Environmental Science & Policy 55 (2016) 178–185

Contents lists available at ScienceDirect

Environmental Science & Policy

journal homepage: www.elsevier.com/locate/envsci

The EU Cohesion Policy implications to GHG emissions from production-based perspective

Genovaitė Liobikienė[a,b,*], Justina Mandravickaitė[c]

[a] Department of Environmental Sciences, Vytautas Magnus University, Vileikos st. 8, 44404 Kaunas, Lithuania
[b] Departament of Drug Technology and Social Pharmacy, Lithuanian University of Health Sciences, Eiveniu str. 4, 50009 Kaunas, Lithuania
[c] Baltic Institute of Advanced Technology, Sauletekio av. 15, 10224 Vilnius, Lithuania

ARTICLE INFO

Article history:
Received 30 May 2015
Received in revised form 7 October 2015
Accepted 7 October 2015

Keywords:
GHG emissions
Convergence
EU Cohesion Policy
Production
Europe 2020 strategy
Environmental Kuznets Curve

ABSTRACT

The European Union (EU) Cohesion Policy is the cornerstone of the EU policy. Therefore the aim of this study is to cover the implication of cohesion policy to greenhouse gas emissions from production-based perspective. Considering that the main task of the EU Cohesion Policy 2007–2013 was the convergence process, by applying the β-convergence the study showed that the EU Cohesion Policy (2007–2013) was implemented successfully and economic convergence in the EU countries was observed. Furthermore, the convergence of GHG emissions from a production-based perspective was confirmed as well. Evaluating the correlation coefficient between the technological contribution to changes in GHG emissions and GDP growth rate, the results showed that contribution of technological progress was the largest in those EU countries where the fastest GDP growth rate was observed. However, despite the considerable technological contribution to GHG emissions reductions, it does not offset the effect of production scale in the countries such as Bulgaria, Poland and the Baltic States. In terms of economic structural changes, the result revealed that economic growth did not seem to make an effect on larger contribution of economic structural change to GHG emissions reductions. Meanwhile, considering the implication of the new EU Cohesion Policy (2014–2020), it was shown the importance of the EU 2020 strategy implementation. Using correlation coefficient between changes in GHG emissions and changes in the share of renewable energy, expenditure on R&D as a percentage of GDP and energy efficiency, only the growth in the share of renewable energy resources had significant direct impact on the reduction of GHG emissions. Therefore the promotion of the share of renewable energy as well as technologies which contributed to the decrease of GHG emissions and the growth of energy saving rate, is the most important in seeking GHG reduction in the EU.

1. Introduction

The increasing threat of global warming and climate change has been a major on-going concern in recent decades. Considering that the EU is one of the largest greenhouse gas (GHG) emitters in the world, researchers have paid much attention to GHG emissions. A number of studies (see Saikku et al., 2008; Fernández González et al., 2014a,c; Kaivo-oja et al., 2014; Brizga et al., 2014) have applied decomposition analysis in order to explain factors affecting general GHG emission in the EU countries.

However, there is a lack of studies about changes in GHG emissions caused by economic activities in all the EU countries. Most studies (see Marin et al., 2012; Butnar and Llop, 2011; Hammond and Norman, 2012; Padilla and Duro, 2013; Wood, 2009; Alves and Mountinho, 2013) have analysed tendencies of GHG emissions for separate activities only, such as manufacturing, service industries, agriculture and others.

Furthermore, considering the EU Cohesion Policy, it is very important to analyse the outcomes of the Policy implementation to changes in GHG emissions in the EU. The main task of the EU Cohesion Policy 2007–2013 was the convergence process when the main budget was allocated to less economically developed EU countries. Therefore in this paper it is analysed whether convergence of GHG emissions from a production-based perspective occurred in the case of the EU economic convergence.

* Corresponding author at: Department of Environmental Sciences, Vytautas Magnus University, Vileikos st. 8, 44404 Kaunas, Lithuania.
E-mail address: g.liobikiene@gmf.vdu.lt (G. Liobikienė).

http://dx.doi.org/10.1016/j.envsci.2015.10.007
1462-9011/

Additionally, fast economic growth (particularly in the new EU members where the level of GDP is the lowest) could influence the growth in GHG emissions. However, according to Environmental Kuznets Curve (EKC) theory, in mature economies in the case of economic growth that is related to effect of technological and economic structural changes, the environmental impact should decrease (Pasche, 2002; Dinda, 2004; Robalino-López et al., 2015; Farhani et al., 2014; Kaika and Zervas, 2013; Turner and Hanley, 2011). Therefore, this study reveals whether the EKC exists among the EU countries or not and in which the EU countries the contribution of technological and structural changes to a reduction in GHG emissions was the largest as well as its relationship to the level of GDP growth.

Moreover, in relation to the new EU Cohesion Policy (2014–2020), which links the allocation of funds to the Europe 2020 strategy objectives, this paper analyses how the changes in energy efficiency, share of renewable energy in the final energy consumption and expenditure on R&D influence changes in GHG emissions. According to these findings, the implications for the EU policy are suggested.

Thus, the rest of the paper proceeds as follows. Section 2 presents literature review of the EU enlargement process, studies of the EKC, the EU Cohesion Policy and GHG emissions from a production-based perspective. The methods of this paper are described in Section 3. Section 4 discusses the results of the convergence process on economies and GHG emissions, contribution of technological and structural alterations to changes in GHG emissions and the implications for the EU Cohesion Policy (2014–2020) implementation. Finally, Section 5 closes the paper with the main conclusions.

