Transport-Related Energy Consumption and Economic Activity – To which extent this Relationship can be Decoupled?

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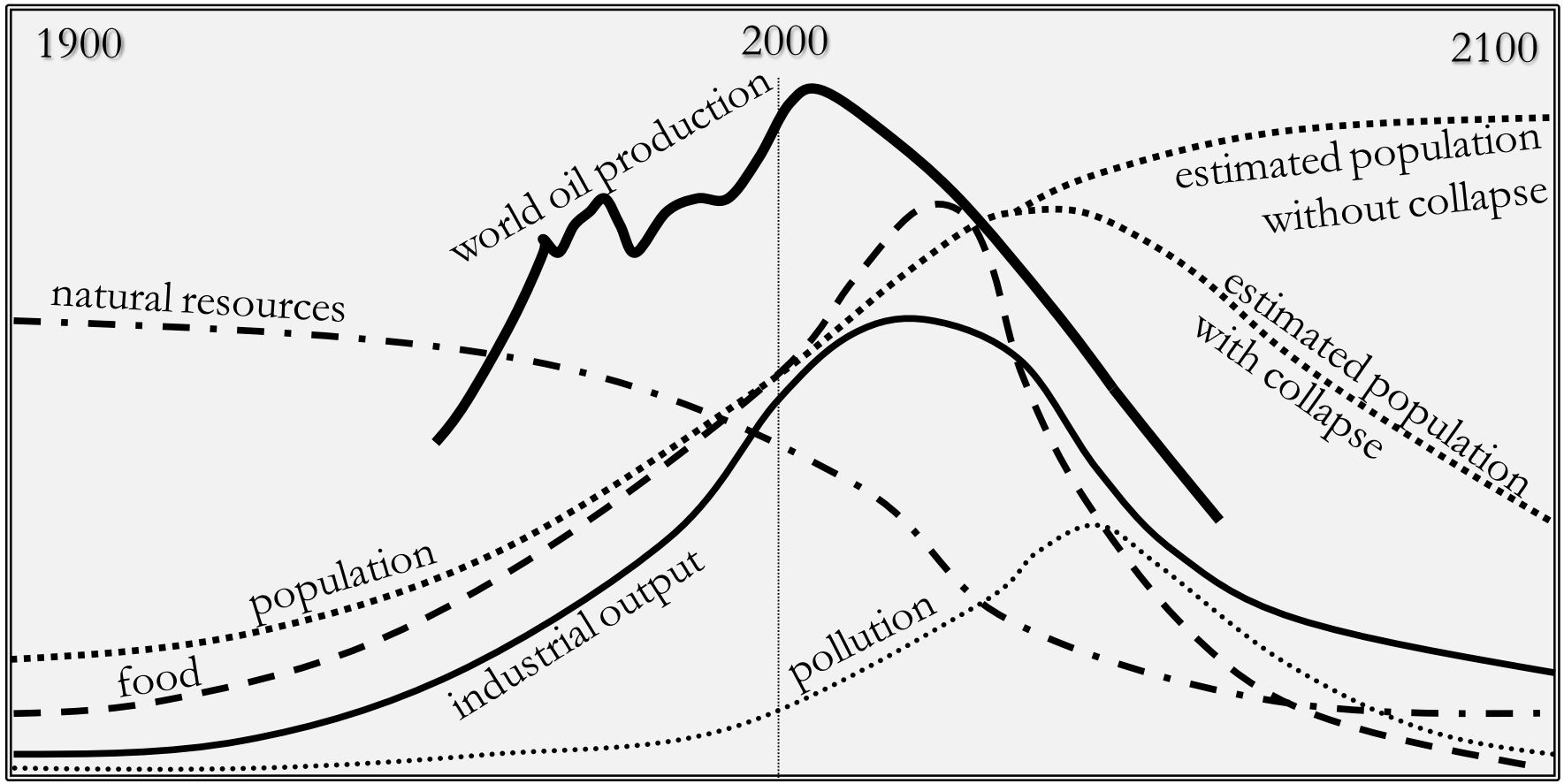
ENERGY CONSUMPTION OF THE TRANSPORT SECTOR

- Every human activity has a minor or major effect on the environment.
- Up to a certain level of industrial production, the environment may absorb the effects of human activities through a natural procedure.
- However, beyond this level, climate change may appear; this change is understood as a significant and lasting change in the statistical distribution of weather patterns over periods from some decades to centuries or even millions of years.
- The origins of climate change can be traced to human activities but also to factors exogenous to the human being, such as oceanic processes, solar radiation, plate tectonics, and volcanic activity (Profillidis, 2016).
- Figure 1, illustrates the evolution of key factors of human activity and the forecasting of their eventual evolution until the year 2100.

ENERGY CONSUMPTION OF THE TRANSPORT SECTOR

- *Figure 1: Evolution of key factors of human activity between 1900 and 2100. Modified by the authors from (Smith, 1998).*



ENERGY CONSUMPTION OF THE TRANSPORT SECTOR

- The rapid growth of the transport sector results in significant environmental impacts.
- The excessive consumption of energy resources, the excessively high levels of pollutants and noise in the environment attenuate the importance of transport growth in order to raise standards of living.
- The increase of passenger and freight mobility could not have been achieved without environmental implications.
- However, these repercussions could have been minimized, if in the early stages the necessity had been realized that the transport system should be developed in a rational manner.

