Nufar Finel & Petri Tapio

DECOUPLING TRANSPORT CO_2 FROM GDP

FINLAND FUTURES RESEARCH CENTRE
FFRC eBOOK 1/2012

FINLAND FUTURES RESEARCH CENTRE

Turun yliopisto
University of Turku

Nufar Finel and Petri Tapio

Contacts petri.tapio@utu.fi, www.fidea.fi

ISBN 978-952-249-135-0

ISSN 1797-1322

Finland Futures Research Centre

University of Turku

ElectroCity, Tykistökatu 4 B, FI-20014 University of Turku

Korkeavuorenkatu 25 A 2, FI-00130 Helsinki

Pinninkatu 47, FI-33100 Tampere

Tel. +358 2 333 9530

Fax +358 2 333 8686

www.utu.fi/ffrc

tutu-info@utu.fi, firstname.lastname@utu.fi

FINLAND FUTURES RESEARCH CENTRE

CONTENTS

ABSTRACT

The sectors that contribute the most to the growth of greenhouse gas emissions are energy supply, transport and industry. Transportation accounted for 26% of global CO_2 emissions in 2007. Transport and the economy have been connected with one another for many decades. The growth of CO_2 emissions from transport has followed the growth of the gross domestic product, especially in Europe, Africa and South and Central America. Decoupling the link between economic growth and environmental harm is a major societal challenge.

The goal of this study is to broaden the scope of decoupling research within the transport sector to a global level and test the significance of the decoupling framework entitled Decoupling Diamond. A total of 137 countries and 4 groups of countries are included in the study. The data is divided into six five-year-periods (1975-2005), and the relative changes in the emissions and GDP are calculated. The GDP elasticity of transport CO_2 emissions is calculated for each country for each of the five-year periods. Based on the results, the countries are divided into eight forms of decoupling: expansive coupling, recessive coupling, weak decoupling, strong decoupling, recessive decoupling, weak negative decoupling, strong negative decoupling and recessive negative decoupling.

Throughout the 30 years examined, the countries spread out into many different forms of decoupling. The two largest groups throughout the years are weak negative decoupling, where both emissions and GDP grew, but the emissions grew at a faster rate than GDP, and weak decoupling, where again both emissions and GDP grew, but this time GDP grew faster than the emissions. There were however also cases of strong decoupling, where GDP grew and emissions decreased. This group of 21 countries would need a further study.

Key words: Transport, carbon dioxide emissions, decoupling.

1. TRANSPORT AND CO_2 EMISSIONS

The growing concern about climate change has made carbon dioxide (CO_2) emissions an important matter of research. According to the inter-governmental panel on climate change IPCC (IPCC, 2007), emissions of greenhouse gases have grown since pre-industrial times due to human activities, with an increase of 70% between 1970 and 2004. An increase in the global atmospheric concentration of CO_2 from a pre-industrial value of about 280 ppm to 379 ppm in 2005 has occurred. (IPCC, 2007) The most important anthropogenic greenhouse gas is carbon dioxide (CO_2) and fossil fuel burning is the most important cause of the global increase of CO_2 concentrations.

The sectors that have contributed the most to the growth of greenhouse gas emissions from fossil fuel burning are energy supply, transport and industry. If international transport is included, transportation accounted for a steady 23-24% of global CO_2 emissions between 1970 and 1985. Thereafter the share of transport grew and peaked at 27.7% in 1999. After that the share reduced to 26.4 (Fig. 1.1; IEA 2009). Although this recent turn could give hope for a change, the absolute transport CO_2 emissions grew from 3.37 Gt in 1971 to 6.35 Gt in 1999 and further to 7.65 Gt in 2007. That is, the emissions grew faster in the other sectors.