2. Literature review

In 2004 the European Union had its largest enlargement when eight new Central and Eastern European countries joined the EU. Curran and Zignago (2012) stated that the Union had never experienced such a major change in its structure and economic geography in such a short period of time before. By entering the EU new member states took full advantage of economic integration within the European Single Market through the free movement of goods (Doyle and Fidrmuc, 2006). Thus the enlargement coincided with major changes in the structure of trade within and beyond the EU (Curran and Zignago, 2012). Moreover, the new EU members were included in the EU-wide system of redistribution, including Structural and Cohesion funds. Doyle and Fidrmuc (2006) confirmed that eligibility for regional aid is directly related to the new EU members' economic development. Thus impact of enlargement was greater on the new EU member states than on the old ones (Liobikienė and Mandravickaitė, 2011; Curran and Zignago, 2012). In the new EU member states the rate of accelerating growth was related to the benefits of institutional and financial investment resulting from the old member states of the European Union (Kolodko, 2009).

Therefore many authors (see Welsch and Bonn, 2008; Rapacki and Prochniak, 2009; Juknys et al., 2014) found that faster economic growth in the new EU member states than in the old members determined the process of the EU economic convergence. Thus the EU convergence process was influenced by the successful implementation of the EU Cohesion Policy (2007–2013) via reallocation of funds across the poorest EU regions (Rakauskienė and Kozlovskij, 2014). Despite that one third of the EU Cohesion Policy (2007–2013) budget was meant to environmental issues and climate change, the main concern was about the integration impact on economies (Jacoby, 2010; Curran and Zignago, 2012).

2.1. Studies of Environmental Kuznets Curve (EKC) in the EU

Considering that the EU Cohesion Policy's (2007–2013) main aim was the convergence process, when economy in the less developed EU countries grew fast, it is very important that the environmental impact would grow more slowly or, even better, decrease. However, researchers (see Zhang et al., 2012; Kim and Kim, 2012; Kumar and Managi, 2010) revealed that in developing countries economic growth was the most important contributor to the increase in GHG emission. Meanwhile other authors (see Liou and Wu, 2011; Alves and Mountinho, 2013; Botringer and Rutherfors, 2013; Voigt et al., 2014; Herrerias, 2013; Turner and Hanley, 2011) declared that in countries with mature economies GHG emissions should decrease through the use of advanced technologies and innovations. Moreover, some authors (see Parith et al., 2009; Wood, 2009; Butnar and Llop, 2011; Wang et al., 2013; Brizga et al., 2014) also highlighted that an alteration of economic structure, which reveals whether an economy grows faster in less polluting sectors (i.e. services) than in more polluting ones, also contributes to the reduction of GHG emissions. Thus technological and economic structural changes lead to the occurrence of EKC (Pasche, 2002; Dinda, 2004; Robalino-López et al., 2015; Farhani et al., 2014; Kaika and Zervas, 2013; Turner and Hanley, 2011).

However, Fernández González et al. (2014a) found that in the EU countries the inertia of European economic growth affected GHG emissions. Bölük and Mert (2014) during the period of 1990–2008 found no statistical evidence of existing EKC for GHG emissions in 16 EU countries. As for separate EU countries that the authors covered, the EKC during the period of 1960–2011 was observed in Sweden and Germany (Waslekar, 2014). According to the study of López-Menéndez and colleagues (2014), the decreasing EKC pattern during the period of 1996–2010 was observed in Austria, Belgium, Finland, France, Germany, Italy, Netherlands, Sweden and the UK. However, the increasing EKC pattern was found in almost all new EU members: Bulgaria, Romania, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Portugal (López-Menéndez et al., 2014). Thus many EU countries must make additional efforts in order to reduce GHG emissions.

2.2. GHG emissions from a production-based perspective and the implementation of EU Cohesion Policy (2014–2020)

Regarding emissions of GHG in the EU countries, the most important is the production perspective, especially production activities that require fossil fuels (Parith et al., 2009; EEA, 2010). In Fig. 1 it is shown that greenhouse gas emissions from a

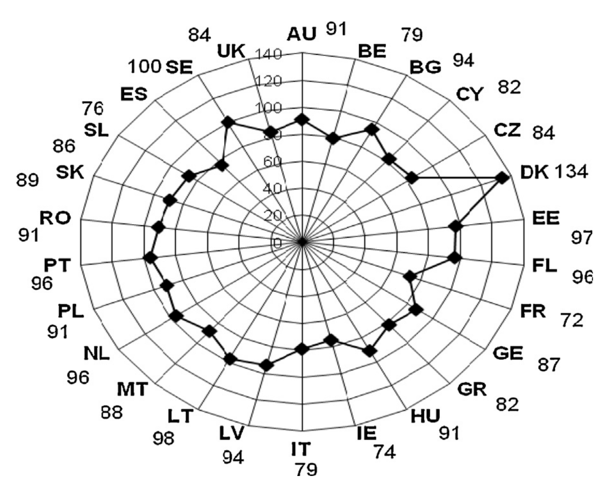

Fig. 1. The share of GHG emissions from a production-based perspective.

production-based perspective amount to the largest share of general GHG emissions in the EU countries. The data errors are observed in the case of Denmark, as the GHG emissions exceeded general level of country's GHG emission. Meanwhile only in France and Ireland the share of GHG emissions from a production-based perspective comprised a lower share among the EU countries. Nevertheless, this share amounts two thirds of general emissions.

As for a production-based perspective, imports are not included in this amount. Thus the production perspective takes into account the responsibility of country-producer, considering direct emissions in a particular country due to domestic production processes that generate pressures and impacts within that country (Peters, 2008; Wood, 2009; Marin et al., 2012). Therefore a government has direct authority to implement policies over emissions which certain industries generate (Peters, 2008).

Meanwhile, considering the EU Cohesion Policy (2014–2020), this policy links the allocation of funds to the Europe 2020 strategy objectives. The main task of the Europe 2020 strategy is to reduce GHG emissions 20%, in comparison to the level in 1990, by 2020 (EC, 2010). Moreover, in this policy the growth of expenditure on R&D, energy efficiency and the share of renewable energy resources are introduced as well. All the mentioned factors contribute to the reduction of GHG emissions. For example, Apak and Atay (2013) declared that investment in R&D is one of the most important instruments for supporting the development of a low-carbon economy at the local and the EU level. Expenditure on R&D is related to the spillover of innovation and is a key factor by which a positive influence on future emission reductions may occur (Corradini et al., 2014; Kaika and Zervas, 2013).

