International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2015, 5(4), 949-954.

Coupling and Decoupling Relationships between Energy Consumption and Air Pollution from the Transport Sector and the Economic Activity

George N. Botzoris[1]*, Athanasios T. Galanis[2], Vassilios A. Profillidis[3], Nikolaos E. Eliou[4]

[1]Department of Civil Engineering, Democritus University of Thrace, Vas. Sofias 12, 67100 Xanthi, Greece, [2]Department of Civil Engineering, University of Thessaly, Pedion Areos, 38334, Volos, Greece, [3]Department of Civil Engineering, Democritus University of Thrace, Vas. Sofias 12, 67100 Xanthi, Greece, [4]Department of Civil Engineering, University of Thessaly, Pedion Areos, 38334, Volos, Greece. *Email: gbotzori@civil.duth.gr

ABSTRACT

In the present paper an analysis of whether and under which conditions coupling or decoupling exists between growth rates (as reflecting in gross domestic product rates) of the economy and energy consumption and air pollution from the transport sector. An extensive time period from 1995 to 2012 is surveyed and divided into two periods, from 1995 to 2008 (growth period) and from 2008 to 2012 (recession period). The analysis is conducted for the 28 European Union countries and illustrates, for most of these countries, a coupling phenomenon for the growth period and a decoupling phenomenon for the recession period. This finding may be essential for the further institutional steps to be undertaken, in view of the reduction of carbon dioxide and of energy conservation.

Keywords: Coupling, Decoupling, Transportation, Environment, Sustainability
JEL Classifications: H23, O44, R4, Q53

1. INTRODUCTION

In environmental terms, decoupling is referring to the ability of an economy to grow without increasing proportionally environmental effects, such as energy consumption and air pollution. So, an economy that is able to achieve gross domestic product (GDP) growth without environmental deterioration and increased energy consumption is said to be decoupled.

Although the increase of human and freight mobility could not have been achieved without environmental implications, these repercussions, however, could have been minimized, if in the early stages had been realized the necessity that the transport system (in regard to its infrastructure, as well as its operation) should be developed in a rational manner. It must be provided that the properly developed various transport infrastructure networks and transport systems would cooperate efficiently in order to serve any emerging demand. They should compete on equal terms and would be organized in an environmental-friendly way, thus securing better environmental conditions, lower energy consumption and less congestion and traffic accidents (Tricker, 2007; Teodorescu, 2010; Profillidis et al., 2014).

The use of renewable energy consumption has a positive effect on economic growth only in the more developed countries (Bozkurt and Destek, 2015). There is a short-run and long-relationship among economic growth, energy consumption and carbon emission in the case of developing countries like Pakistan and Nigeria (Abalaba and Dada, 2013; Ali et al., 2015).

A number of factors can be identified as influencing the total amount of emissions and the energy consumption attributable to the transport sector: The number of vehicles in a given area, the age of the vehicle fleet and the technology used, the extent of maintenance of vehicles, the availability of appropriate fuels and the extent to which they are used, and finally, topographical and climatological conditions of the specific area.

The target of this study is to analyze the relationship between the economic development and the energy consumption and the air pollution from the transport sector in countries of the European Union (EU). The present economic crisis in European countries with a starting time in year 2008 presented significant effects in the development of passenger and freight transportation, by reducing significantly their mobility. It will be examined if the reduction of passenger and freight mobility affected the air pollution and the energy consumption and the way it did so. The next target of this study is to quantify separately for each country through the coupling-decoupling relationship, the grade that the economic recession affected air pollution and energy consumption.

The economic crisis, as every event that reduces the available assets, is an opportunity to change a polluting and energy consumer sector, as the transport one, towards a more sustainable framework, by helping economic development without a proportional raise of energy consumption and air pollution.

2. EVOLUTION OF PASSENGER AND FREIGHT TRANSPORT ACTIVITY

It is established that the evolution of transport activity as a whole is at approximately the same rate as the evolution of the GDP. Air transport rates are greater than GDP rates (almost double), whereas rail transport rates are much slower. The almost continuously upward tendency of both passenger and freight for five decades after 1950 was stopped in Europe by the economic crisis of 2008-2010, which affected principally some EU countries (Figure 1).