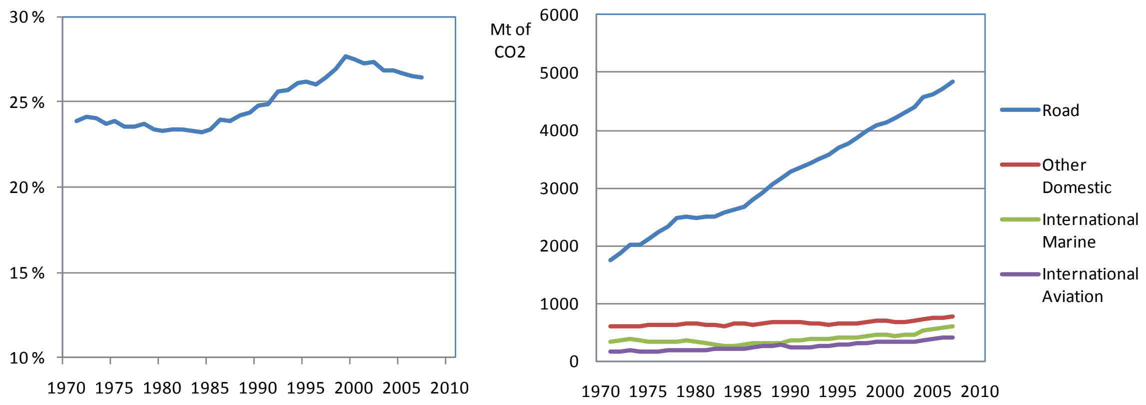

Figure 1.1 *Share of transport (including international aviation and maritime transport) of global CO_2 emissions from fossil fuel burning (left) and absolute emissions by within transport sector in 1971-2007 (IEA 2009).*

Mobility is an important factor in the quality of life of people and in the functioning of the economy (Banister 1998). Transport connects the different stages of production chains, brings companies and consumers together and also acts as a significant employer in itself. However transport also imposes external costs on the society. The growth of CO_2 emissions from transport has followed the growth of the gross domestic product in Europe (IEA 2007). The growth of the economy has increased the demand for both passenger and freight transportation. People and products move more and further than before (Banister and Stead 2002; Schipper and Fulton 2003).

The development of total carbon dioxide emissions, transport carbon dioxide emissions and gross domestic product (in purchasing power parities) in world countries from 1975 to 2005 is shown in Fig. 1.2. The blue line shows the development of GDP, the green line shows the development of total CO_2 emissions and the orange line shows the development of CO_2 emissions from transport. 1975 is used as a base year and has been given the value 100. Both the emissions and GDP have been growing, but GDP grew faster than the emissions. The growth of total CO_2 emissions slowed down in 1989 and since then CO_2 emissions from transport grew faster. (IEA 2007)