Considering energy efficiency, research works (see Marrero, 2010; Kaika and Zervas, 2013; Acaravci and Ozturk, 2010; Liou and Wu, 2011) highlighted that in general energy consumption accompanies economic growth. However, when decomposition analysis was applied, it was revealed that in order to reduce GHG emissions it is very important to reduce energy intensity (Fernández González et al., 2014a,c; Brizga et al., 2014). Other authors (Moya and Pardo, 2013; Holt and Galligan, 2013; Blesl et al., 2010; Siitonen et al., 2010) also declare that energy efficiency is essential to attenuate the impact on global warming. However, Fernández González and colleagues (2014b) stated that improvement of energy efficiency is not enough to offset joint influence of growing overall activities as actual impact of increased energy efficiency on total energy use and CO_2 emissions is uncertain due to the phenomenon of 'rebound' effects (Turner and Hanley, 2011). Therefore it is more important to reduce energy consumption rather to increase energy efficiency.

The promotion of renewable energy resources determined the reduction of GHG emissions as well (Blesl et al., 2010; Capros et al., 2011; Kitzing et al., 2012; Klessmann et al., 2011). Bölük and Mert (2014) and López-Menéndez et al. (2014) have found that renewable energy consumption significantly lowers GHG emission in the EU.

3. Methods and data

This analysis covers 25 EU countries (Austria, Belgium, Bulgaria, Czech Republic, Cyprus, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Ireland, Latvia, Lithuania, Malta, Netherlands, Poland, Portugal, Romania, Spain, Slovenia, Slovakia, Sweden, United Kingdom) which had joined the EU by 2007, excluding Denmark due to the errors in data, and Luxembourg due to lack of data. In order to evaluate GHG emissions from the production-based activities, air emission account data of 14 economic activities (Annex 1), taken from the Eurostat database, were analysed. Eurostat for the compilation of air emission accounts applied the "inventory-first-approach". The "inventory-first-approach" starts from existing national emission inventories and re-arranges the data to a format compatible with national accounts. GHG emissions were aggregated referring to carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions (de Leeuw, 2002).

In order to reveal economic impact on changes in GHG emissions, GDP per capita PPP (constant 2005 international $) instead of market exchange rate was used. This was done in order to compare the outputs of economies in real terms. Economic development was the main factor in analysing the contributors, such as technology and structural alterations as well.

3.1. Evaluation of convergence of GDP and GHG emissions from the production-based perspective

In order to evaluate convergence process in the EU countries, β-convergence was applied. β-Convergence considers whether poorer countries and regions are able to catch-up with richer ones (Barro and Sala-i-Martin, 1992). Taking into account GHG emissions, β-convergence occurs in the EU countries where GHG emissions are lower, and it tends to grow faster (or decrease more slowly) than in countries where GHG emissions are larger (Markandya et al., 2006; Li and Lin, 2013). The β-convergence was estimated as follows:

$$\frac{1}{T}\ln\left(\frac{Y_{iT}}{Y_{i0}}\right) = a + b\ln Y_{i0} \qquad (1)$$

where

T – the duration of investigated period (number of years).
Y_{i0} – the value of the analysed indicator (GDP, GHG emissions) in the initial year of the period investigated.
Y_{iT} – the value of the analysed indicator in the end year of the period investigated.

When the slope of linear regression (coefficient b) is negative and statistically significant, it indicates the occurrence of convergence.

3.2. Evaluation of technology and structure alteration contribution to changes in GHG emissions

When the technological contribution to GHG changes was considered, its effect was indicated by a change in GHG emissions intensity within the given sectors (Voigt et al., 2014). Definition of technology in this article includes not only technological progress, but also other instruments, such as renewable energy consumption, expansion of eco-labelled agriculture and other tools related to GHG emission intensity reduction. In other words, it indicates how well each EU country enhances its capability for innovating in new, advanced technology to reduce GHG emissions (Kim and Kim, 2012).

Decomposition analysis could not be used for the evaluation of the technological contribution to changes in GHG emissions because of the lack of data. However, two scenarios there were compared in this instance. In the first scenario coefficient of air emissions intensity was calculated for 2000. Referring to the fact that intensity coefficient during the period analysed was the same as in 2000, it was assumed that GHG equivalent emissions grew at the same rate as economic activities. The second scenario was based on the real growth of air emissions from economic activities, which conveys real changes in emissions and the emission intensity coefficient. A difference between these two scenarios in 2010 reveals technological contribution to changes in GHG emissions. Therefore the technological contribution from 2000 to 2010 was calculated as follows:

$$\mathrm{Tc} = \frac{\sum_i \mathrm{VA}_{it} \times I_{i0}}{\sum_i \mathrm{VA}_{it} \times I_{it}} \qquad (2)$$

where

Tc – the technology contribution to changes in GHG emissions in the EU country.
VA_{it} – the value added of economic activity i in the year 2010 in Euros in constant prices.
I_{i0} – the GHG emissions intensity of economic activity i in year 2000.
I_{it} – the GHG emissions intensity of economic activity i in year 2010.

In order to evaluate structural changes of economies to contribution to the alterations of GHG emissions during 2000–2010, two further scenarios were also compared. The first one describes situation when the economic structure does not change and the second scenario is based on real change in production structure. Thus the following formula was used:

$$Sc = \frac{\sum_i (VA_{i0} \times \omega) \times I_{it}}{\sum_i VA_{it} \times I_{it}} \quad (3)$$

where

Sc – the contribution of economic structural changes to changes of GHG emissions in the EU country.
VA_{i0} – the value added of economic activity i in the year 2000 in Euros in constant prices.
ω – the changes in gross value added of all economic activities during 2000–2010.

Therefore in this study the extent of contribution of technological and economic structural changes to GHG emissions in the distinct EU countries was evaluated.