3. TRANSPORT AND AIR POLLUTION

Transport is an important air pollution emitter worldwide, accounting for 90÷95% of carbon monoxide emissions, 60÷70% of nitrogen oxides (NOx), 40÷50% of hydrocarbons and volatile organic compounds (VOCs), 30÷35% of carbon dioxide (CO_2) emissions, 5% of sulfur dioxide and 25% of suspended materials, (IEA-UIC, 2013). Figure 2 presents the emissions of some air pollutants provoked by the various transport modes for passenger and freight transport (emissions per passenger km or ton km).

Some air pollutants (NOx, CO_2, VOCs, etc.) emitted by the transport activity consist greenhouse gases (GHG): They absorb and emit radiation within the thermal infrared range, a process that is the fundamental cause of the greenhouse effect.

In early 2007, the EU adopted the objective to limit climate change to 2°C (CEC, 2007a). More specifically, it has been defined a target to reduce GHG by at least 20% by 2020 (or 30% if an international agreement is achieved), compared with the emission levels of 1990. By 2050 the reductions of the EU emissions should reach 60-80%. Given the overall GHG reduction targets, it is obvious that the transport sector will have to contribute to GHG emission reductions and develop strategies and policies to meet these targets.

CO_2 emissions represent on the average 98.5% of the total GHG emitted by the transport sector (EU, 2014). Meanwhile, trends in CO_2 emissions continue to be bound closely to those of the global economy (Figure 3), with the few declines observed in the last decades being associated with events such as the oil price crises, asymmetrical events and the recent economic recession (Acaravci and Ozturk, 2010; Li et al., 2011; Abid and Sebri, 2011; Dritsaki and Dritsaki, 2014; Isa et al., 2015).

In 2012, the transport sector was responsible for the EU-28 countries for a 29.0% of total CO_2 emissions (20.5% in 1990 and 26.3% in 2000), the other sectors contributing: Energy industries (public electricity, heat production, petroleum refining, etc.) 34.9% (36.1% in 1990 and 34.2% in 2000), the manufacturing and construction sector 13.2% (18.5% in 1990 and 15.9% in 2000), the residential sector 10.3% (10.9% in 1990 and 10.7% in 2000), the commercial and institutional sector 4.4% (4.3% in 1990 and 4.0% in 2000), the agriculture sector 1.9% (2.0% in 1990 and 1.9% in 2000) and the other sectors 6.4%, (EU, 2014).

Figure 1: Trends in the passenger traffic (passenger-km), the freight traffic (ton-km) in relation to the gross domestic product in the European Union-28 countries (compiled by authors based on data of EU (2014))

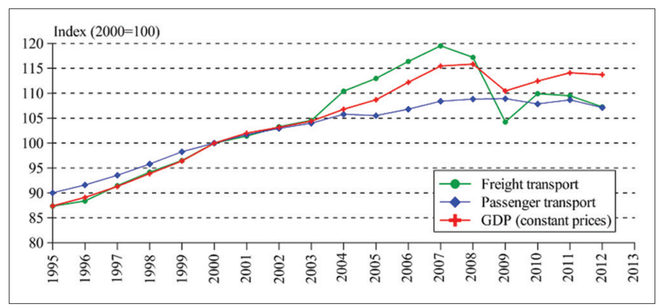


Figure 2: Emissions of pollutants provoked by various transport modes (compiled by authors based on data of Profillidis, 2014)