ENERGY CONSUMPTION OF THE TRANSPORT SECTOR

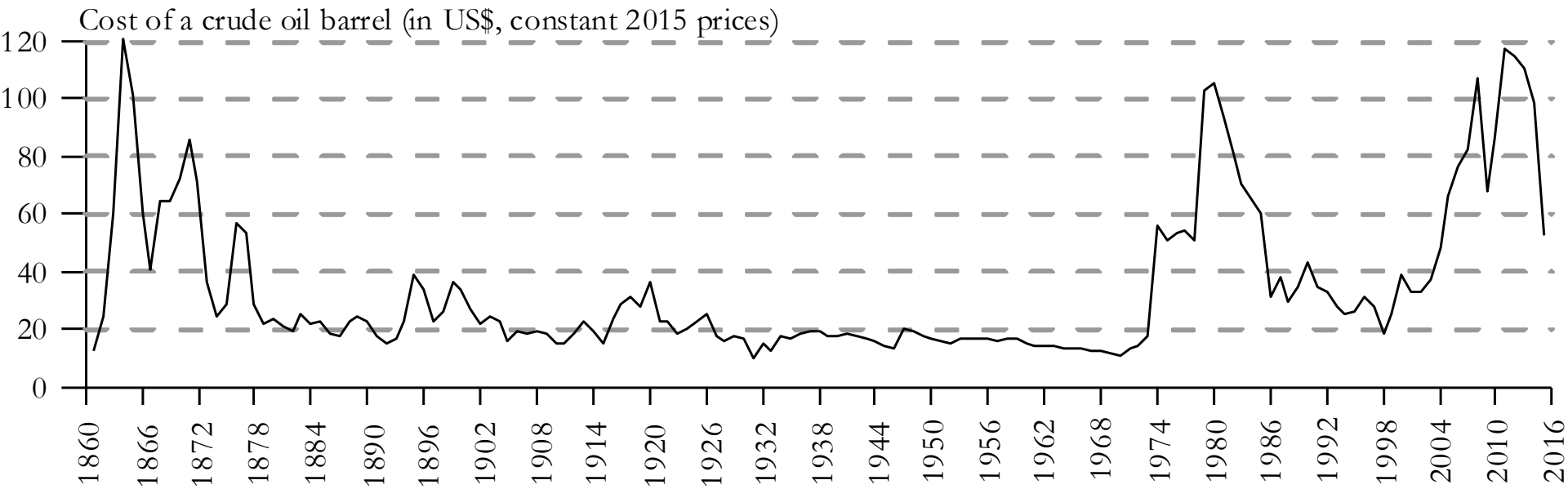
- It must be provided that the properly developed various transport infrastructure networks and transport systems would cooperate efficiently in order to serve any emerging demand.
- They should be organized in an environmental-friendly way, securing better environmental conditions, lower energy consumption and less congestion and traffic accidents (Tricker, 2007; Vehmas et al., 2007; Li et al., 2011; Dritsaki and Dritsaki, 2014; Profillidis et al., 2014; Isa et al., 2015).

ENERGY CONSUMPTION OF THE TRANSPORT SECTOR

- Transport is strongly dependent on energy and it cannot exist without energy feeding.
- Energy costs represent 15%÷35% of air passenger and 35%÷45% of air freight transport costs, 5%÷10% of rail passenger and 15%÷25% of rail freight transport costs, 15%÷25% of road passenger and 20%÷30% of road freight transport costs, and 50%÷70% of ocean shipping operating costs (Profillidis, 2016; Profillidis et al., 2014), depending on the price of a barrel of crude oil, which has significant fluctuations over time (Figure 2).

ENERGY CONSUMPTION OF THE TRANSPORT SECTOR

- *Figure 2: Evolution of the cost of a crude oil barrel. Compiled by the authors, based on data of (BP, 2016).*