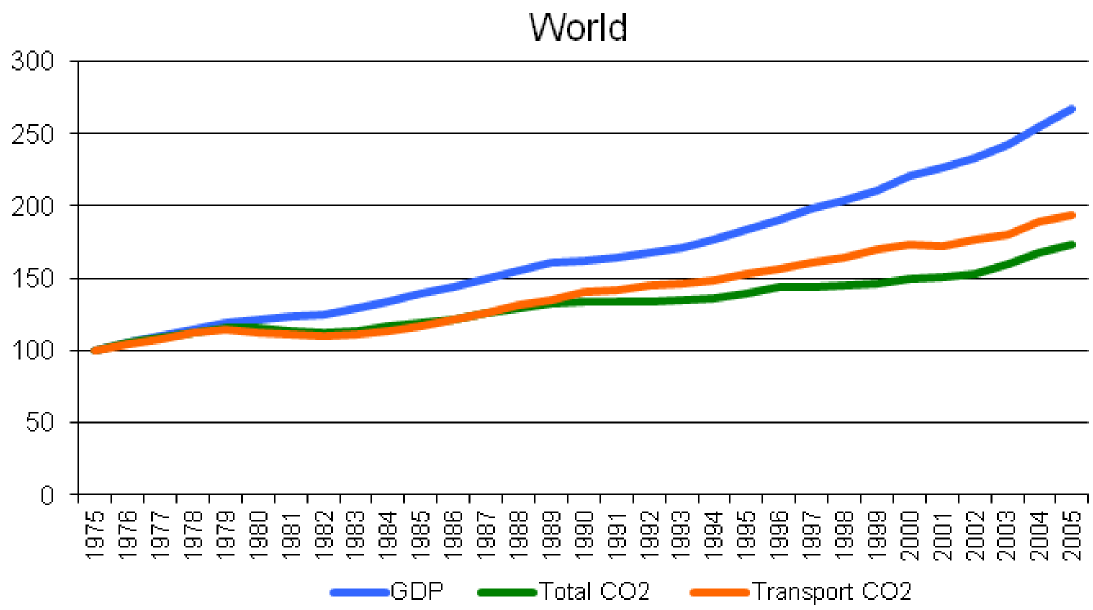

Figure 1.2 *Total CO_2 emissions, transport CO_2 emissions and GDP (ppp) in world countries in 1975-2005 (1975 = 100). Data (IEA, 2007).*

In Figs. 1.3-1.8 the development of total and transport CO_2 emissions in different areas in the world is presented. There are differences in the growth rates and levels of the indicators, but in all the areas presented, CO_2 emissions from transport have been growing. Especially in Europe, Africa and South and Central America the transport emissions have followed the growth of GDP, in spite of the fact that Europe has been the only continent being able to stop the growth of total CO_2 emissions.

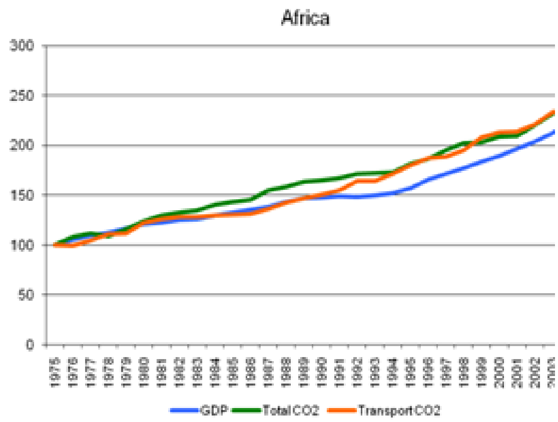

Figure 1.3. Total CO_2 emissions, transport CO_2 emissions and GDP in Africa in 1975-2005 (1975 = 100). Data IEA 2007

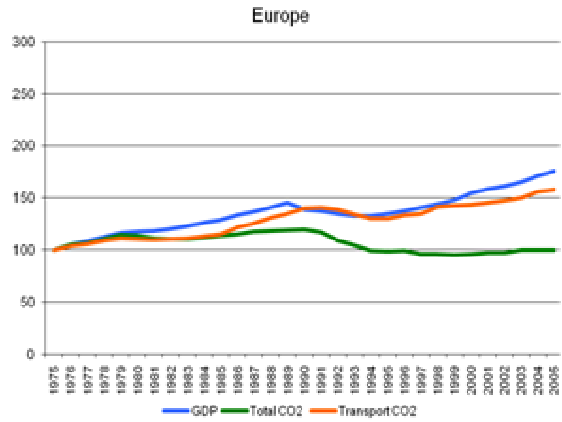

Figure 1.6. Total CO_2 emissions, transport CO_2 emissions and GDP in Europe in 1975-2005 (1975 = 100). Data IEA 2007

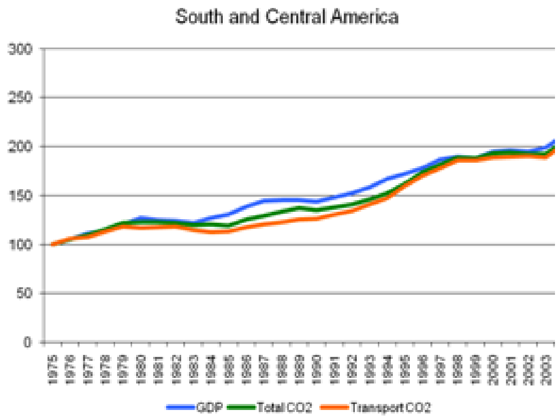

Figure 1.4. Total CO_2 emissions, transport CO_2 emissions and GDP in South and Central America in 1975-2005 (1975 = 100). Data IEA 2007