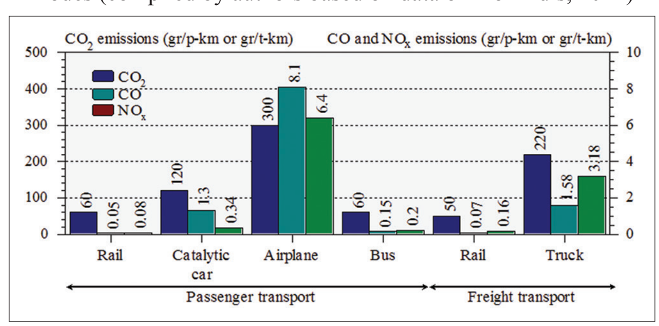
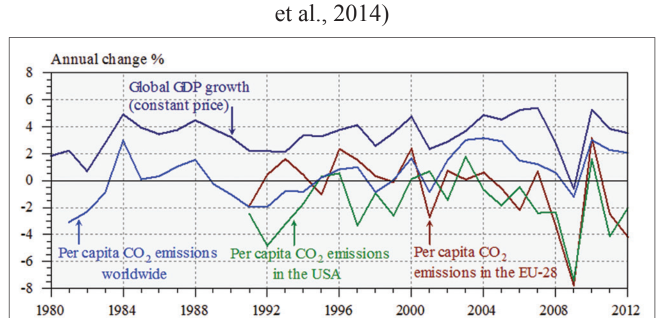


Figure 3: Annual growth of global gross domestic product and carbon dioxide emissions (compiled by authors based on data of Profillidis et al., 2014)



Within the transport sector, contribution of the various transport modes in CO_2 emissions was for the year 2012 as follows: Roads 71.8% (74.9% in 1990 and 73.4% in 2000), navigation 13.9% (13.9% in 1990 and 13.3% in 2000), civil aviation 12.9% (8.8% in 1990 and 11.7% in 2000), railways 0.6% (1.4% in 1990 and 0.8% in 2000), other (non-specified) 0.8%, (EU, 2014). In Figure 4 are illustrated the CO_2 emissions of the transport sector, in comparison to the total emission of all other sectors, for the EU-28 countries. From the year 2007 and afterwards, we can remark, a considerable reduction of transport sector CO_2 emissions, as well as of other sectors' CO_2 emissions.

In what transport sector emissions is concerned, it is significant to clarify to what extend this reduction is due to the impairment of economic growth after 2008 and the consequent reduction of both passenger and freight transport activity (Figure 5) or is the result of the EU policies and initiatives regarding the manipulation of GHG emissions. Indeed, the fluctuation of CO_2 emissions of the transport sector is following the transport activity; however, in 2010 for first time the CO_2 emissions accompanied by the transport of one passenger or 1 ton in a distance of 1 km were <120 g (Figure 6). This could be a signal for the effectiveness of the relative EU policies, as part of efforts to ensure it meets CO_2 and other GHG emission reduction targets (under the Kyoto Protocol), which are:

- Inclusion (since January 2012) of aviation in the EU Emissions Trading System, (CEC, 2009c)
- Strategy for the reduction of emissions from cars and vans, including emissions targets for new vehicles (CEC, 2007b). Cars manufacturers are obliged to ensure that their new car fleet does not emit more than an average of 95 g of CO_2/km by 2021. This can be compared with an average of almost 160 g CO_2/km in 2007 and 132.2 g CO_2/km in 2012
- Strategy for reducing heavy duty vehicle fuel consumption and CO_2 emissions
- Setting of tangible targets aiming to the reduction of the GHG intensity of fuels (CEC, 2009b)
- Introduction rolling resistance limits and tire labeling requirements have been introduced on new vehicles
- Legislation encouraging national authorities to deploy gas and electricity infrastructure (CEC, 2009a)
- Requirement of public authorities to take into account energy consumption and CO_2 emissions when procuring vehicles.

4. TRANSPORT AND ENERGY CONSUMPTION

For the EU-28 countries in the year 2012, the transport sector consumed 31.8% of the total energy (26.3% in 1990 and 30.5% in 2000), households 26.2% (25.3% in 1990 and 26.0% in 2000), industry 25.6% (34.0% in 1990 and 29.4% in 2000), services 13.5% (10.1% in 1990 and 10.3% in 2000), agriculture 2.2% (2.9% in 1990 and 2.4% in 2000), and other activities 0.7% (EU, 2014). Percentages of the energy consumption at the world level were for the year 2010 as follows: Transport 27.3%, industry 27.8%, domestic and tertiary sector 36.0%, whereas world energy demand was satisfied from five main sources: Oil 37.8%, gas 23.8%, coal 25.6%, nuclear 8.1%, hydroelectric 6.1%, alternative 0.9% (Profillidis et al., 2014).