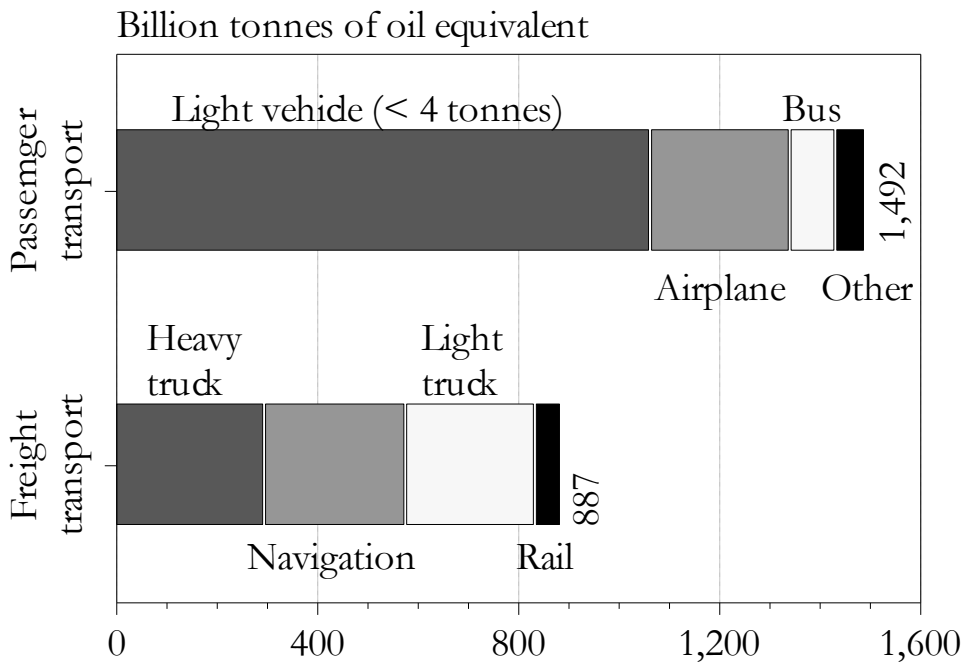


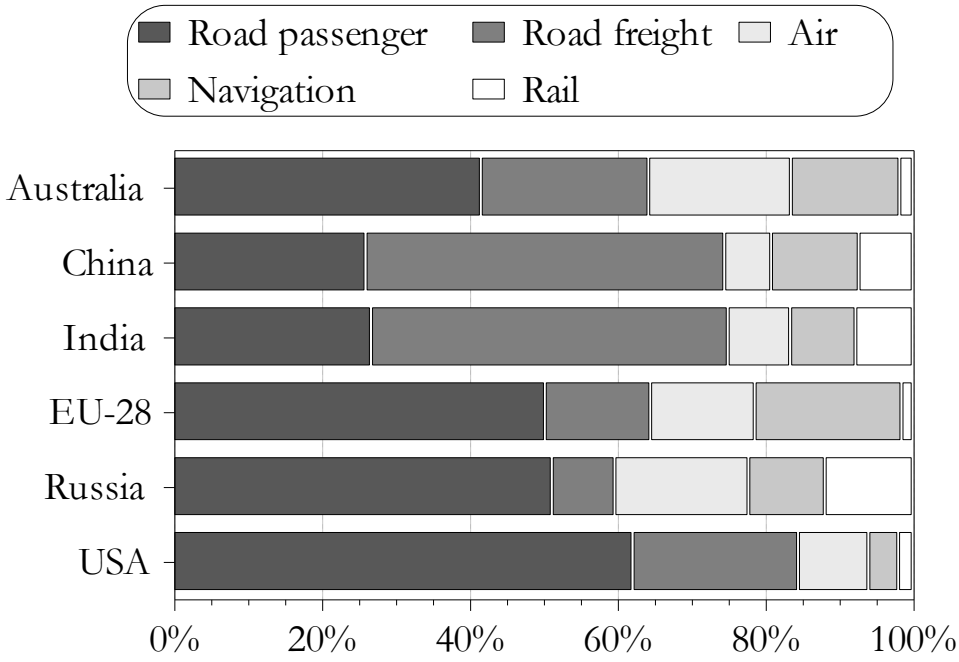
ENERGY CONSUMPTION OF THE TRANSPORT SECTOR

- Transport absorbs 27.6% of the energy consumption worldwide for the year 2013 (23.2% in 1973, 27.5% in 2000, 27.3% in 2008), a percentage almost equal to industry (29.0% in 2013), (Profillidis, 2016).
- The rest is consumed for residential and service purposes and other non-energy related uses.
- For the 28 European Union countries (EU-28), consumption of energy was, for the year 2014, as follows: transport 33.2%, households 24.8%, industry 25.9%, agriculture 2.3%, services and other activities 13.8% (EU, 2016).
- Within the transport sector, road and air transport are the most consuming modes (Figure 3 and Figure 4).

ENERGY CONSUMPTION OF THE TRANSPORT SECTOR

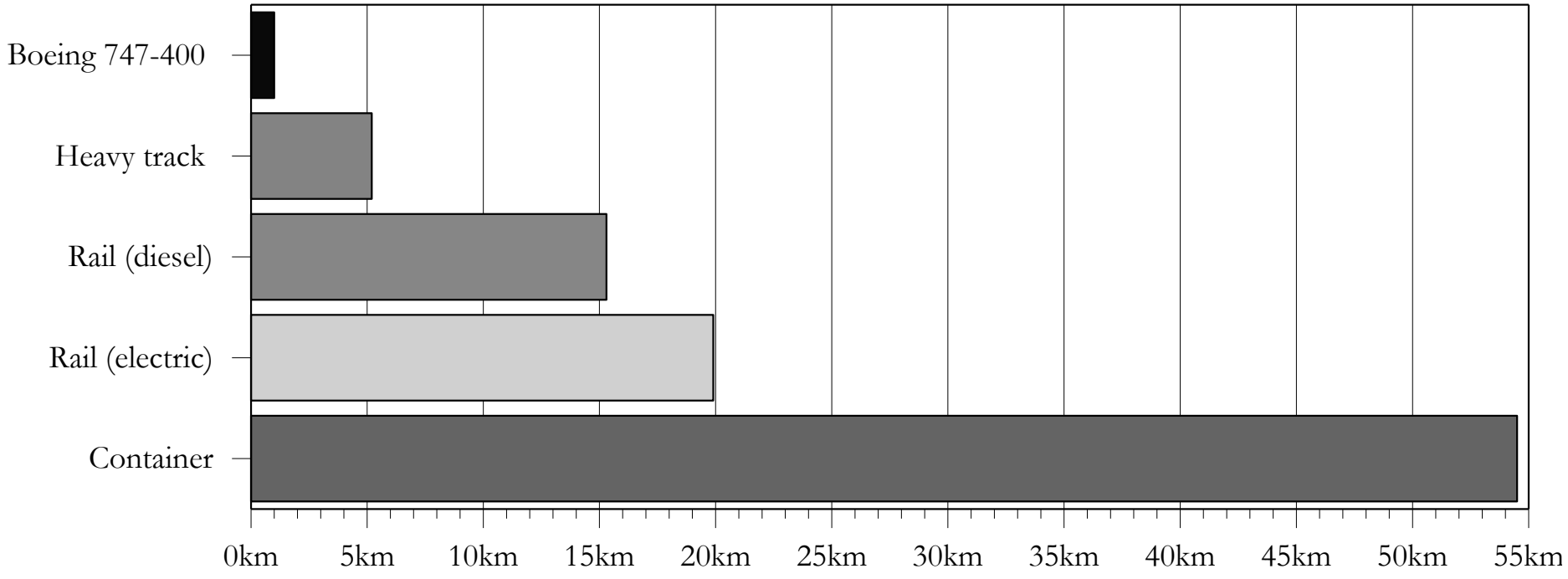
- *Figure 3: World transport energy consumption by mode (2012). Compiled by the authors, based on data of (EIA, 2016).*





ENERGY CONSUMPTION OF THE TRANSPORT SECTOR

- *Figure 4: Distance traveled for 1 tonne of freight when using 1 kWh of energy (Profillidis, 2014).*

