission	current US\$ dollar in million	WDI
Foreign direct investment, (FDI)	net inflows	current US\$ in million	WDI
Economic growth (GDPPC)	GDP per capita	current US\$ in million	WDI
Inflation (I)	consumer prices	annual %	WDI
Labor (L)	labor force participation rate	% of total population ages 15-64	WDI
Urbanization (U)	urban population growth	annual %	WDI
Tax (TA)	taxes on income, profits and capital gains	% of total taxes	WDI
Technology (ICT)	Individuals using the Internet	% of population	WDI
Gross Value-Added Agriculture sectors (GVA-A)	Representing the agriculture, industry, and services sectors	current US\$ in million	WDI
Gross value added of Industry involved in construction and mining (CGVA)	industry including construction, mining, electricity, water, and gas (resource extractive industry)	current US\$ in million	WDI
Gross Value Added of Manufacturing (GVA-M)	manufacturing industries	current US\$ in million	WDI
Gros Value Added Service sectors (SGVA)	industry including Wholesale, retail, trade transport, government, financial, professional, and personal services (education, health care real estate services, hotels, and restaurants	current US\$ in million	WDI

Source: author

Table 4 descriptive statics

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	Obs	Mean	Std. Dev.	Min	Max
(1) logCO2	1.000												399	7.834	1.03	5.341	10.145
(2) log FDI	0.282*	1.000											399	6.937	.063	6.459	7.458
(3) log GDPPC	-0.078	0.218*	1.000										399	10.119	.88	6.455	11.542
(4) log ICT	-0.006	0.149*	0.784*	1.000									399	3.952	.712	-.334	4.578
(5) log Inflation	-0.019	-0.107*	-0.627*	-0.608*	1.000								399	2.526	.238	1.709	4.072
(6) log Labor	-0.136*	0.158*	0.616*	0.523*	-0.340*	1.000							399	4.268	.078	4.084	4.421
(7) log Urban	-0.152*	0.203*	0.658*	0.405*	-0.340*	0.439*	1.000						399	1.714	.13	1.11	2.107
(8) log Taxes	0.218*	0.245*	0.434*	0.131*	-0.193*	0.031	0.353*	1.000					399	3.651	.319	2.526	4.096
(9) log CGVA	0.769*	0.350*	0.520*	0.404*	-0.353*	0.228*	0.261*	0.438*	1.000				399	11.443	1.113	8.729	13.897
(10) log AGVA	0.771*	0.360*	0.533*	0.420*	-0.376*	0.227*	0.282*	0.445*	0.985*	1.000			399	12.721	1.196	9.782	15.085
(11) log MGVA	0.769*	0.356*	0.480*	0.386*	-0.363*	0.167*	0.205*	0.394*	0.972*	0.963*	1.000		399	10.924	1.118	8.388	13.6
(12) log SGVA	0.752*	0.365*	0.552*	0.434*	-0.398*	0.233*	0.302*	0.451*	0.972*	0.997*	0.953*	1.000	399	12.329	1.261	9.302	14.697

Source: author, *, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5 results of panel unit root test

LLC test		
Variables	t-stat	P value
log CO2	-3.019*	0.001
log GDPPC	-9.332*	0.000
log FDI	-3.478*	0.001
log Labor	-9.485*	0.000
log Inflation	-7.436*	0.000
log Urban	-5.845*	0.000
log ITC	-19.81*	0.000
log Taxes	-2.383*	0.009
log CGVA	-7.678*	0.000
log AGVA	-9.261*	0.000
log MGVA	-7.606*	0.000
log SGVA	-11.525*	0.000

Source: author, *, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6, CGVA model equation summary statistics.

	Eastern Europe				South Europe				Norther Europe				Western Europe			
	RMSE	R2	Chai2	P	RMSE	R2	Chai2	P	RMSE	R2	Chai2	P	RMSE	R2	Chai2	P
logCO2	0.26	0.87	1065.55	0.00	.37	0.90	966.28	0.00	.20	0.94	3469.51	0.00	.29	0.89	1481.09	0.00
logFDI	.01	0.14	20.89	0.007	.01	0.54	169.01	0.00	.03	0.48	148.36	0.00	.01	0.08	20.56	0.00
logGDPPC	.19	0.94	2271.38	0.00	.14	0.77	382.60	0.00	.14	0.80	545.69	0.00	.10	0.82	458.35	0.00
logCGVA	14326.93	0.87	1233.99	0.00	61966.14	0.86	764.76	0.00	35267.91	0.94	3544.61	0.00	89135.33	0.91	1631.04	0.00

Source: author, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 7, AGVAmodelequation summary statistics.