Figure 4: Evolution of carbon dioxide emissions of the transport sector in comparison to other activities emissions for the European Union-28 countries (compiled by authors based on data of EU, 2014)

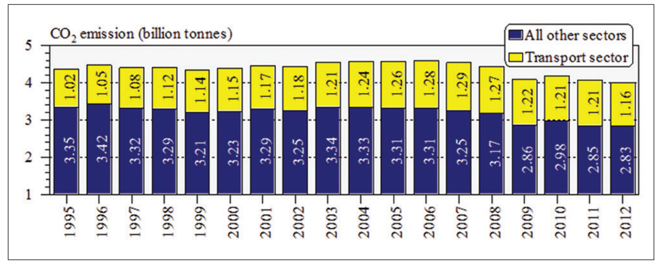


Figure 5: Evolution of passenger and freight transport activity of all transport modes (air, road, rail and sea) for the European Union-28 countries (compiled by authors based on data of EU (2014)

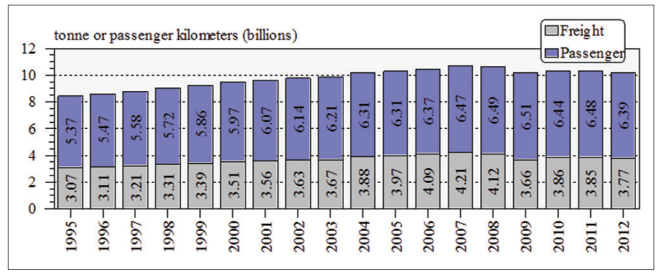
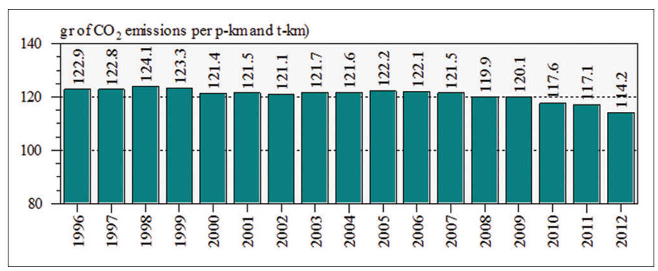


Figure 6: Evolution of average carbon dioxide emissions in case of transport of one passenger or one passenger or 1 ton for a distance of 1 km for the European Union-28 countries (compiled by authors based on data of EU, 2014)



Within the transport sector for the EU-28 countries in the year 2012, railways consumed 1.7% of total energy for transport activities (2.6% in 1990 and 2.1% in 2000), road transport 73.5% (75.2% in 1990 and 73.7% in 2000), navigation and pipelines 12.5% (13.0% in 1990 and 12.6% in 2000), and air transport 12.3% (9.3% in 1990 and 11.7% in 2000) (EU, 2014).

Figure 7 illustrates the energy consumption of the transport sector in comparison to other sectors, for the EU-28 countries. Similarly with CO_2 emissions, we can remark a considerable reduction of transport sector energy consumption from the year 2007 and afterwards. However, by dividing the energy consumption of the transport sector with the passenger and freight transport activity we realized that the reduction of energy consumption is not associated with the corresponding reduction of the unitary energy consumption (Figure 8).

5. COUPLING-DECOUPLING BETWEEN GDP AND TRANSPORTATION-RELATED ENERGY CONSUMPTION AND CO_2 EMISSION

Previous analysis, and especially Figure 3, risks misleading to the conclusion that economic activity and CO_2 emissions (or energy consumption) are always analogically correlated. This is the case when we have expansive (or recessive) coupling between the two phenomena studied. However, there may be decoupling, which is non-analogical correlation between the two phenomena studied.

Decoupling can be either absolute or relative. Absolute decoupling occurs when the transportation-related environmental indices are stable or decreasing, while the economic index increases. In relative decoupling, however, both the economic and transportation-related indexes increase, but the transportation-related index grows more slowly than the economic index (Banister and Stead, 2002; Tight et al., 2004; Tapio, 2005).