3.3. Evaluation of EU Cohesion Policy (2014–2020) implementation impact on changes in GHG emissions

In order to reveal implications of the EU Cohesion Policy (2014–2020) implementation regarding its impact on GHG emissions, this study applied Spearman correlation. Using the EU countries panel data 2010 there was evaluated correlation coefficient between changes in GHG emissions and changes in the share of renewable energy, expenditure on R&D as a percentage of GDP, and energy efficiency.

4. Results and discussion

4.1. The EU convergence of GDP and implication regarding GHG emissions

In the case of EU enlargement and implementation of the EU Cohesion Policy (2007–2013), new EU members took full advantage of the Structural and Cohesion funds as well as economic integration within the European Single Market. These factors drove the convergence process when economies grew faster in the new EU member states than in old members, which had a higher level of GDP, particularly during the period of economic prosperity (Rapacki and Prochniak, 2009; Juknys et al., 2014). Our results also confirmed occurrence of economic convergence during the period analysed (2000–2010) across the EU countries. Fig. 2 shows that countries such as Romania, Bulgaria and all the Baltic States, which had the lowest initial level of GDP, grew faster than old well developed EU countries and thus the EU Cohesion Policy (2007–2013) was successfully implemented.

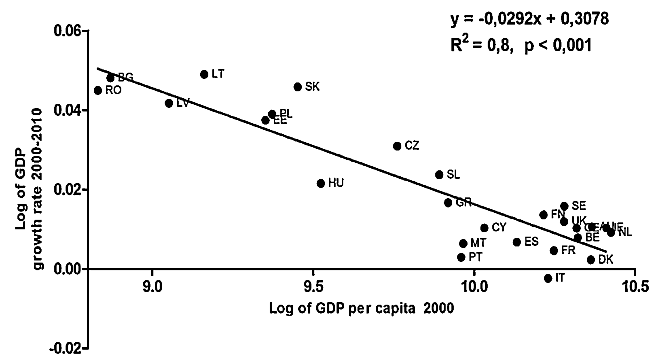

Fig. 2. Regression of GDP growth rate at initial level in the EU-26.

Furthermore, analysing relationship between economic development and the level of GHG emissions of the EU-25 countries, from Fig. 3 (left) it is evident that in 2010 the EKC across the EU countries did not occur. A positive and statistically significant correlation between GDP and GHG emissions conveys that the more developed EU countries, the bigger emitters of GHG they were. Bölük and Mert (2014) found the same results. Therefore, these countries should implement a strict GHG reduction policy and less economically developed EU countries should not follow the experience of the rich ones.

Moreover, as it is shown in Fig. 3 (right) the economic growth affected an increase in GHG emissions as well. Countries where economies grew the most rapidly were characterised by growth in GHG emissions. This was particularly typical for the new EU members. Therefore, taking in to account the EU Cohesion Policy (2007–2013), when the GDP growth, particularly in new EU member states, is desirable, the situation described was not favourable. On the other hand, countries where the growth of GDP was one of the lowest were characterised by the largest decrease in GHG emissions. Thus, furthering the process of convergence, which main attribute is the decelerating growth of GDP, and particularly in developed countries, has positive trends regarding the implementation of GHG reductions.

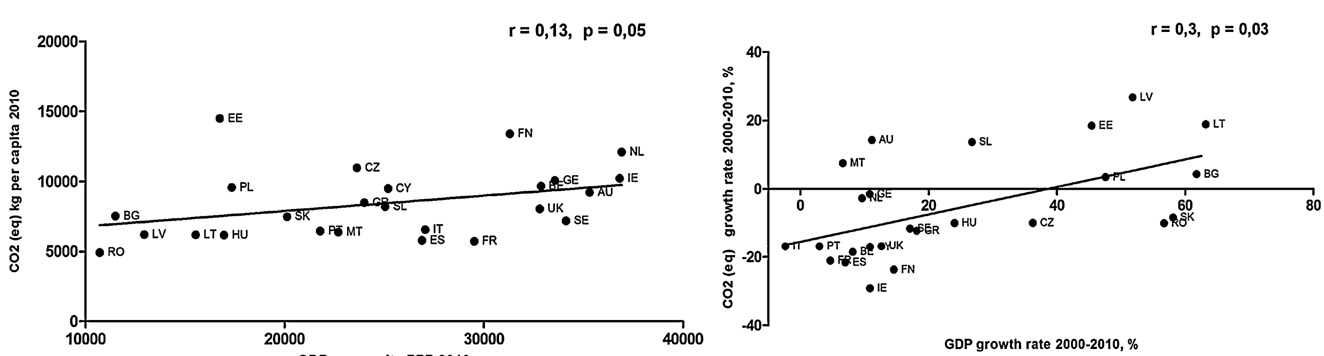

Fig. 3. Correlations between GDP and GHG emissions (left), and between growth rate of GDP and GHG emissions (right).

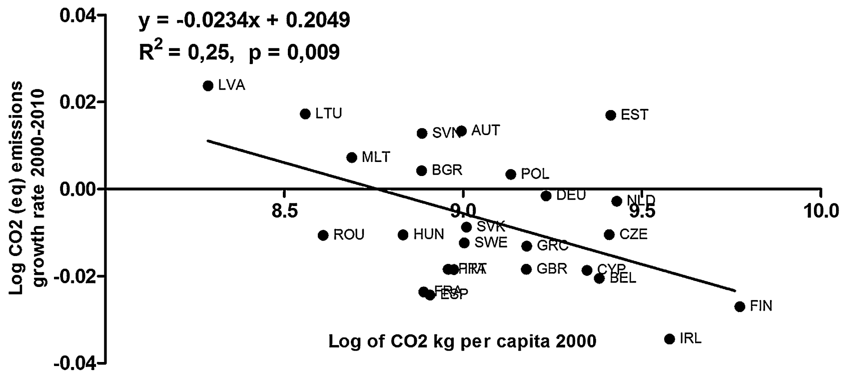

Fig. 4. Regression of growth rate in GHG emissions from a production-based perspective at initial level in the EU-25.