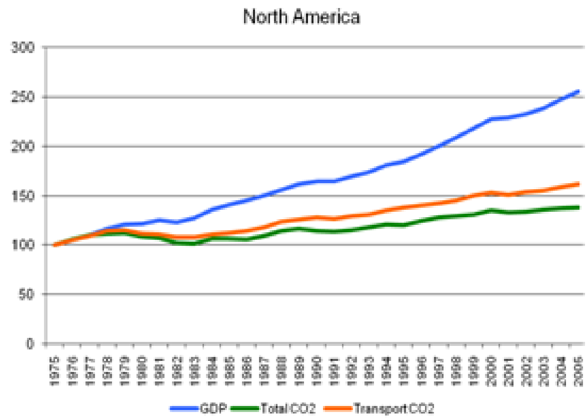

Figure 1.7. Total CO_2 emissions, transport CO_2 emissions and GDP in North America in 1975-2005 (1975 = 100). Data IEA 2007

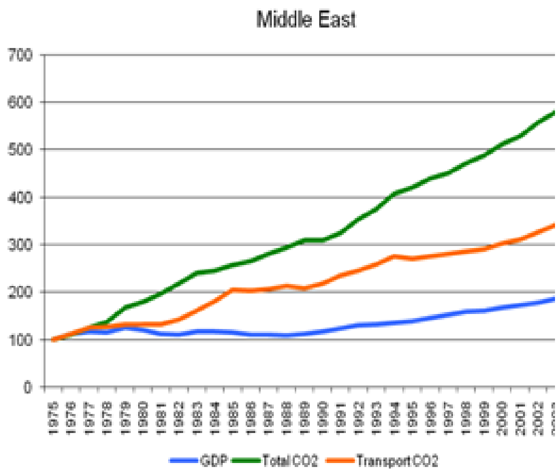

Figure 1.5. Total CO_2 emissions, transport CO_2 emissions and GDP in the Middle East in 1975-2005 (1975 = 100). Data IEA 2007 (Notice different scale!)

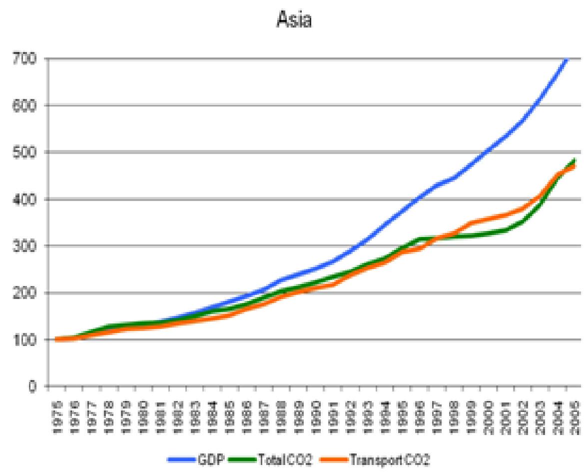

Figure 1.8. Total CO_2 emissions, transport CO_2 emissions and GDP in Asia in 1975-2005 (1975 = 100). Data IEA 2007 (Notice different scale!)

Figures 1.3-1.8. Total CO_2 emissions, transport CO_2 emissions and GDP in world regions.

2. AIM OF THE STUDY

The general goal of this study is to broaden the scope of decoupling research within the transport sector to a global level and test the significance of the decoupling framework. The objectives of this study are to explore the changes in the relationship between the growth rates of CO_2 emissions from transport and GDP, look for signs of different forms of decoupling and briefly consider reasons for differences between groups of countries.

The existing literature concerning the relationship of GDP and transport and decoupling has focused on Europe (and in some cases the OECD countries) e.g. Peake (1994), Stead (2001), Banister and Stead (2002), Tapio (2005), Tapio et al. (2007). This work adds the global perspective to the decoupling discussion. Because of the wide scope, the study does not go into details of the development in each country.

3. DECOUPLING ENVIRONMENTAL HARM FROM ECONOMIC GROWTH

3.1 The Environment and the Economy

There has been wide discussion about the relationship of economic growth and the state of the environment. (e. g. World Bank 1992, Arrow et al. 1995, Ayres 1995). Some argue that continued economic growth in a finite world is not possible, therefore the use of material resources to produce economic growth cannot go on forever. (e.g. Daly 1997) Others, e.g. Grossman and Krueger (1995) say that economic growth only deteriorates the environment in the beginning, when the economy is based on heavy, polluting industry, and that as wealth grows, the structure of the economy is shifted towards less polluting production, for example services, and the environmental impacts stop growing and in the end also start to decrease. This idea has been formulated as the Environmental Kuznets curve (EKC) hypothesis.