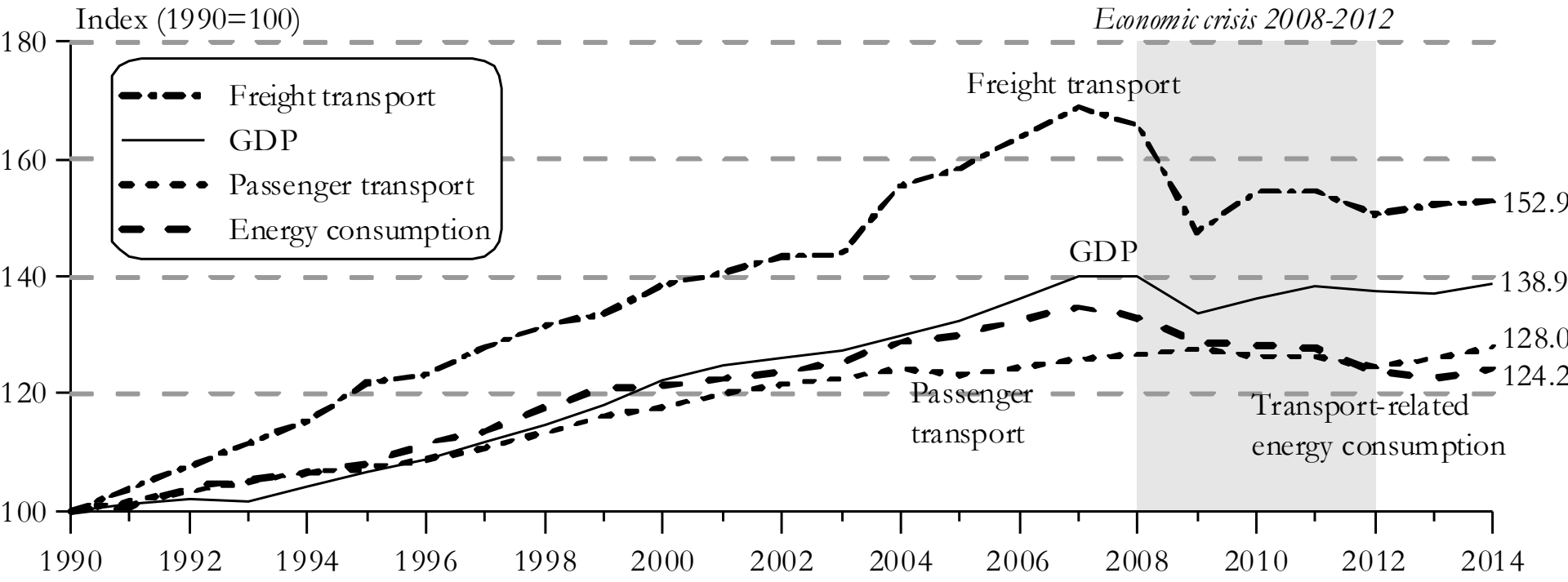


CORRELATION OF TRANSPORT-RELATED ENERGY CONSUMPTION AND ECONOMIC ACTIVITY

- For many years it has been considered that the evolution of transport activity as a whole was at approximately the same rate as the evolution of the Gross Domestic Product (GDP).
- Air transport rates are greater than GDP rates (almost triple), whereas rail transport rates are much slower (Profillidis, 2014).
- The almost continuously upward tendency of both passenger and freight for five decades after 1950 stopped in Europe by the economic crisis of 2008÷2012, which affected principally some European Union (EU) countries, (Figure 5).

CORRELATION OF TRANSPORT-RELATED ENERGY CONSUMPTION AND ECONOMIC ACTIVITY

- *Figure 5: Trends in the passenger traffic (passenger-kms), the freight traffic (ton-kms) and transport-related energy consumption (tonnes of oil equivalent per capita) in relation to the Gross Domestic Product for the EU-28 countries, Compiled by the authors, based on data of (EU, 2016).*