Furthermore, the convergence of GHG emissions from a production-based perspective was confirmed as well (Fig. 4). It shows that the pollution of GHG emissions during analysed period increased the most in least emitting countries. Meanwhile in the most polluting countries the emissions decreased. The most problematic countries are Estonia, Austria and Poland, where the initial level of emissions was one of the highest and the growth in pollution was one of the largest as well (Fig. 4). Therefore, this results shows that implementation of climate change policy in these countries was ineffective. Furthermore, the growth in GHG emissions during period analysed also occurred in Lithuania, Latvia, Malta, Slovenia and Bulgaria, where the initial GHG level was not so high. However, it was negative in terms of the EU climate policy. In contrast, positive changes in GHG emissions were observed in Ireland, Spain, Finland and France, where the reduction in GHG emissions was the largest (Fig. 4).

According to these results, the countries in which the growth of GHG emissions was observed should follow the best practices of the successful reduction in GHG emission. Considering that the most important factors for a GHG emissions reduction is technological improvement and structural composition changes, in the next section it is analysed how these factors contribute to changes in GHG emissions and how this depends on the GDP growth rate.

4.2. Contribution of technological improvements and structure composition alterations to changes in GHG emissions

Many research works (see Voigt et al., 2014; Zhang et al., 2012; Alves and Mountinho, 2013) have stated that economic growth can stimulate innovations and technological progress, and this should decrease GHG emissions. It was also observed that technological component plays a particularly prominent role in Romania, Slovakia and Bulgaria, where intensity of GHG emissions caused by economic activities in 2010 decreased the most in comparison with 2000. This showed that technological improvements and introduction of innovations related to reduction of GHG emissions intensity contributed between 55% and 75% to the GHG emissions reduction in these countries (Fig. 5). Meanwhile, between 2000 and 2010 in Austria the GHG emissions intensity increased (Fig. 5). Therefore, this EU country should devote more attention to decreasing economic activities based on GHG emissions intensity in order to implement the GHG emissions reduction policy.

Taking into account the fast economic convergence of the EU, which was influenced by the implementation of the EU Cohesion Policy (2007–2013), the correlation between technological contribution to changes in GHG emissions and GDP growth rate was analysed. A positive and statistically significant correlation coefficient was detected (Fig. 5), which conveys that technological progress's contribution was larger in those EU countries where the fastest GDP growth rate was observed. Therefore, these results reveal that technological progress is related to a decrease in GHG emissions intensity, which depends on the economic development. However, despite the considerable technological contribution to GHG emissions reductions, it does not offset the effect of production scale in countries such as Bulgaria, Poland and the Baltic States. During the analysed period an increase in GHG emissions in these countries was observed. Therefore it is additionally important to promote technological contribution, particularly when GDP grows very rapidly.

The second tool, which contributes to GHG emissions reduction, is economic structural alteration. Thus the results show that this factor contributed to GHG emissions reductions the most in the Czech Republic, Bulgaria and Estonia. However, this impact was

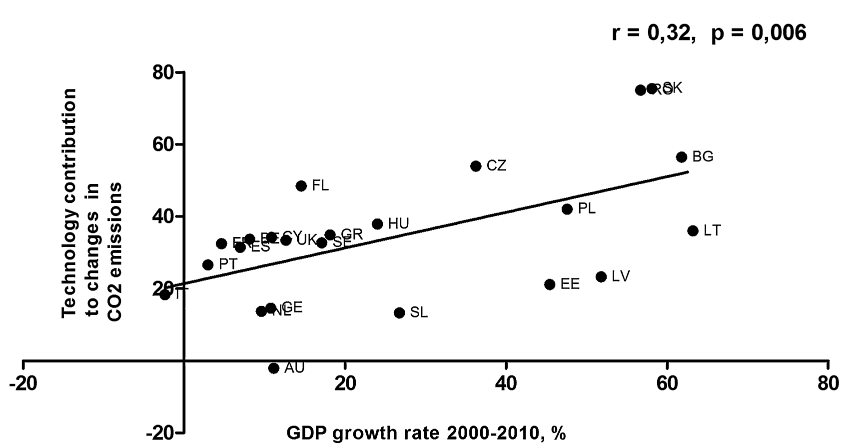

Fig. 5. Relationship between technological contribution to GHG emissions and GDP growth rate in the EU-25 countries.

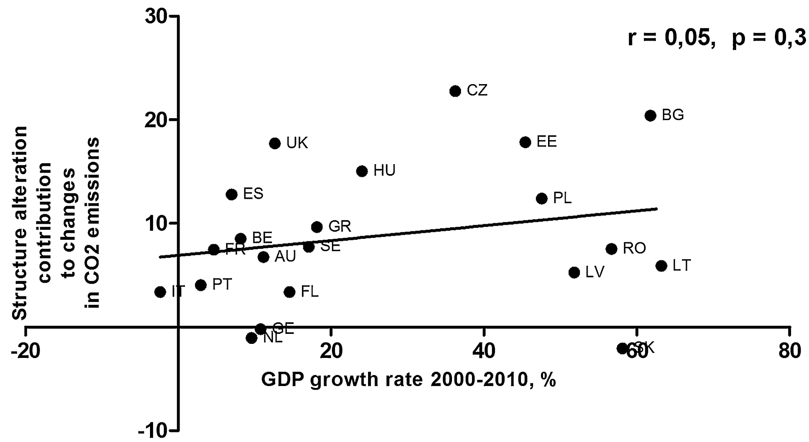

Fig. 6. Relationship between contribution of economic structural alteration in GHG emissions and GDP growth rate in EU-25 countries.

smaller than the technological one. So, in the aforementioned countries economic structural alteration between 2000 and 2010 contributed to a 20% reduction in GHG emissions. Meanwhile in the Netherlands, Slovakia and Germany the impact of structural change had a negative impact (Fig. 6). This implies that in these countries the gross value added grew faster in more polluting economic activities than in services.