The EKC hypothesis is based on the work of economist Simon Kuznets, who wrote about the relationship of economic growth and income inequality (Kuznets, 1955), and Grossman and Krueger (1991) formulated the environmental interpretation. The curve is shaped like an inverted U, with GDP on the horizontal axis and the environmental indicator on the vertical axis. A vast amount of literature (e.g. de Bruyn, 1997, Cole et al. 1997, Panayotou 1997, Stern 2004, Galeotti and Lanza 2005, Huang et al. 2008, Song et al. 2008,) has been written in search of empirical evidence either in support or opposition of the theory.

Different indicators have been used for measuring both the economic and environmental variable. The economic variable is usually GDP, either in absolute or per capita form. Many different environmental indicators have been used, and the results depend on the chosen indicator. Indicators used include total CO_2 emissions (e.g. Galeotti and Lanza 2005), wastes (e.g. Song et al. 2008), GHG emissions (e.g. Huang et al. 2008), sulphur dioxide and particulate matter (e.g. Grossman and Krueger 1995). Support for the EKC theory has been found in some types of emissions (e.g. sulphur dioxide) but for many indicators, including CO_2 emissions, the empirical evidence does not support the theory (e.g. Galeotti and Lanza 2005, Huang et al. 2008), and it has given rise to strong critique. (e.g. Moomaw and Unruh, 1997).

Since most of the world's economies are striving towards economic growth, ways to achieve it with less environmental harm are being sought for. There have been several concepts proposed for this. These include increased eco-efficiency, de-materialisation, immaterialisation, de-linking and decoupling. Eco-efficiency means getting more from less, which means using resources more efficiently to produce the same value with less material. The drawback in this approach is that the same amount of material may be used to produce more value. The environmental impact remains the same, but only the economy grows faster. This is called the rebound effect (e.g. Binswanger, 2001).

Both the economic and environmental indicator may be measured either in absolute terms or divided with the number of people, i.e. per capita. Both ways of measuring have their advantages. Per capita values can be compared throughout countries no matter how large or small they are, and using them is also in line with the idea of environmental equity, that each human being in the world is entitled to produce the same amount of emissions no matter where in the world they live (e.g. Luukkanen et al., 2005). The disadvantage with the per capita approach is that as population grows over time, the per capita value decreases, while the actual impact increases. This is why in this study absolute values of GDP and emissions are used. The problem of comparing different sized countries with one another is avoided by using relative changes in GDP and emissions.

3.2 The Concept of Decoupling

Research has been done on several different forms of decoupling. Vehmas et al. (2007) analyse delinking of material resources and economic growth. Lu et al. (2007) analyse the decoupling of transport energy demand and CO_2 emissions from economic growth in Taiwan, Germany, Japan and South Korea. Tapio (2005) analyses the decoupling of GDP and traffic volume and CO_2 emissions from transport in EU15 countries.

There are two basic forms of decoupling: absolute and relative decoupling (e.g. Ballingall et al. 2003). In absolute decoupling, the environmental variable decreases and the economic variable increases, while in relative decoupling both the economic and environmental variable increase, but the environmental variable grows more slowly than the economic variable. From the environmental point of view, the most important thing is that emissions are actually reduced, not only relatively (weak decoupling) but also in absolute terms (strong decoupling).

In the discussion about the relationship between economic growth and transport, the delinking of the two has been termed decoupling (Banister and Stead 2002, Gilbert and Nadeau 2002, Ballingall et al. 2003, Tapio 2005). In different studies, the transport variable has been different. Some use transport volume measured by passenger-kilometres travelled and tonne-kilometres moved (e.g. Gilbert and Nadeau 2002), others use the transport energy use (e.g. Stead 2001). This work follows Tapio (2005) and compares the changes in CO_2 emissions from transport to changes in the GDP of countries.