There are eight possibilities for the development of the indices in the decoupling framework (Figure 9). The rates of change of a transportation-related environmental index (Δ_{EI}) and GDP (Δ_{GDP}) can be coupled, decoupled or negatively decoupled. The result of this calculation is an elasticity value (e) (Tapio, 2005; Vehmas et al., 2007):

$$e = \%\Delta_{\text{Environmental Index}} / \%\Delta_{\text{GDP}}$$

An elasticity value of 1.0 means that both transportation-related index and GDP grow at a similar rate. In order not to overinterpret very small changes as significant signs of decoupling in the analysis, a ±20% variation of the elasticity values around 1.0 is regarded as coupling (the "funnel" shape in Figure 9), which leads to coupling being defined for elasticity values between 0.8 and 1.2. The rates of change of the indices can be either positive, expressed as expansive coupling, or negative, expressed as recessive coupling.

Decoupling can be divided into three subcategories: Weak, strong and recessive decoupling. In weak decoupling, whereas GDP and transportation-related environmental index both increase, GDP grows faster (elasticity between 0 and 0.8). In strong decoupling, GDP increases and transportation-related environmental index decreases, thus the elasticity is below 0. In recessive decoupling, GDP and transportation-related environmental index both decrease, but the transportation-related environmental index decreases more rapidly than the GDP (elasticity over 1.2) (Vehmas et al., 2007).

Negative decoupling can also be divided into three subcategories. In expansive negative decoupling, GDP and transportation-related environmental index both increase and the latest increases faster than the GDP (e >1.2). In strong negative decoupling, GDP decreases and transportation-related environmental index increases and e <0. In recessive negative decoupling, GDP and transportation-related environmental index both decrease, but GDP decreases faster (0 < e < 0.8).

Figure 7: Evolution of energy consumption of the transport sector in comparison to other activities' consumption for the European Union-28 countries (compiled by authors based on data of EU, 2014)

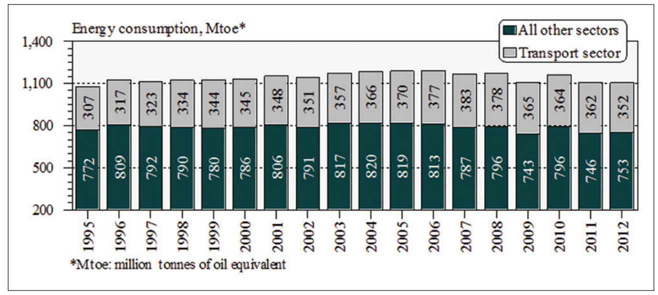


Figure 8: Evolution of average energy consumption accompanied by the transport of one passenger or 1 ton for a distance of 100 km (compiled by authors based on data of EU, 2014)

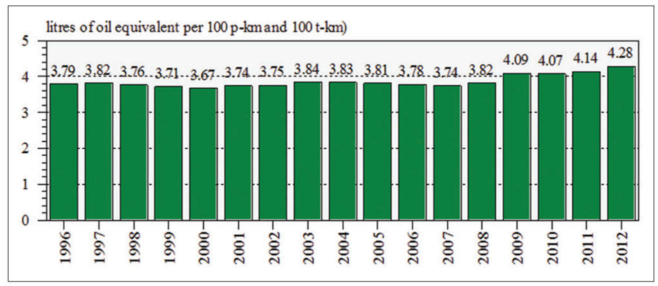


Figure 9: The decoupling framework for environment (compiled by authors based on data of Liimatainen and Pöllänen, 2013)