Analysing the GDP growth rate's impact on the contribution of structural alteration to GHG emissions, a positive, however, statistically insignificant relationship was determined (Fig. 6). This result reveals that economic growth did not seem to affect larger share of contribution of economic structural change to GHG emissions reductions. Furthermore, Voigt and colleagues (2014) have stated that in pursuing long-term aims and thus to reduce the environmental impact it is more important to develop a technological progress in combination with regulatory and institutional changes than to promote alteration in production structure.

4.3. The implication of the EU Cohesion Policy (2014–2020) implementation to the changes in GHG emissions

The latest EU Cohesion Policy (2014–2020) expresses more concern with environmental issues than the EU Cohesion Policy (2007–2013) and it covers the Europe 2020 strategy objectives. One of the main tasks of the Europe 2020 strategy is to reduce GHG emissions in the EU by 20% in comparison with 1990 levels. However, due to the lack of data it was not possible to evaluate GHG emission changes from a production-based perspective in comparison with their initial (1990) level. However, during the period of 2000–2010 negative tendencies were observed when GHG emissions in some EU countries, such as Austria, Poland, Malta, Bulgaria, Slovenia and the Baltic States, even increased.

Taking into account that the most recent EU Cohesion Policy (2014–2020) links the allocation of more funds to research and technology, renewable resources and energy efficiency, how the changes of these variables influenced changes in GHG emissions there is analysed further. Thereby in Table 1 it is shown that the impact of changes in expenditure on R&D is indirectly linked to changes in GHG emissions. However, it is vital to reduce global carbon emissions by using significant technological progress (such as zero emission energy technologies, zero emission vehicles, etc.) in combination with regulatory and institutional change (Apak and Atay, 2013), as the expenditure on R&D impacts the reduction on GHG only when it is implementing the technologies which impact the decrease of GHG emissions.

Analysing the impact of changes in energy efficiency to changes in GHG emissions, general energy efficiency measure there was used due to the lack of energy account data. However, a statistically insignificant positive correlation coefficient was determined (Table 1). This result reveals that the changes in energy efficiency did not have direct impact on changes in GHG emissions as well. However, the result should be evaluated cautiously because the impact of general energy efficiency was studied. Nevertheless, considering that GHG emissions from the production-based perspective formed the largest share of general GHG emissions in EU countries, it was assumed that energy consumption from a production-based perspective should form the largest share in the EU countries as well. Thus the fact that a change in energy efficiency does not influence changes in GHG emissions could be due to the phenomenon of rebound effects (Turner and Hanley, 2011). Moreover, it could also be related to the fact that, despite the growth of energy efficiency, energy consumption increased further. EEA (2013) and Smit et al. (2014) also stated the energy saving target is the most problematic in the EU. Therefore, in order to achieve GHG emissions targets, it is very important the increase of energy efficiency in order to reduce the energy consumption in the EU countries.

Meanwhile our results showed that only the growth in the share of renewable energy drives a reduction in GHG emissions and this relationship is statistically significant (Table 1). Bölük and Mert (2014) and López-Menéndez et al. (2014) also found that renewable energy consumption significantly lowers GHG emission in the EU. Therefore implementing the target to increase the share of renewable energy resources is successful as contribution to GHG emissions reductions. However, Klessman and colleagues (2011) stated that many EU members have a very low policy effectiveness and deployments status for almost all renewable energy sources. Therefore, it is very important to make additional policy efforts to implement European targets of renewable energy sources (Klessmann et al., 2011; Kitzing et al., 2012; Capros et al., 2011).

Table 1
Matrix of correlation coefficients.

	ΔGHG emissions from a production-based perspective
ΔExpenditure on R&D, % of GDP	0.1
ΔEnergy efficiency	0.13
ΔShare of renewable energy %	−0.41*

* $p < 0.05$.

5. Conclusions

The results from this study show that in the period of 2000–2010 in the EU countries economic convergence there was observed. This means that the EU Cohesion Policy (2003–2007) was implemented successfully. Considering that in the case of convergence process GDP in the new EU members grew very fast, it drove an increase in GHG emissions from a production-based perspective, which is not favourable from a GHG emissions reduction policy viewpoint. On the other hand, countries where the growth of GDP was one of the lowest were characterised by the largest decrease in GHG emissions. Thus, furthering the process of convergence, which main attribute is the decelerating growth of GDP, and particularly in developed countries, has positive trends regarding the implementation of GHG reductions. Moreover, convergence of GHG emissions was confirmed as well. It was determined that the most problematic countries were Austria, Poland, Slovenia, Bulgaria, Malta and the Baltic States, where the growth of GHG emissions was observed. Therefore these countries, in order to reach the targets of GHG emissions reductions, should follow the best practices of countries, where the largest decrease in GHG emissions was observed.

The most important tools for a reduction in GHG emissions are technology and structural alteration of economy. Contribution of technological progress was larger in those EU countries where the fastest GDP growth rate was observed. The results of this study show that technological component plays a particularly prominent role in Romania, Slovakia and Bulgaria, where the intensity of GHG emissions in separate economic activities in 2010 in comparison with 2000 decreased the most. Despite the big technological contribution to GHG emissions reductions, it does not offset the effect of production scale in countries such as Bulgaria, Poland and the Baltic States. Meanwhile in Austria GHG emissions intensity between 2000 and 2010 increased. Therefore it is additionally important to promote technological contributions, particularly in Austria and in those countries where GDP grows very fast.

Economic structural changes contributed to GHG emissions reductions the most in the Czech Republic, Bulgaria and Estonia. However, this impact was smaller than the technological one. Meanwhile, in the Netherlands, Slovakia and Germany structural change had a negative impact. Moreover, economic growth did not seem to affect larger part of contribution of economic structural change to GHG emissions reductions. Thus, pursuing long-term aims, it is more important to develop technological progress than to promote alteration of the production structure.

Considering new EU Cohesion Policy (2014–2020), which links the allocation of funds to Europe 2020 strategy objectives, no significant correlation coefficient between changes in GHG emission and changes in expenditure on R&D and energy efficiency was found. The impact of expenditure on R&D is indirectly related to changes in GHG emissions, but can appear later when particular technologies, which are related to expenditure on R&D, are implemented. Therefore it is very important to increase expenditure on R&D and spillover of innovations further.