	Eastern Europe				South Europe				Norther Europe				Western Europe			
	RMSE	R2	Chai2	P	RMSE	R2	Chai2	P	RMSE	R2	Chai2	P	RMSE	R2	Chai2	P
logCO2	.16	0.94	2811.73	0.00	.12	0.90	12411.79	0.00	.17	0.96	5084.60	0.00	.18	0.95	4013.33	0.00
logFDI	.01	0.14	2811.73	0.003	.01	0.52	12411.79	0.00	.03	0.46	133.04	0.00	.09	0.08	17.17	0.028
logGDPPC	.14	0.97	3990.98	0.00	.11	0.87	862.94	0.00	.12	0.83	795.75	0.00	.08	0.87	898.22	0.00
logGVA-A	.12	0.96	3991.38	0.00	.11	0.90	17694.01	0.00	.18	0.95	4694.05	0.00	.17	0.96	4238.11	0.00

Source: author, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 8, MGVAmodel equation summary statistics.

	Eastern Europe				South Europe				Norther Europe				Western Europe			
	RMSE	R2	Chai2	P	RMSE	R2	Chai2	P	RMSE	R2	Chai2	P	RMSE	R2	Chai2	P
logCO2	.22	0.90	1423.45	0.00	.28	0.94	1783.85	0.00	.32	0.87	1270.03	0.00	.17	0.96	4639.56	0.00
logFDI	.01	0.14	21.38	0.006	.01	0.55	148.29	0.00	.03	0.51	159.07	0.00	.10	0.07	33.99	0.00
logGDPPC	.14	0.97	4158.75	0.00	.14	0.78	366.24	0.00	.14	0.80	520.84	0.00	.10	0.86	799.78	0.00
logMGVA	.15	0.95	2797.99	0.00	.29	0.95	2315.99	0.00	.27	0.87	1371.89	0.00	.17	0.96	5252.78	0.00

Source: author, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 9, SGVA model equation summary statistics.

	Eastern Europe				South Europe				Norther Europe				Western Europe			
	RMSE	R2	Chai2	P	RMSE	R2	Chai2	P	RMSE	R2	Chai2	P	RMSE	R2	Chai2	P
logCO2	.17	0.94	2492.16	0.00	.12	0.95	11289.97	0.00	.19	0.95	4102.69	0.00	.19	0.95	3420.00	0.00
logFDI	.01	0.15	18.66	0.016	.01	0.50	117.99	0.00	.03	0.45	119.42	0.00	.10	0.09	12.51	0.012
logGDPPC	.14	0.95	3869.97	0.00	.11	0.87	867.99	0.00	.13	0.81	628.47	0.00	.08	0.87	849.71	0.00
logSGVA	.13	0.96	3884.47	0.00	.12	0.95	15540.88	0.00	.21	0.95	3843.10	0.00	.19	0.95	3561.65	0.00

Source: author, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 10, result of 3SLS using GVA-A