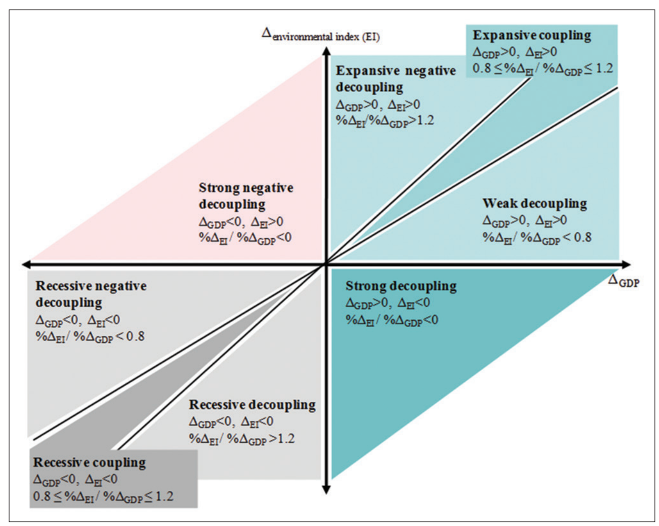
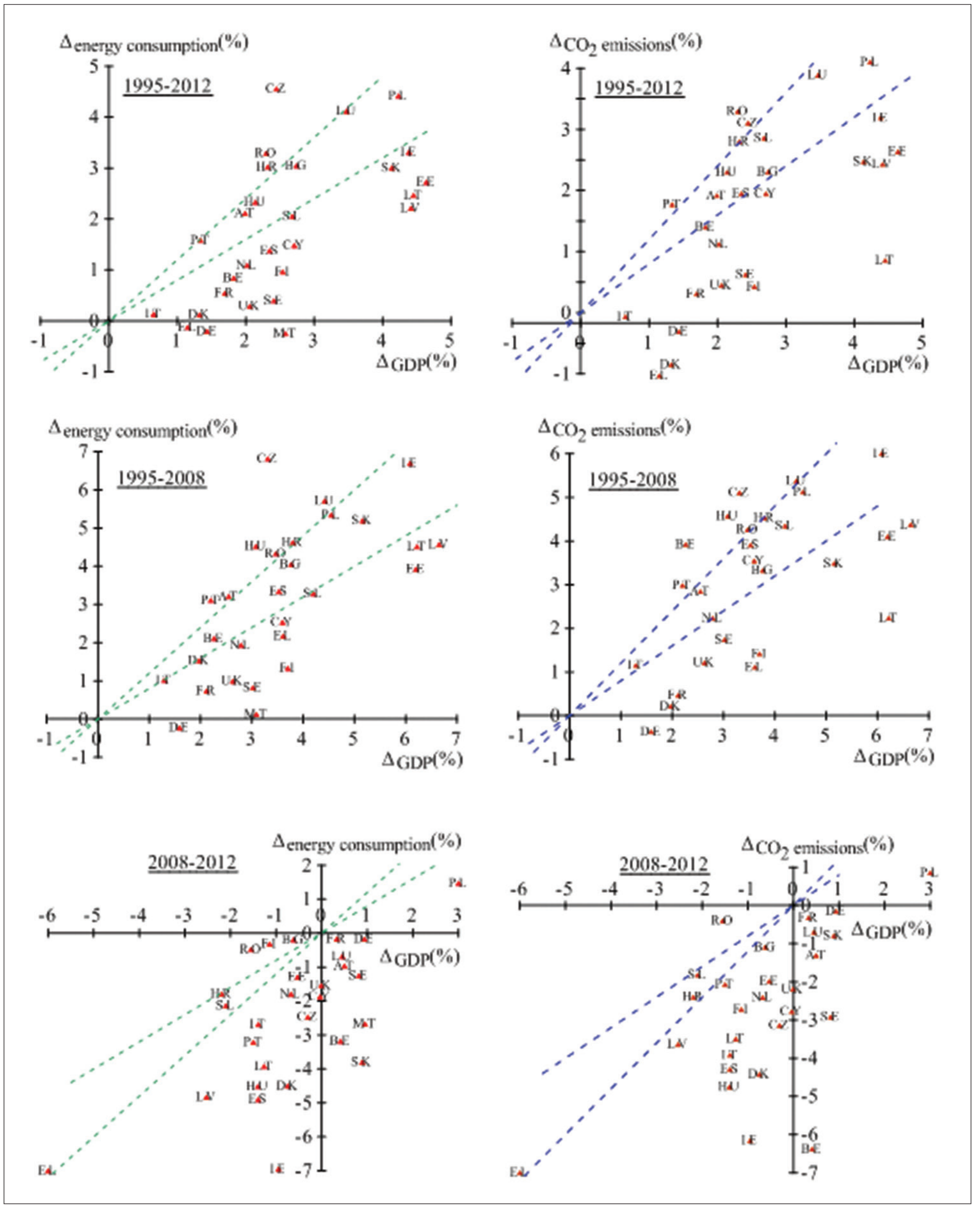


Figure 10 illustrates the coupling – Decoupling relationship between the GDP and the transportation-related CO_2 emissions and between GDP and transportation-related energy consumption for the EU-28 countries. The analysis is divided into three distinct time-periods: From 1995 to 2012, which represents the whole period of analysis, from 1995 to 2008 (period before the economic crisis) and from 2008 to 2012, namely the period after the appearance of the economic crisis.