The fact that energy efficiency does not influence changes in GHG emissions could be related to the case that, despite the growth of energy efficiency, energy consumption increased further and thus the EU energy policy is implemented ineffectively. Therefore it is very important to reduce the energy consumption in order to increase the energy efficiency in the EU countries. Meanwhile only the growth in the share of renewable energy resources significantly drives a reduction in GHG emissions. Therefore it is very important to make additional policy efforts to implement Europe 2020 targets of renewable energy sources.

Appendix A. Annex 1

See Table A.1.

Table A.1
Aggregates of statistical classification of economic activities (NACE rev. 1.1) used in research.

NACE code	Economic activity
A	Agriculture, forestry and fishing
C	Mining and quarrying
D	Manufacturing
E	Electricity, gas, steam and air conditioning supply and water supply
F	Construction
G	Wholesale and retail trade; repair of motor vehicles and motorcycles
I	Transportation and storage
I64	Post and telecommunications
J	Financial and insurance activities
K	Real estate activities
L	Public administration and defence; compulsory social security
M	Education
N	Human health and social work activities
O	Other service activities

References

Acaravci, A., Ozturk, I., 2010. On the relationship between energy consumption, CO_2 emissions and economic growth in Europe. Energy 35, 5412–5420.
Alves, M.R., Mountinho, V., 2013. Decomposition analysis and innovative accounting approach for energy-related CO_2 (carbon dioxide) emissions intensity over 1996–2009 in Portugal. Energy 57, 775–787.
Apak, S., Atay, E., 2013. A look at the EU countries carbon dioxide emissions and Turkey's sustainable industrial growth. Proc. Soc. Behav. Sci. 99, 11–18.
Barro, R.J., Sala-i-Martin, X., 1992. Convergence. J. Polit. Econ. 100 (2), 223–251.
Blesl, M., Kobert, T., Bruchof, D., Kuder, R., 2010. Effects of climate and energy policy related measure and targets on the future structure of the European energy system in 2020 and beyond. Energy Policy 38, 6278–6292.
Bölük, G., Mert, M., 2014. Fossil and renewable energy consumption, GHG (greenhouse gases) and economic growth: evidence from a panel of EU (European Union) countries. Energy 74, 439–446.
Botringer, C., Rutherfors, T.F., 2013. Transition toward a low carbon economy: a computable general equilibrium analysis for Poland. Energy Policy 55, 16–26.
Brizga, J., Feng, K., Hubacek, K., 2014. Drivers of greenhouse gas emissions in the Baltic States: a structural decomposition analysis. Ecol. Econ. 98, 22–28.
Butnar, I., Llop, M., 2011. Structural decomposition analysis and input-output subsystems: changes in CO_2 emissions of Spanish service sectors (2000–2005). Ecol. Econ. 70, 2012–2019.
Capros, P., Mantzos, L., Parousos, L., Tasios, N., Klaassen, G., Ierland, T.V., 2011. Analysis of the EU policy package on climate change and renewable. Energy Policy 39, 1476–1485.
Corradini, M., Costantini, V., Mancinelli, S., Mazzanti, M., 2014. Unveiling the dynamic relation between R&D and emission abatement National and sectoral innovation perspectives from the EU. Ecol. Econ. 102, 48–59.
Curran, L., Zignago, S., 2012. EU enlargement and the evolution of European production networks. Res. Int. Bus. Financ. 26, 240–257.
de Leeuw, F.A.A.M., 2002. A set of emission indicators for long-range transboundary air pollution. Environ. Sci. Policy 5, 135–145.
Dinda, S., 2004. Environmental Kuznets Curve hypothesis: a survey. Ecol. Econ. 49, 431–455.
Doyle, O., Fidrmuc, J., 2006. Who favors enlargement? Determinants of support for EU membership in the candidate countries' referenda. Eur. J. Polit. Econ. 22, 520–543.
EC, 2010. Europe 2020: A European Strategy for Smart, Sustainable and Inclusive Growth. Communication COM(2010) 2020 Final European Commission, Brussels.
EEA (European Environmental Agency), 2010. The European environment – State and Outlook 2010: Synthesis State of environment report No 1, pp. 113.
EEA, 2013. Trends and Projections in Europe 2013: Tracking Progress towards Europe's Climate and Energy Targets until 2020.
Farhani, S., Mrizak, S., Chaibi, A., Rault, C., 2014. The environmental Kuznets curve and sustainability: a panel data analysis. Energy Policy 71, 189–198.
Fernández González, P., Landajo, M., Presno, M.J., 2014a. Tracking European Union CO_2 emissions through LMDI (logarithmic-mean Division index) decomposition. The activity revaluation approach. Energy 73, 741–750.
Fernández González, P., Landajo, M., Presno, M.J., 2014b. Multilevel LMDI decomposition of changes in aggregate energy consumption. A cross country analysis in the EU-27. Energy Policy 68, 576–584.

Fernández González, P., Landajo, M., Presno, M.J., 2014c. The driving forces behind changes in GHG emission levels in EU-27. Differences between member states. Environ. Sci. Policy 38, 11–16.

Hammond, G.P., Norman, J.B., 2012. Decomposition analysis of energy-related carbon emissions from UK manufacturing. Energy 41, 220–227.

Herrerias, M.J., 2013. The environmental convergence hypothesis: carbon dioxide emissions according to the source of energy. Energy Policy 61, 1140–1150.

Holt, L., Galligan, M., 2013. Energy efficiency policies as part of carbon reduction efforts: lessons from the EU for the U.S. Electr. J. 26 (7), 33–42.

Jacoby, W., 2010. Managing globalization by managing Central and Eastern Europe: the EU's backyard as threat and opportunity. J. Eur. Public Policy 17 (3), 416–432.

Juknys, R., Liobikienė, G., Dagiliūtė, R., 2014. Sustainability of catch-up growth in the extended European Union. J. Clean. Prod. 63, 54–63.