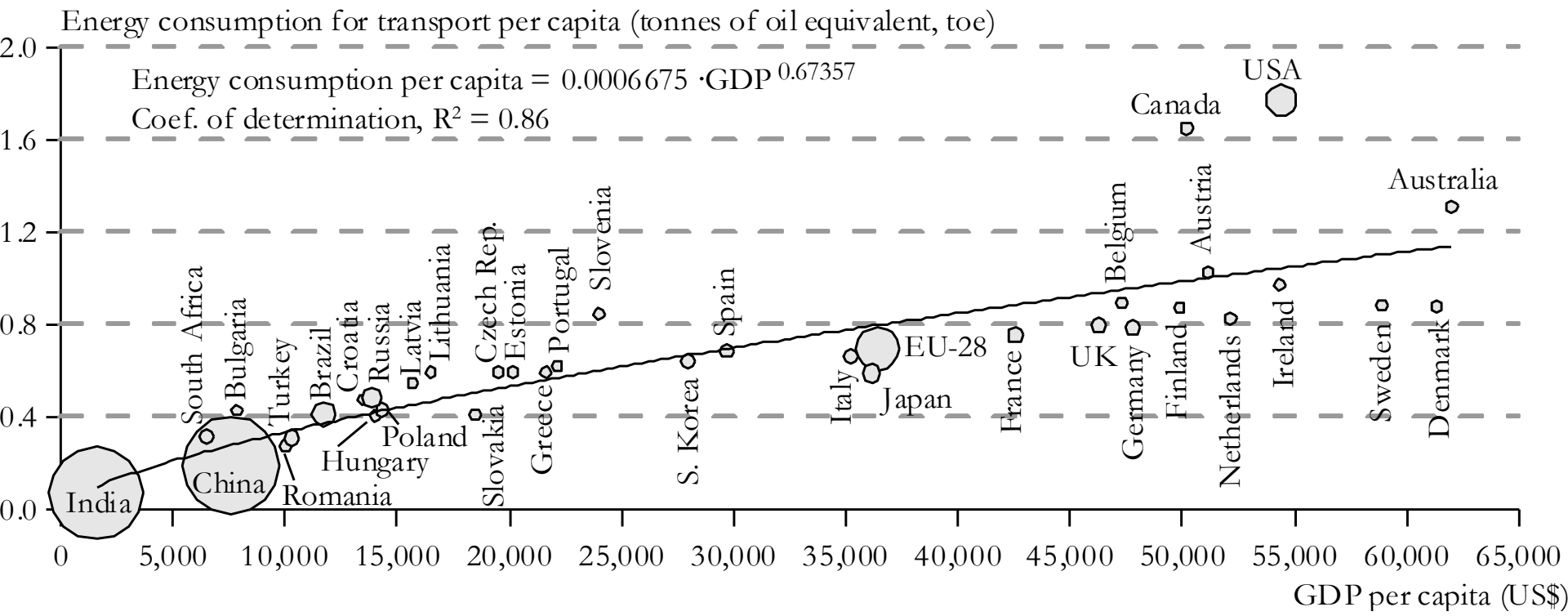


CORRELATION OF TRANSPORT-RELATED ENERGY CONSUMPTION AND ECONOMIC ACTIVITY

- During the years of economic prosperity, for a number of economists and engineers predicting future transport demand and thus transport-related energy consumption was a rather easy task: according to their beliefs, growth rates of transport activity and energy consumption should follow a pattern similar to growth rates of GDP.
- This approach has useful results on an aggregate level, since it ensures an acceptable correlation between economic development and transport-related energy consumption.
- Figure 6, depicts the correlation between per capita GDP and per capita energy consumption for transport (passenger + freight) activities in various developing and developed countries worldwide, which represent 58.2% of world population and 80.5% of world GDP.

CORRELATION OF TRANSPORT-RELATED ENERGY CONSUMPTION AND ECONOMIC ACTIVITY

- *Figure 6: Correlation between transport-related energy consumption and economic activity for various countries for the year 2014. Compiled by the authors, based on data of (OECD, 2016; The World Bank, 2016).*