	Eastern Europe				Southern Europe				Northern Europe				Western Europe			
	Model 1				Model 2				Model 3				Model 4			
logCO21	0.0252** (-2.89)	-0.881*** (-26.68)	0.769*** (-39.00)		0.00 (-0.17)	-0.834*** (-12.29)	0.976*** (-47.63)		-0.0734*** (-3.78)	-0.617*** (-12.93)	1.004*** (-54.08)		0.145* (-2.50)	-0.427*** (-13.15)	0.984*** (-52.04)	
logFDI	3.213** (-2.89)	2.447* (-2.450)	-1.70 (-1.94)	0.16 (-0.17)		-1.21 (-1.30)	0.94 (-1.03)	-1.375*** (-3.78)		-0.809** (-2.83)	2.041*** (-5.75)	0.438* (-2.50)		0.217** (-2.60)	-0.383* (-2.21)	
logGDPPC	-1.119*** (-26.68)	0.0243* -2.45		0.867*** (-30.11)	-0.878*** (-12.29)	-0.01 (-1.30)		0.919*** (-14.96)	-1.169*** (-12.93)	-0.0817** (-2.83)		1.119*** (-11.11)	- 1.896*** (-13.15)	0.318** (-2.60)		1.860*** (-13.05)
logAGVA	1.286*** (-39.00)	-0.02 (-1.94)	1.141*** (-30.11)		1.004*** (-47.63)	0.01 (-1.03)	0.898*** (-14.96)		0.966*** (-54.08)	0.105*** (-5.75)	0.569*** (-11.11)		1.015*** (-52.04)	-0.131* (-2.21)	0.433*** (-13.05)	
logICT	0.01 (-0.45)	0.00 (-0.13)	0.02 (-0.68)	-0.01 (-0.47)	0.245*** (-5.01)	0.01 (-1.23)	0.323*** (-8.95)	-0.268*** (-5.75)	0.657*** (-7.70)	0.02 (-0.99)	0.609*** (-13.95)	-0.604*** (-6.58)	0.800*** (-7.65)	-0.158* (-2.18)	0.447*** (-12.90)	-0.782*** (-7.47)
logInflation	-0.09 (-1.59)	0.01 (-0.98)	-0.08 (-1.64)	0.07 (-1.52)	-0.07 (-0.68)	0.0240* (-2.31)	0.03 (-0.32)	0.03 (-0.30)	0.24 (-1.78)	-0.02 (-0.63)	0.13 (-1.24)	-0.22 (-1.58)	0.32 (-1.23)	0.05 (-0.31)	0.18 (-1.44)	-0.32 (-1.25)
logLabor	4.314*** -14.29	-0.157*** (-3.55)	3.789*** -12.95	-3.280*** (-13.17)	-1.604*** (-5.49)	0.05* -1.38	-1.683*** (-6.43)	1.596*** -5.57	-3.800*** (-7.22)	-0.608*** (-4.38)	-2.044*** (-4.63)	4.110*** (-7.75)	4.937*** (-7.88)	-0.29 (-0.65)	2.271*** -7.35	-4.883*** (-8.22)
logUrban	1.250*** (-6.47)	-0.01 (-0.45)	1.123*** (-6.71)	-0.985*** (-6.77)	0.07 (-0.47)	0.02 (-1.06)	0.26 (-1.74)	-0.13 (-0.80)	0.507* (-2.09)	0.03 (-0.47)	0.811*** (-5.33)	-0.41 (-1.63)	- 0.732*** (-3.97)	0.262* (-2.38)	-0.347*** (-3.97)	0.713*** (-3.95)
logTaxes	-0.04 (-0.32)	0.0248* -1.98	0.00 (-0.04)	0.00 (-0.05)	-0.398*** (-4.26)	-0.01 (-0.60)	-0.442*** (-4.46)	0.411*** (-4.83)	0.353*** (-7.71)	0.0361** (-3.01)	0.275*** (-8.91)	-0.351*** (-7.35)	2.296*** (-7.38)	-0.23 (-1.00)	1.060*** (-6.79)	-2.270*** (-7.87)
Const.	-39.15*** (-4.94)	7.335*** -38.46	-31.91*** (-4.47)	24.82*** (-3.96)	10.07 (-1.60)	6.629*** (-37.31)	20.47*** (-3.35)	-17.75** (-2.91)	27.99*** (-7.56)	9.42*** (15.92)	17.13*** (-5.75)	-33.47*** (-9.34)	- 21.32*** (-6.05)	6.387** (-2.65)	-8.767*** (-4.70)	20.87*** (-6.32)

Source: author, Note: t statistics in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 11, result of 3SLS using SGVA