Kaika, D., Zervas, E., 2013. The Environmental Kuznets Curve (EKC) theory – part A: concept, causes and the CO_2 emissions case. Energy Policy 62, 13392–21402.

Kaivo-oja, J., Luukkanen, J., Panula-Ontto, J., Vehmas, J., Chen, Y., Mikkonen, S., Aufferman, B., 2014. Are structural change and modernisation leading to convergence in the CO_2 economy? Decomposition analysis of China. Energy 72, 115–125.

Kim, K., Kim, Y., 2012. International comparison of industrial CO_2 emission trends and the energy efficiency paradox utilizing production-based decomposition. Energy Econ. 34, 1724–1741.

Kitzing, L., Mitchell, C., Morthorst, P.E., 2012. Renewable energy policy in Europe: converging or diverging? Energy Policy 51, 192–201.

Klessmann, C., Held, A., Rathmann, M., Ragwitz, M., 2011. Status and perspectives of renewable energy policy and deployment in the European Union – what is needed to reach the 2020 targets? Energy Policy 39, 7637–7657.

Kolodko, G.W., 2009. A two-thirds of success. Poland's post-communist transformation 1989–2009. Communist Post-Communist Stud. 42, 325–351.

Kumar, S., Managi, S., 2010. Environment and productivities in developed and developing countries: the case of carbon dioxide and sulphur dioxide. J. Environ. Manag. 91, 1580–1592.

Li, X., Lin, B., 2013. Global convergence in per capita CO_2 emissions. Renew. Sustain. Energy Rev. 24, 57–363.

Liobikienė, G., Mandravickaitė, J., 2011. Achievements of Lithuanian sustainable development during the integration process into the European Union. Technol. Econ. Dev. Econ. 17 (1), 62–73.

Liou, J.-L., Wu, P.-I., 2011. Will economic development enhance the energy use efficiency and CO_2 emission control efficiency? Exp. Syst. Appl. 38, 12379–12387.

López-Menéndez, A.J., Pérez, R., Moreno, B., 2014. Environmental costs and renewable energy: re-visiting the Environmental Kuznets Curve. J. Environ. Manag. 145, 368–373.

Marin, G., Mazzanti, M., Montini, A., 2012. Linking NAMEA and input output for consumption vs. production perspective' analysis. Evidence on emission efficient and aggregation biases using the Italian and Spanish environmental accounts. Ecol. Econ. 74, 71–84.

Markandya, A., Pedroso-Galinato, S., Streimikiene, D., 2006. Energy intensity in transition economies: is there convergence towards the EU average? Energy Econ. 28, 121–145.

Marrero, G.A., 2010. Greenhouse gas emissions, growth and the energy mix on Europe. Energy Econ. 32, 1356–1363.

Moya, J.A., Pardo, N., 2013. The potential for improvements in energy efficiency and CO_2 emissions in the EU27 iron and steel industry under different payback periods. J. Clean. Prod. 52, 71–83.

Padilla, E., Duro, J.A., 2013. Explanatory factors of CO_2 per capita emission inequality in the European Union. Energy Policy 62, 1320–1328.

Parith, J., Panada, M., Ganesh-Kumar, A., Singh, V., 2009. GHG emissions structure of Indian economy. Energy 34, 1024–1031.

Pasche, M., 2002. Technical progress, structural change, and the environmental Kuznets curve. Ecol. Econ. 42, 381–389.

Peters, G.P., 2008. From production-based to consumption-based national emission inventories. Ecol. Econ. 65, 13–23.

Rakauskienė, O.R., Kozlovskij, V., 2014. Overview of EU economic cohesion process performance for new member states. Proc. Soc. Behav. Sci. 110, 284–292.

Rapacki, R., Prochniak, M., 2009. Real beta and sigma convergence in 27 transition countries, 1990–2000. Post-Communist Econ. 21 (3), 307–326.

Robalino-López, A., Mena-Nieto, A., García-Ramos, J.-E., Golpe, A.A., 2015. Studying the relationship between economic growth, CO_2 emissions, and the environmental Kuznets curve in Venezuela (1980–2025). Renew. Sustain. Energy Rev. 41, 602–614.

Saikku, L., Rautiainen, A., Kauppi, P.E., 2008. The sustainability challenge of meeting carbon dioxide targets in Europe by 2020. Energy Policy 36 (2), 730–742.

Siitonen, S., Tuomaala, M., Suominen, M., Ahtila, P., 2010. Implications of process energy efficiency improvements for primary energy consumption and CO_2 emissions at the national level. Appl. Energy 87, 2928–2937.

Smit, T.A.B., Hu, J., Harmsen, R., 2014. Unravelling projected energy savings in 2020 of the EU Members States using decomposition analyses. Energy Policy 74, 271–285.

Turner, K., Hanley, N., 2011. Energy efficiency, rebound effects and the environmental Kuznets Curve. Energy Econ. 33, 709–720.

Voigt, S., Cian, E.D., Schymura, M., Verdolini, E., 2014. Energy intensity developments in 40 major economies: structural change or technology improvement? Energy Econ. 41, 47–62.

Wang, Y., Zhao, H., Li, L., Liu, Z., Liang, S., 2013. Carbon dioxide drivers for a typical metropolis using input–output structural decomposition analysis. Energy Policy 58, 312–318.

Waslekar, S.S., 2014. World environmental Kuznets curve and the global future. Proc. Soc. Behav. Sci. 133, 310–319.

Welsch, H., Bonn, U., 2008. Economic convergence and life satisfaction in the European Union. J. Socio-Econ. 37, 1153–1167.

Wood, R., 2009. Structural decomposition analysis of Australia's greenhouse gas emissions. Energy Policy 37, 4943–4948.

Zhang, X.-P., Tan, Y.-K., Tan, Q.-L., Yuan, J.-H., 2012. Decomposition of aggregate CO_2 emissions within a joint production framework. Energy Econ. 34, 1088–1097.