Immaterialisation, dematerialisation and decarbonisation in the EU15 countries are discussed in Tapio et al. (2007). Transport has been growing both in the passenger and in the freight sector in line with growth in GDP. Referring to the literature (Banister and Stead 2002, Gilbert and Nadeau 2002, Tapio 2005) they write that the "key question discussed is whether that link can and should be broken". Tapio et al. (2007) go on to say that "decoupling is a crucial element in achieving sustainable transport".

Tapio (2005) analyses the decoupling of transport volume (passenger and freight transport separated) and CO_2 emissions from transportation from GDP in the EU15 countries between 1970 and 2001. He finds some cases of weak decoupling, but no evidence of strong decoupling. The current study analyses a wider set of countries and a timeframe up to 2005.

3.3 The Decoupling Diamond

A method to calculate the degree of decoupling is needed in order to compare countries and time periods. We build this analysis on an earlier article on the decoupling framework (Tapio 2005), originating partly from the work by Vehmas et al. (2003; 2007). Originally, the framework was developed on analysing the decoupling of transport volume growth and economic growth. In the current study, instead of transport volume, the transport variable is CO_2 emissions from transportation, but the basic idea of the calculations remains the same. Some conceptual modifications have been made here in order to increase the clarity.

There are eight logical possibilities for the development of the variables in the decoupling framework (Fig. 4). The rates of change of CO_2 emissions (ΔCO_2) and GDP (Δ GDP) can be either coupled, decoupled or negatively decoupled. The decoupling of CO_2 emissions from transportation and economic growth is calculated by dividing the percentage unit change of CO_2 emissions with the percentage unit change of GDP in a given time period. The result of this calculation is an elasticity value *e* (Equation 1):

$$e = \%\Delta CO_2 \, / \, \%\Delta GDP \qquad \text{(Equation 1)}$$

The time period studied should comprise several years, and the more general the trend analysed, the longer the time period should be (Tapio, 2005). In this study, the time period was chosen to be 5 years, in order for rather rapid and detailed changes to be observed.

An elasticity value of 1.0 means that both emissions and GDP grow at a similar rate. In order not to over interpret 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 Fig. 4), which leads to coupling being defined as elasticity values between 0.8 and 1.2. The rates of change of the variables can be either positive, expressed as *expansive coupling*, or negative, expressed as *recessive coupling*.

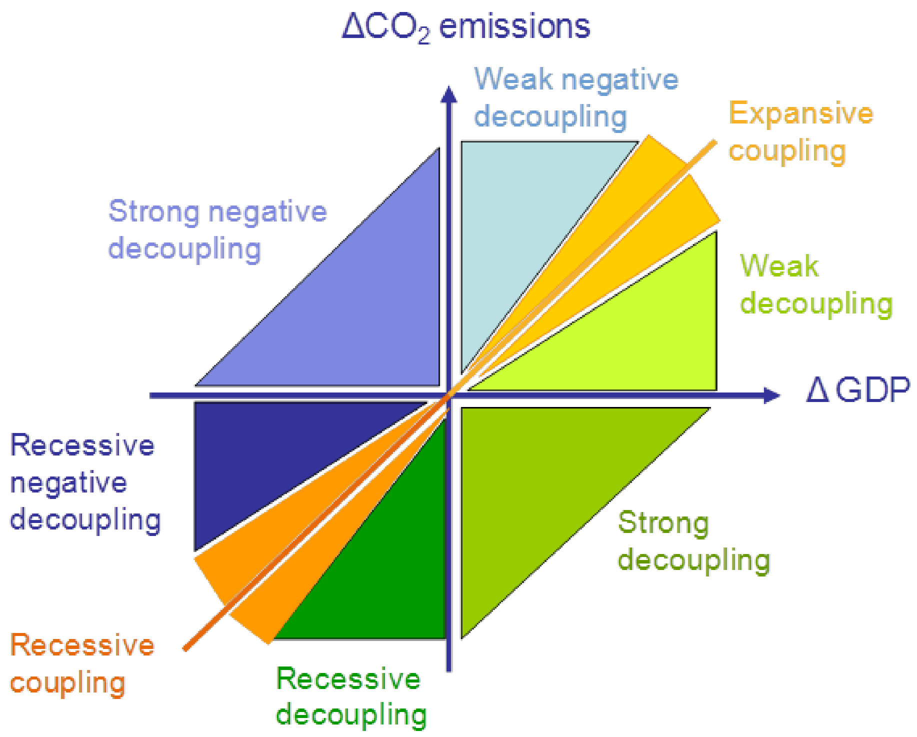

Figure 3.1 *The Decoupling Diamond (modified from Vehmas et al. 2003; Tapio 2005; Vehmas 2007)*