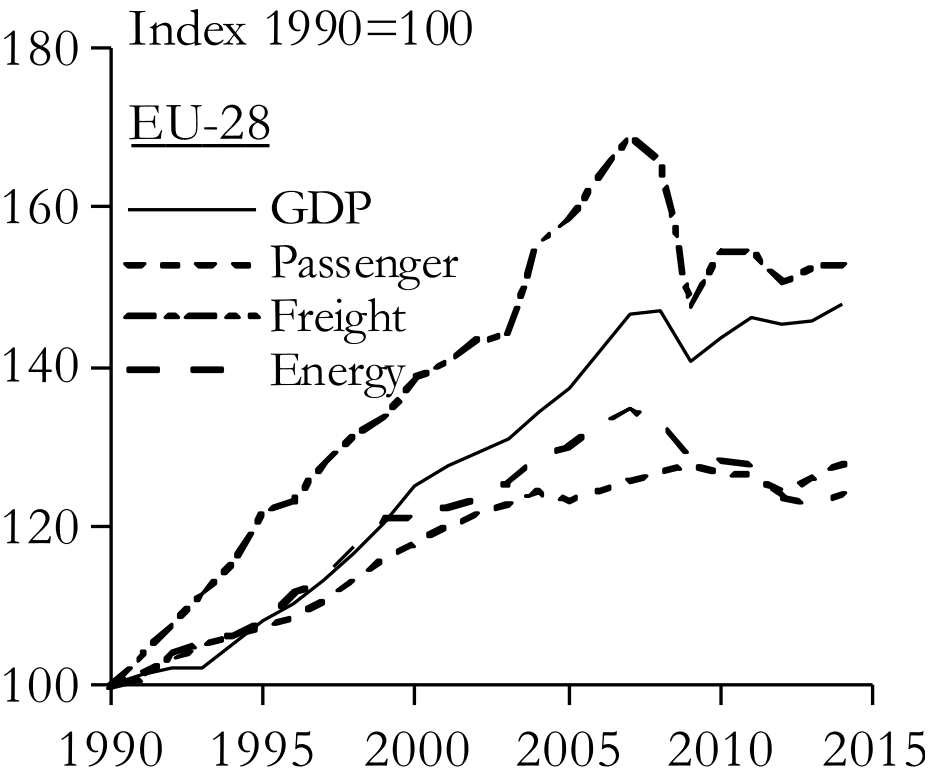


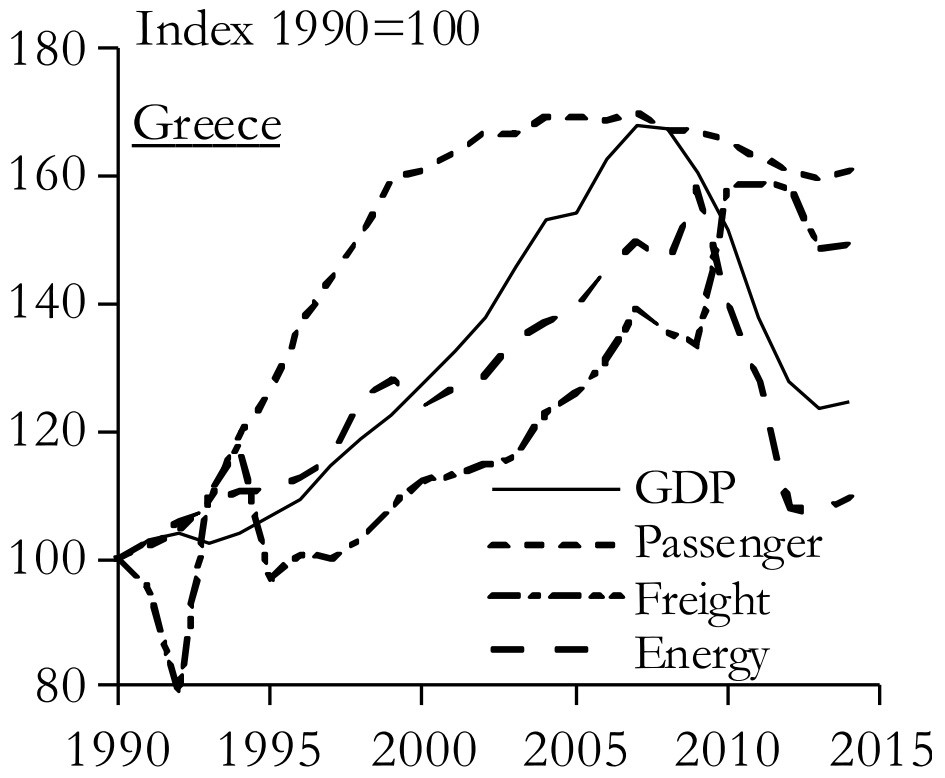
CORRELATION OF TRANSPORT-RELATED ENERGY CONSUMPTION AND ECONOMIC ACTIVITY

- At disaggregate country level, however, this close relationship between transport-related energy consumption and economic activity seems not to be the mainstream trend, at least after the economic crisis of 2008.
- Figure 7, illustrates for the last 25 years the evolution of GDP, passenger and freight transport activity and transport-related energy consumption for some EU countries.
- Overall, between the peak of the year 2007 and the year 2014, transport-related energy consumption in the EU-28 fell by 7.87%.

CORRELATION OF TRANSPORT-RELATED ENERGY CONSUMPTION AND ECONOMIC ACTIVITY

- *Figure 7: Evolution of GDP (US$), transport activity (passenger-km and freight tonne-km) and transport-related energy consumption (tonnes of oil equivalent) for some EU countries. Compiled by the authors, based on data of (OECD, 2016; The World Bank, 2016).*





COUPLING – DECOUPLING BETWEEN GDP AND TRANSPORT-RELATED ENERGY CONSUMPTION

- In Figures 5 and 6, risks misleading to the conclusion that economic activity and energy consumption of the transport sector 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 transport-related energy consumption is stable or decreasing, while the economic index increases.
- In relative decoupling, however, both economic and transport-related energy consumption indexes increase, but the energy consumption related index grows more slowly than the economic index (Banister and Stead, 2002; Tapio, 2005; McKinnon, 2007).

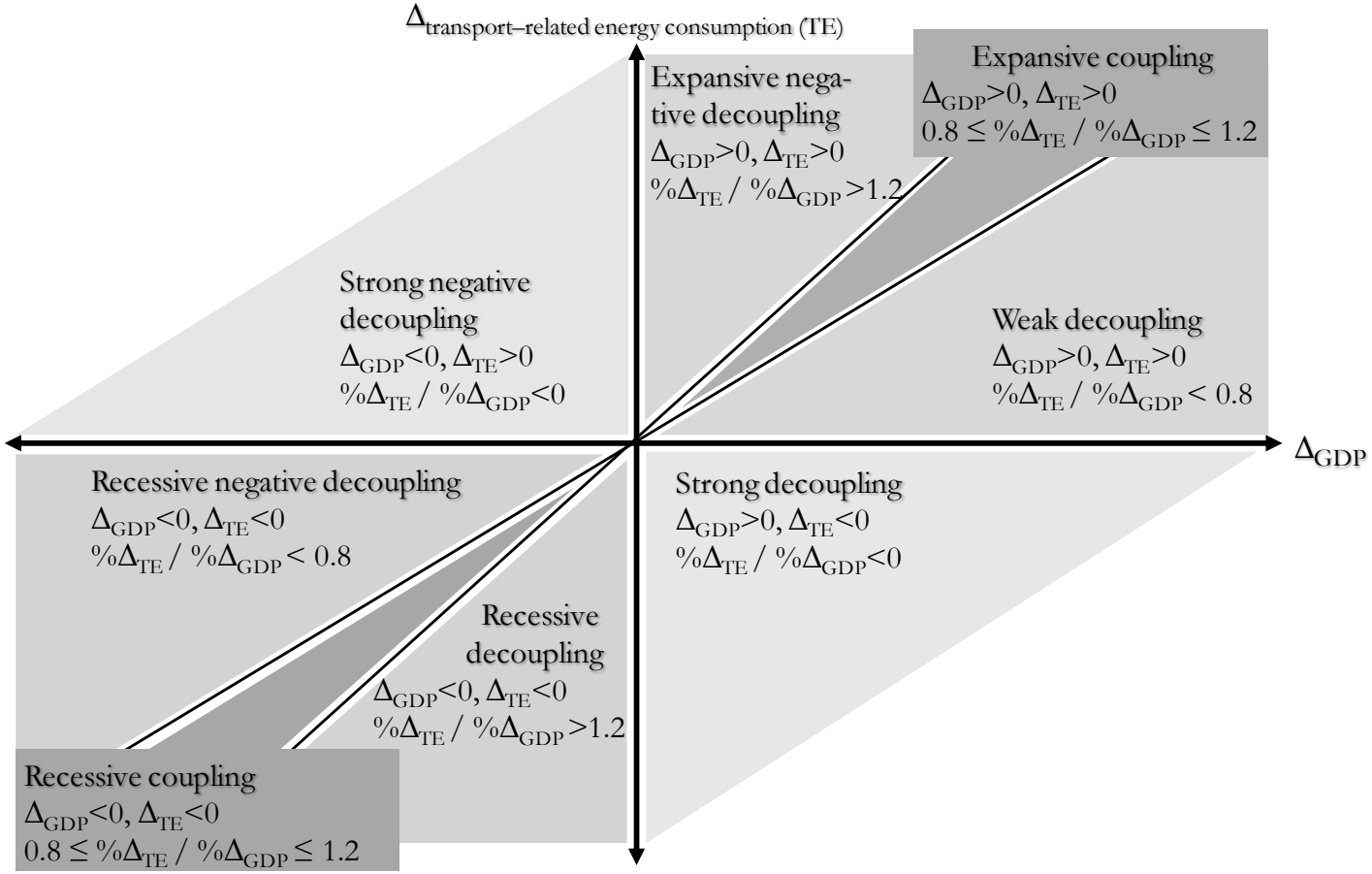
COUPLING – DECOUPLING BETWEEN GDP AND TRANSPORT-RELATED ENERGY CONSUMPTION

- There are eight possibilities for the development of the indices in the decoupling framework (Figure 8).
- The rates of change of the transport-related energy consumption and GDP can be coupled, decoupled or negatively decoupled. The result of this calculation is an elasticity value $\varepsilon_{\text{transport energy, GDP}}$ of transport-related energy consumption in relation to GDP (Liimatainen and Pöllänen, 2013, Alises et al., 2014; Alises and Vassallo, 2015):

$$\varepsilon_{\text{transport energy,GDP}} = \frac{\%\,\Delta\text{transport-related energy consumption}}{\%\,\Delta\text{GDP}}$$