Focusing on the coupling-decoupling relationship before and after the economic crisis, we can remark that the period before the economic crisis only in the case of Germany appears a strong

Figure 10: The evolution across different time periods of coupling and decoupling relationship between energy consumption and gross domestic product (GDP) and between carbon dioxide emissions and GDP for the European Union-28 countries (compiled by authors based on data of EU, 2014) (Abbreviation: AT: Austria, BE: Belgium, BG: Bulgaria, HR, Croatia, CY: Cyprus, CZ: Czech Republic, DE: Germany, DK: Denmark, EE: Estonia, FI: Finland, FR: France, GR: Greece, HU: Hungary, IE: Ireland, IT: Italy, LT: Lithuania, LV: Latvia, MT: Malta, PL: Poland, PT: Portugal, RO: Romania, ES: Spain, SE: Sweden, SK: Slovakia, SL: Slovenia, NL: The Netherlands, UK: United Kingdom)



decoupling relationship between GDP and both transportation-related CO_2 emissions and energy consumption. In the same period, in other countries it appears a weak decoupling relationship between GDP and transportation-related CO_2 emissions (Denmark, France, United Kingdom, Finland, Greece, Sweden, Lithuania, Latvia, Slovakia, Estonia and marginally the Netherlands). In the same countries (plus Slovakia and Malta) it appears weak decoupling relationship and between GDP and transportation-related energy consumption. For other EU countries, a more or less expansive coupling relationship between GDP and transportation-related CO_2 emissions and energy consumption is remarked.

The Figure 10 is radically different after the economic crisis (period 2008-2012) where only one country, Poland, still remains in a weak decoupling relationship between GDP and transportation-related CO_2 emissions and energy consumption. All the other countries, except Greece, Hungary and Slovenia, have entered in a decoupling phase concerning the linkage between GDP and transportation-related CO_2 emissions and energy consumption. For Greece, Hungary and Slovenia, the relationship between GDP and transportation-related CO_2 emissions and energy consumption is recessive coupling which can be interpreted as negative coupling.

It is very important that after the economic crisis, countries like Germany, France, Austria, Belgium, Slovakia, Sweden, United Kingdom, etc., have achieved economic growth while maintaining decrease at transportation-related CO_2 emissions and energy consumption.

6. CONCLUSION

In the present paper, the evolution across different time periods of coupling and decoupling relationship between transportation-related energy consumption and GDP and between CO_2 emissions from transportation and GDP for the EU-28 countries was analyzed. Focusing on the period before (1995-2008) and after the economic crisis (2008-2012), it is remarkable a significant differentiation of the interaction between economic growth and transportation-related energy consumption and CO_2 emissions, as after the economic crisis the vast majority of EU-28 countries have passed the threshold of coupling and are subjected to a form of decoupling (weak decoupling or strong decoupling or recessive decoupling).

The paper does not analyze whether the economic crisis was the one that acted as a catalyst in the transition from coupling to decoupling between GDP and transportation-related energy consumption and CO_2 emissions. We describe and depict a new promising for the environment reality. This new reality creates a significant opportunity for transport activities and for travel habits to enter into a continuous process of rationalization and reduction of both energy consumption and CO_2 emissions. It is a political and institutional challenge to maintain the observed decoupling after the economic crisis of 2008, by strengthening and encouraging the green mobility, the environmentally friendly and efficient mobility, which is one of the greatest tasks of the future.

REFERENCES

Abalaba, B.P., Dada, M.A. (2013), Energy consumption and economic growth nexus: New empirical evidence from Nigeria. International Journal of Energy Economics and Policy, 3(4), 412-423.

Abid, M., Sebri, M. (2011), Energy consumption – Economic growth nexus: Does the level of aggregation matter? International Journal of Energy Economics and Policy, 2(2), 55-62.