Decoupling is divided into three subcategories: In *weak decoupling*, GDP and transport CO_2 emissions both increase, but the GDP grows faster than the emissions. The GDP elasticity of CO_2 emissions is between 0 and 0.8. Decoupling occurs to some extent, because emissions grow more slowly than the GDP, but it is weak, since the absolute amount of emissions nevertheless continues to grow. In *strong decoupling*, the GDP increases and transport CO_2 emissions decrease. Thus the GDP elasticity of CO_2 emissions is below 0. This is the case of absolute decoupling and the best case for both the economy and the environment. In *recessive decoupling*, GDP and transport CO_2 emissions both decrease, but the emissions decrease more rapidly than the GDP. The GDP elasticity of CO_2 emissions is over 1.2.

Also negative decoupling can be divided into three subcategories: In *weak negative decoupling*, GDP and transport CO_2 emissions both increase and the emissions increase faster than the GDP. Here, $e > 1.2$. In *strong negative decoupling*, GDP decreases and transport CO_2 emissions increase and $e < 0$. Strong negative decoupling might be characterized as the worst case development. In *recessive negative decoupling*, GDP and transport CO_2 emissions both decrease but GDP decreases faster than the emissions ($0 < e < 0.8$).

Next, global data about the relative changes of GDP and CO_2 emissions from transport are placed in the decoupling framework so that the form of decoupling in different countries at different times can be analysed.

4. MATERIAL AND METHODS

The study is based on data on CO_2 emissions from transportation and gross domestic product (GDP) for 141 world countries and groups of countries. The data was acquired from the International Energy Agency's (IEA) CD-Rom "CO_2 Emissions from Fuel Combustion" (IEA, 2007). The transportation data includes emissions from road traffic, other domestic traffic, international aviation and international maritime transport (using the Intergovernmental Panel on Climate Change (IPCC) "sectoral approach"). The emissions from international aviation and maritime transportation are allocated to the place where the ships and planes are bunkered.

The CO_2 emissions are measured in mega tonnes of CO_2. GDP in real terms is measured using purchasing power parities (GDPppp) and expressed as United States dollars of the year 2000 ($US\$_{2000}$). The countries included in the study are listed in Appendix 2.

In order to observe decoupling development, the data on CO_2 emissions from transport and GDP is divided into six five-year-periods (1975-1980, 1980-1985, 1985-1990, 1990-1995, 1995-2000 and 2000-2005). The relative change in CO_2 emissions and in GDP within each five-year-period is calculated for each country. Data for some countries (former USSR and former Yugoslavia and some others) was only available from 1990 onwards, so the number of countries analysed grows slightly in the last three five-year-periods. The strength of the Decoupling Diamond is that it works directly both as the framework and method. No operationalization is needed. The GDP elasticity of transport CO_2 emissions is calculated by dividing the relative change of CO_2 emissions from transport (in a given five-year-period) with the relative change of GDP (in the five-year-period) according to Equation 1. The world countries are categorized into different forms of decoupling in each period according to the calculated relative changes of emissions and GDP and elasticity values.

The availability of data imposed certain limitations on the study. Detailed data on emissions from different forms of transportation was not available for all the countries included in the study. The choice was made to use aggregated data in order for almost all the world countries to be included. The CO_2 emissions from all the different forms of transportation (passenger and freight transportation, road, maritime, rail and air transportation, domestic and international transportation) are aggregated in the study. In the IEA data, emissions from international transport are allocated to where bunkering took place.