	Eastern Europe			Southern Europe			Northern Europe			Western Europe						
	Model 1			Model 2			Model 3			Model 4						
logCO21	0.013 (-1.55)	-0.844*** (-25.83)	0.773*** (-36.68)	0.04*** (-4.21)	-0.798*** (-12.26)	1.013*** (-45.23)	-0.048** (-2.64)	-0.504*** (-9.40)	1.059*** (-48.71)	0.073 (-1.340)	-0.397*** (-12.50)	1.004*** (-47.99)				
logFDI	1.848 (-1.55)		1.129 (-1.11)	-0.483 (-0.52)	4.010*** (-4.21)		1.787 (-1.90)	-3.010** (-3.00)	-1.059** (-2.64)		-0.439 (-1.41)	1.999*** (-4.78)	0.255 9-1.34)		0.146 (-1.710)	-0.193 (-1.01)
logGDPPC	-1.164*** (-25.83)	0.011 (-1.11)		0.908*** (-29.61)	-0.928*** (-12.26)	0.021 (-1.90)		1.009*** -15.050	-0.991*** (-9.40)	-0.039 (-1.41)		0.938*** (-7.65)	-1.969*** (-12.50)	0.207 (-1.71)		1.972*** (-12.41)
logSGVA	1.276*** (-36.68)	-0.006 (-0.52)	1.087*** (-29.61)		0.967*** (-45.23)	-0.029** (-3.00)	0.828*** (-15.05)		0.906*** (-48.71)	0.0770*** 9-4.78)	0.408*** (-7.65)		0.994*** (-47.99)	-0.055 (-1.01)	0.393*** (-12.41)	
logICT	0.031 (-0.98)	-0.001 (-0.20)	0.033 (-1.27)	-0.025 (-1.02)	0.297*** -5.760	-0.003 (-0.52)	0.357*** -10.190	-0.334*** (-6.57)	0.556*** (-5.74)	-0.002 (-0.08)	0.647*** (-13.76)	-0.487*** (-4.45)	0.811*** (-7.13)	-0.115 (-1.59)	0.442*** (-12.43)	-0.808*** (-6.96)
logInflation	-0.030 (-0.50)	0.004 (-0.80)	-0.027 (-0.53)	0.019 (-0.42)	0.031 (-0.29)	0.0211* (-2.03)	0.121 (-1.25)	-0.071 (-0.66)	0.307* (-2.04)	-0.024 (-0.74)	0.110 (-1.00)	-0.300 (-1.83)	0.457 (-1.63)	0.064 (-0.42)	0.228 (-1.82)	-0.468 (-1.67)
logLabor	4.914*** -15.380	-0.109* (-2.31)	4.140*** -13.780	-3.76*** (-14.17)	-2.179*** (-7.09)	0.112** (-3.27)	-2.092*** (-7.98)	2.259*** (-7.23)	-3.884*** (-6.69)	-0.538*** (-3.87)	-1.407** (-2.92)	4.546*** (-7.34)	5.383*** (-7.92)	0.049 (-0.11)	2.320*** (-7.27)	-5.445*** (-8.30)
logUrban	0.830*** (-4.11)	0.009 (-0.52)	0.723*** (-4.29)	-0.67*** (-4.30)	0.337* (-2.01)	0.007 (-0.40)	0.479** (-3.25)	-0.403* (-2.38)	0.501 (-1.83)	0.019 (-0.30)	1.131*** (-7.17)	-0.343 (-1.14)	-0.940*** (-4.70)	0.229* (-2.01)	-0.415*** (-4.57)	0.935*** (-4.69)
logTaxes	0.146 (-1.10)	0.025 (-1.95)	0.161 (-1.43)	-0.148 (-1.44)	-0.484*** (-4.91)	0.015 (-1.17)	-0.483*** (-4.87)	0.514*** (-5.54)	0.335*** (-6.58)	0.0267* (-2.25)	0.270*** (-8.04)	-0.343*** (-6.10)	2.181*** (-6.51)	-0.050 (-0.23)	0.958*** (-6.08)	-2.206*** (-6.93)
Const.	-31.25*** (-3.70)	7.128*** (-36.15)	-23.50** (-3.23)	17.70** (-2.65)	-13.41* (-2.10)	6.178*** (-33.96)	1.779 (-0.29)	5.892 (-0.88)	25.72*** (-6.30)	9.023*** (-15.36)	12.50*** (-3.86)	-34.37*** (-8.17)	-20.15*** (-5.30)	4.797* (-2.02)	-7.678*** (-4.07)	20.13*** (-5.51)

Source: author, Note: t statistics in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 12, result of 3SLS using GVA-M