COUPLING – DECOUPLING BETWEEN GDP AND TRANSPORT-RELATED ENERGY CONSUMPTION

- *Figure 8: Degrees of coupling and decoupling between transport activity and GDP. Modified by authors from (Tapio, 2005; Liimatainen and Pöllänen, 2013).*



COUPLING – DECOUPLING BETWEEN GDP AND TRANSPORT-RELATED ENERGY CONSUMPTION

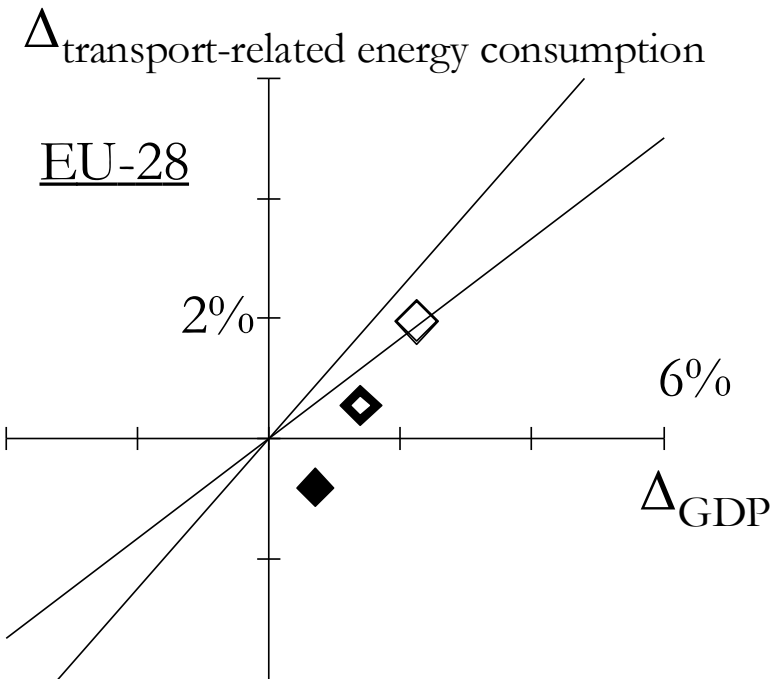
- Decoupling of GDP from transport-related energy consumption is considered as an efficient way to maintain economic growth while assuring efficiency of transport, from an economic and environmental point of view, since:
  - if transport-related energy consumption has lower rates of growth compared to GDP, this will lead to less emissions and environmental effects, thus contributing to environmental sustainability,
  - if the link between economic development and transport-related energy consumption is not broken, then any increase of GDP will result in increased requirements of energy consumption, and thus, dependence of economic development from both transport activity and energy consumption will remain equable, which is neither economically nor environmentally efficient (Tight et al., 2004; Banister 2005; Kveiborg and Fosgerau, 2007; Botzoris et al., 2015).

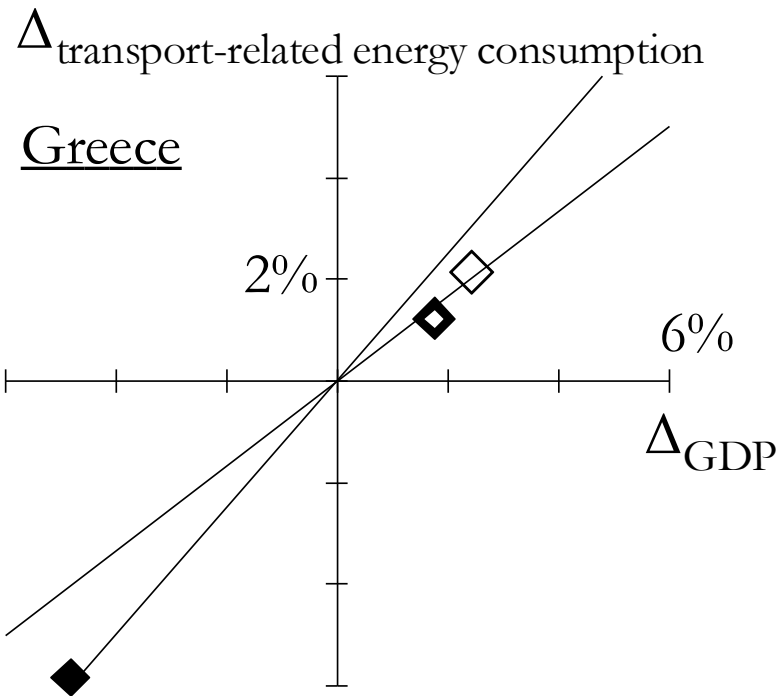
COUPLING – DECOUPLING BETWEEN GDP AND TRANSPORT-RELATED ENERGY CONSUMPTION

- Figure 9, illustrates the coupling-decoupling relationship between the GDP and the transportation-related energy consumption for some European Union countries.
- The analysis is divided into three distinct time-periods: from 1990 to 2000, from 2000 to 2010 (period before and during economic crisis) and from 2010 to 2014, namely the period after the economic crisis.
- It is remarkable and worth mentioning that after the economic crisis (period 2010÷2014) there is no country with clearly expansive coupling relationship between GDP and transport sector energy consumption and the only one country with some form of coupling is Bulgaria (expansive negative decoupling where both growth rates of GDP and transport-related energy consumption are positive).