Acaravci, A., Ozturk, I. (2010), On the relationship between energy consumption, CO_2 emissions and economic growth in Europe. Energy, 35(12), 5412-5420.

Ali, A., Khatoon, S., Ather, M., Akhtar, N. (2015), Modeling energy consumption, carbon emission and economic growth: Empirical analysis for Pakistan. International Journal of Energy Economics and Policy, 5(2), 624-630.

Banister, D., Stead, D. (2002), Reducing transport intensity. European Journal of Transport and Infrastructure Research, 2(3-4), 161-178.

Bozkurt, C., Destek, M.A. (2015), Renewable energy and sustainable development nexus in selected OECD countries. International Journal of Energy Economics and Policy, 5(2), 507-514.

Commission of the European Communities (CEC). (2007a), Limiting Global Climate Change to 2 degrees Celsius. The way ahead for 2020 and beyond. COM/2007/2 Final, Brussels.

Commission of the European Communities (CEC). (2007b), Results of the review of the Community Strategy to reduce CO_2 emissions from passenger cars and light-commercial vehicles, COM/2007/19 Final, Brussels.

Commission of the European Communities (CEC). (2009a), Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, Brussels. Official Journal of the European Union, L140, 52, 16-62.

Commission of the European Communities (CEC). (2009b), Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC, Brussels. Official Journal of the European Union, L140, 52, 88-113.

Commission of the European Communities (CEC). (2009c), Directive 2008/101/EC of the European Parliament and of the Council of 19 November 2008 amending Directive 2003/87/EC so as to include aviation activities in the scheme for greenhouse gas emission allowance trading within the community, Brussels. Official Journal of the European Union, L8, 52, 3-21.

Dritsaki, C., Dritsaki, M. (2014), Causal relationship between energy consumption, economic growth and CO_2 emissions: A dynamic panel data approach. International Journal of Energy Economics and Policy, 4(2), 125-136.

EU–European Union. (2014), Energy and Transport in Figures – Statistical Pocketbook 2014. Luxembourg: Publications Office of the European Union.

IEA–International Energy Agency, UIC–International Union of Railways. (2013), Railway Handbook 2013, Energy Consumption and CO_2 Emissions. Paris, France: ETF-Railway Technical Publications.

Isa, Z., Alsayed, A., Kun, S.S. (2015), Review paper on economic growth – Aggregate energy consumption nexus. International Journal of Energy Economics and Policy, 5(2), 385-401.

Li, F., Dong, S., Li, X., Liang, Q., Yang, W. (2011), Energy consumption – Economic growth relationship and carbon dioxide emissions in China. Energy Policy, 39, 568-574.

Liimatainen, H., Pöllänen, M. (2013), The impact of sectoral economic development on the energy efficiency and CO_2 emissions of road freight transport. Transport Policy, 27, 150-157.

Profillidis, V. (2014), Railway Management and Engineering. 4th ed. London, UK: Ashgate.

Profillidis, V.A., Botzoris, G.N., Galanis, A.T. (2014), Environmental effects and externalities from the transport sector and sustainable transportation planning – A review. International Journal of Energy Economics and Policy, 4(4), 647-661.

Tapio, P. (2005), Towards a theory of decoupling: degrees of decoupling in the EU and the case of road traffic in Finland between 1970 and 2001. Transport Policy, 12(2), 137-151.

Teodorescu, G. (2010), Climate change impact on urban ecosystems and sustainable development of cities in Romania. WSEAS Transactions on Environment and Development, 6(2), 103-112.

Tight, M.R., Delle Site, P., Meyer-Rühle, O. (2004), Decoupling transport from economic growth: Towards transport sustainability in Europe. European Journal of Transport and Infrastructure Research, 4(4), 381-404.

Tricker, R.C. (2007), Assessing cumulative environmental effects from major public transport projects. Transport Policy, 14(4), 293-305.

Vehmas, J., Luukkanen, J., Kaivo-Oja, J. (2007), Linking analyses and environmental Kuznets curves for aggregated material flows in the EU. Journal of Cleaner Production, 15(17), 1662-1673.