	Eastern Europe				Southern Europe				Northern Europe				Western Europe			
	Model 1				Model 2				Model 3				Model 4			
logCO2I	0.017** (-2.62)	-0.621*** (-22.93)	0.664*** (-27.17)		-0.003 (-0.72)	0.044 (-0.85)	0.833*** (-14.12)		-0.029** (-2.88)	-0.221*** (-5.99)	0.772*** (-25.99)		0.274*** (-4.65)	-0.464*** (-11.85)	0.960*** (-55.97)	
logFDI	4.035** (-2.62)		1.766 (-1.79)	-1.335 (-1.26)	-1.808 (-0.72)		-3.030* (-2.26)	12.47*** (-5.500)	-2.061** (-2.88)		-0.076 (-0.22)	3.908*** (-7.29)	0.745*** (-4.65)		0.357*** (-4.11)	-0.683*** (-4.40)
logGDPPC	-1.565*** (-22.93)	0.018 (-1.79)		1.065*** (-30.77)	0.163 (-0.85)	-0.0172* (-2.26)		0.560** (-3.04)	-1.123*** (-5.99)	-0.005 (-0.22)		0.513** (-3.06)	-1.624*** (-11.85)	0.460*** (-4.11)		1.551*** (-11.69)
logMGVA	1.462*** (-27.17)	-0.012 (-1.26)	0.929*** (-30.77)		0.846*** (-14.12)	0.019*** (-5.50)	0.152** (-3.04)		1.103*** (-25.99)	0.078*** (-7.29)	0.144** (-3.06)		1.041*** (-55.97)	-0.272*** (-4.40)	0.480*** (-11.69)	
logICT	0.155*** (-3.72)	-0.002 (-0.51)	0.105*** (-4.520)	-0.108*** (-3.95)	-0.389** (-2.89)	0.000 (-0.06)	0.434*** (-8.20)	0.125 (-0.96)	0.889*** (-5.33)	-0.009 (-0.41)	0.732*** (-15.10)	-0.396** (-2.68)	0.803*** (-8.15)	-0.241*** (-3.38)	0.510*** (-14.430)	-0.766*** (-7.94)
logInflation	-0.141 (-1.80)	0.005 (-0.960)	-0.088 (-1.80)	0.089 (-1.690)	-0.749** (-2.99)	0.013 (-1.32)	0.208 (-1.56)	0.401 (-1.59)	0.643* (-2.52)	-0.004 (-0.12)	0.051 (-0.44)	-0.479* (-2.23)	-0.112 (-0.47)	0.109 (-0.74)	0.003 (-0.02)	0.105 (-0.45)
logLabor	3.647*** (-8.71)	-0.115*** (-3.39)	2.225*** (-7.96)	-2.344*** (-7.79)	1.787* (-2.24)	0.0891** (9-2.93)	-1.216** (-3.09)	-1.855* (-2.43)	2.638** (-2.70)	-0.005 (-0.04)	0.890* (-2.03)	-1.753* (-2.15)	4.346*** (-7.48)	-0.824 (-1.91)	2.226*** (-6.81)	-4.186*** (-7.75)
logUrban	1.990*** (-7.22)	-0.004 (-0.17)	1.288*** (-7.81)	-1.387*** (-7.91)	-1.364*** (-3.39)	0.001 (-0.06)	0.633** (-3.06)	0.820* (-2.03)	0.834 (-1.76)	-0.011 (-0.19)	1.495*** (-9.53)	-0.055 (-0.14)	0.465** (-2.73)	0.018 (-0.16)	0.174 (-1.82)	-0.454** (-2.76)
logTaxes	-0.395* (-2.38)	0.0283* (-2.25)	-0.195 (-1.75)	0.210 (-1.78)	0.349 (-1.48)	-0.019 (-1.74)	-0.248 (-1.74)	0.155 (-0.67)	0.812*** (-9.34)	0.0479*** (-3.96)	0.290*** (-6.90)	-0.641*** (-8.60)	2.818*** (9-9.55)	-0.671** (-2.75)	1.400*** (-7.79)	-2.711*** (-10.33)
Const.	-38.16*** (-3.47)	7.128*** (-52.05)	-18.67** (-2.65)	16.09* (-2.13)	6.382 (-0.38)	6.564*** (-44.83)	31.83*** (-3.66)	-83.26*** (-5.51)	0.382 (-0.06)	6.268*** (-12.05)	0.488 (-0.16)	-14.45** (-2.66)	-25.31*** (-7.66)	9.850*** (-3.98)	-11.07*** (-5.32)	24.24*** (-8.08)

Source: author, Note: *t* statistics in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 13, result of 3SLS using CGVA