COUPLING – DECOUPLING BETWEEN GDP AND TRANSPORT-RELATED ENERGY CONSUMPTION

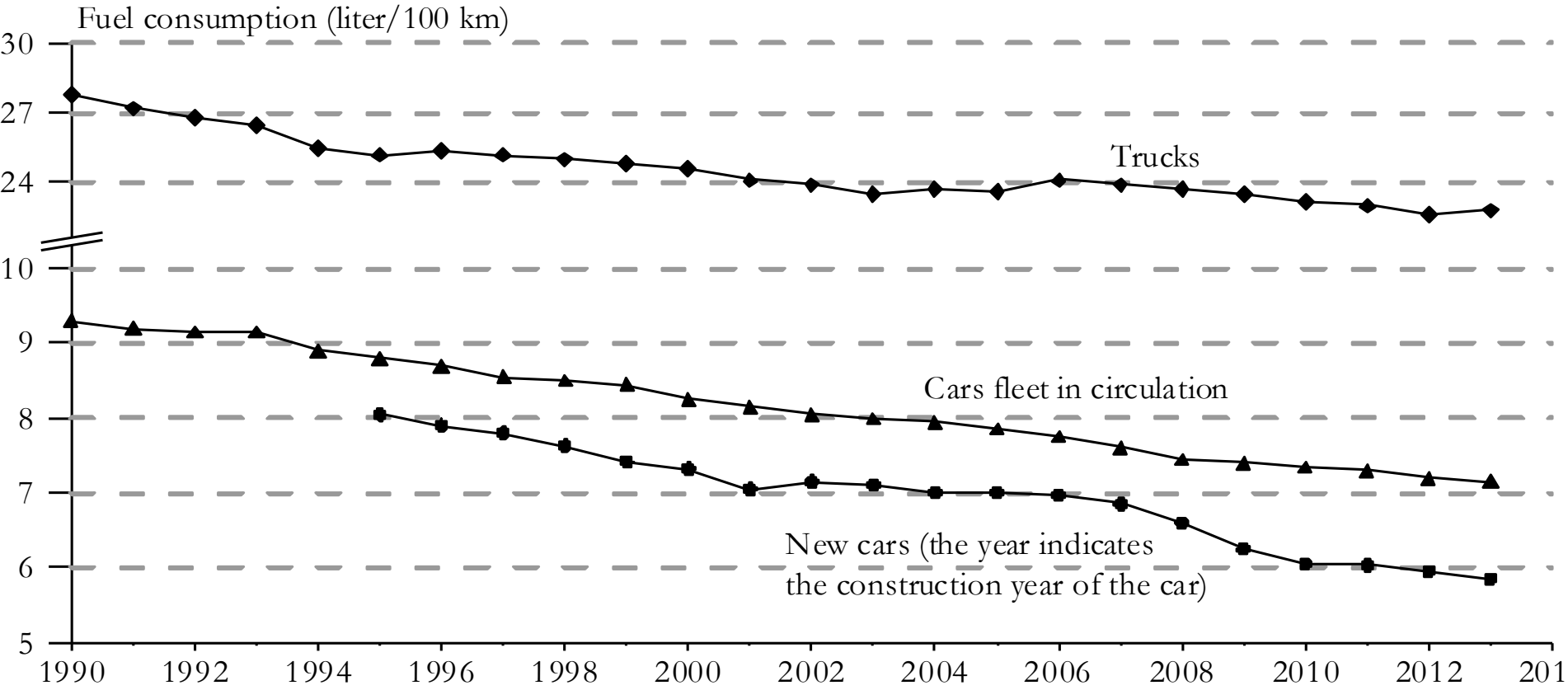
- *Figure 9: Coupling and decoupling of transport-related energy consumption for some EU countries for the period 1990÷2014. Compiled by the authors, based on data of (OECD, 2016; The World Bank, 2016).*





COUPLING – DECOUPLING BETWEEN GDP AND TRANSPORT-RELATED ENERGY CONSUMPTION

- *Figure 10 : Evolution of the average fuel consumption (in liter/100 km) of trucks and of new and in circulation car fleet in Germany. Compiled by the authors, based on data of (Schlomann et al., 2015).*



COUPLING – DECOUPLING BETWEEN GDP AND TRANSPORT-RELATED ENERGY CONSUMPTION

- However, the explanation for the decoupling trend, during last years, between economic development and energy consumption is the gradual reduction of the dependence of economic development from the passenger and freight transport activity, mainly because of (Profillidis, 2016):
  - Expansion of internet, teleworking, mobile apps and other evolutions on telecommunications.
  - Extensive use of GPS, car sharing and carpooling.
  - Changes in the sectoral composition of the economy – dematerialization of the economy.
  - Scale economies and concentration.
  - Further trade liberalization, deregulation of the transport market and strengthening of competition.
  - Environmental taxation.

CONCLUSIONS

- Decoupling between GDP and transport-related energy consumption is the only way to reduce CO_2 emissions while assuring increasing growth rates of economic activity.
- In the present paper it was examined the coupling-decoupling situation for European countries from 1990 to 2014.
- Focusing principally on the period before (1990÷2000) and after the economic crisis (2010÷2014), it is remarkable a significant differentiation of the interaction between economic growth and transport-related energy consumption, as after the economic crisis the vast majority of EU-28 countries (with the exception of Bulgaria) have passed the threshold of coupling and are subjected to a form of decoupling (weak, strong or recessive).

CONCLUSIONS

- The paper does not analyze whether the economic crisis was the driving force for the transition from coupling to decoupling between GDP and transport-related energy consumption.
- It describes the new, desirable for the environment, reality, which creates the significant opportunity for passenger and freight transport activities to enter into a continuous process of rationalization and reduction of energy consumption.
- It is mainly a political challenge to preserve and defend the observed decoupling situation by motivating the environmentally friendly and efficient mobility.

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