	Eastern Europe				South Europe				Norther Europe				West Europe			
	Model 1				Model 2				Model 3				Model 4			
logCO2I	0.0136*	-0.712***	53586.2***		0.009**	0.147***	68769.6***		-0.067***	-0.377***	167989.5***		0.109**	-0.0976**	313218.7***	
	(-2.45)	(-17.93)	(-23.05)		(-3.08)	(-3.90)	(-4.76)		(-4.21)	(-6.62)	(-45.10)		(-3.04)	(-2.59)	(-31.37)	
logFDI	4.339*		2.12	-83088.90	10.04**		-3.833**	2884903.8***	-1.836***		-0.36	472725.8***	0.851**		0.219*	-229945.7**
	(-2.45)		(-1.60)	(-0.84)	(-3.08)		(-2.85)	(-5.90)	(-4.21)		(-1.07)	(-6.73)	(-3.04)		(-2.06)	(-2.59)
logGDPPC	-1.314***	0.01		73106.5***	0.954***	-0.022**		135107.6***	-0.783***	-0.03		104020.4***	-0.698**	0.200*		182512.4*
	(-17.93)	(-1.60)		(-21.77)	(-3.90)	(-2.85)		(-3.40)	(-6.62)	(-1.07)		(-4.84)	(-2.59)	(-2.06)		(-2.14)
logCGVA	1.78e-5***	-8.67e-8	1.32e-5***		2.65e-6***	9.69e-8***	8.03e-7***		5.65e-6***	5.83e-7***	1.68e-6***		3.15e-6***	-2.96e-7**	2.57e-7*	
	(-23.05)	(-0.84)	(-21.77)		(-4.76)	(-5.90)	(-3.40)		(-45.10)	(-6.73)	(-4.84)		(-31.37)	(-2.59)	-2.14	
logICT	0.322***	0.00	0.259***	-18298.1***	-0.580**	0.00	0.387***	46777.90	0.687***	0.02	0.756***	-93784.8***	0.34	-0.12	0.557***	-81584.40
	(-6.51)	(-0.62)	(-9.29)	(-7.04)	(-3.22)	(-0.39)	(-6.93)	(-1.67)	(-6.55)	(-0.72)	(-15.72)	(-4.94)	(-1.80)	(-1.75)	(-13.03)	(-1.38)
logInflation	-0.288**	0.01	-0.218***	15287.6**	-1.278***	0.01	0.18	131934.3*	-0.10	-0.06	-0.06	24068.60	-0.904*	0.15	0.11	284546.0*
	(-3.23)	(-1.05)	(-3.39)	(-3.10)	(-3.81)	(-0.85)	(-1.31)	(-2.43)	(-0.60)	(-1.80)	(-0.53)	(-0.86)	(-2.19)	(-1.01)	(-0.68)	(-2.17)
logLabor	4.065***	-0.108**	2.869***	-209956.1***	2.08	0.137***	-0.64	-858836.3***	-2.481***	-0.442***	-0.24	487580.1***	1.13	0.16	0.838*	-359382.70
	(-8.48)	(-3.21)	(-7.57)	(-7.46)	(-1.78)	(-4.19)	(-1.44)	(-5.26)	(-4.02)	(-3.64)	(-0.52)	(-4.61)	(-1.15)	(-0.46)	(-2.29)	(-1.17)
logUrban	1.762***	0.00	1.354***	-101952.7***	-1.926***	0.00	0.620**	172378.0*	0.29	-0.01	1.333***	-2263.70	1.805***	0.00	-0.02	-582411.1***
	(-5.63)	(-0.22)	(-6.10)	(-6.24)	(-3.61)	(-0.14)	(-2.98)	(-1.99)	(-0.96)	(-0.20)	(-8.25)	(-0.04)	(-6.06)	(-0.04)	(-0.13)	(-6.26)
logTaxes	0.02	0.0256*	0.14	-9035.30	1.834***	-0.0217*	-0.316*	-23326.80	0.08	0.00	0.189***	-8733.60	1.205*	-0.08	0.425*	-389160.6**
	(-0.12)	(-2.02)	(-0.95)	(-0.82)	(-7.19)	(-2.13)	(-2.34)	(-0.43)	(-1.52)	(-0.37)	(-5.43)	(-0.90)	(-2.45)	(-0.41)	(-2.16)	(-2.59)
Const.	-31.53*	7.052***	-15.70	643763.40	-78.54***	6.538***	36.20***	-18777466.8***	34.90***	9.629***	10.64**	-7218971.5***	-2.95	3.74	1.99	1055879.80
	(-2.49)	(-58.68)	(-1.66)	(-0.91)	(-3.68)	(-44.77)	(-4.17)	(-5.76)	(-7.86)	(-16.70)	(-2.93)	(-10.15)	(-0.54)	(-1.86)	(-0.94)	(-0.62)

Source: author, Note: *t* statistics in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Figures

Figure 1
Relation summary of AGVAand SGVA.

Figure 2
relation summary of MGVA and CGVA.