Because the emissions data comprises information gathered from 141 countries or groups of countries over a time period of three decades, there is a possibility that there are differences in the quality of the statistical data. Data from larger countries is often more accurate than from smaller countries, and data for the most recent years in a time series is more accurate than older data. It has been estimated that national total CO_2 emissions data collected from the industrialised OECD countries is, on average, more accurate than data from less developed countries (Olivier and Peters, 2005). A study by Marland et al. (1999) comparing two different data sets of CO_2 emissions (one data set was based on statistics from the United Nations and the other on statistics from the International Energy Agency) found differences between the two estimates. Absolute differences between the two estimates of emissions were largest for countries with very large total emissions, but relative differences were largest in countries with small total emissions and also weaker national energy statistics systems. The IEA data on emissions is based on fuel consumption. According to a number of studies, this method of calculating emissions may have resulted in the amount of emissions from international marine transportation being underestimated (IMO 2009, Corbett and Köhle, 2003).

Due to the limitations described above, the study acts as a general overview of the relationship of transportation emissions and the economy in the world. It does not go into details about individual countries situations. The problem of allocating emissions from international transportation to individual countries is acknowledged, but the choice was made to include these emissions in the study, because international transportation is an important part of transportation. As for bunkering, embedded emissions were allocated to the producer country, which is a standard procedure in international trade of goods and electricity. The use of GDP as the economic indicator might give a biased picture of development in some countries.

5. RESULTS

Based on the results, the countries are divided into eight forms of decoupling according to the Decoupling Diamond (Figure 5.1**).** The rate of change of GDP is presented on the x-axis and the rate of change of CO_2 emissions from transport is shown on the y-axis. In the blue-coloured areas (recessive negative decoupling, strong negative decoupling and weak negative decoupling) CO_2 emissions from transport have grown faster or decreased more slowly than GDP. In the green-coloured areas (recessive decoupling, strong decoupling and weak decoupling) GDP has grown faster or decreased more slowly than CO_2 emissions from transport. The yellow and orange sectors (expansive coupling and recessive coupling) represent a situation where both CO_2 emissions from transport and GDP have either increased or decreased at a similar rate. The same colour scheme is used throughout the chapter in Tables 5.1 – 5.8.

5.1 Results by Temporal Development

Countries are grouped according to rates of change of CO_2 emissions and GDP in each 5-year period **(**Table 5.1). Table 5.1 is based on the values shown in Appendix 1 and the colour scheme shown in Figure 3.1.

Table 5.1 Countries grouped into different forms of decoupling based on their GDP elasticity of transport CO_2 emissions.

	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000	2000-2005
Recessive coupling		AR GT		AL GE KZ LV LT MD RU TM ZM		
Expansive coupling	AU CL TP CO CY FR DE ID IE IL MA SG SY TG TT TN GB	BD TP DK DO EG IL IT KR PY PT	AU AT BD CZ DE GH IT JM JP NL PK SE US YE	AR BO CA CL CN CO CY EC GH IS IN ID IE IL JM KW NL NG PE LK	EG FR GI HU IS IE JO MN NI SA LK TT	DZ AO BR CN HR GH GI HK IR JM JO KW MY NZ NG PY SA SI SE TJ TH UY ZM
Recessive decoupling	JM	BH BO GH KW MZ AN PH TG	CG CD CU KW MM PL	AM BY BG CU EE FI HU KP KG MN RO	KP MD PY UA	KP ZW
Weak decoupling	AT BH BE BR CN CU CZ DK DO GT HN HK HU IS IN IT JP JO KE MY MT NL NO PE PT SA LK SD SE TH TR US UY ForYugosl	AO AU BE BG CM CN CG CU FI FR DE HK IN ID KE LB MX NZ NO OM PK PA SG ES LK SE TN TR GB US ZW	CA CN CO IN IE IL KE KP MN LK TZ UY VE ZW	AU BE DE JO KE MY AN NO OM PL SA SN SG SY GB US VE	DZ AO AR AU BH BD BO BA BW BN KH CM CA CN TP CR CI CU EE ET FI DE GR IQ IL IT JP KR KW MK MX MA MZ MM NL NZ NO PA PE PL QA SK ZA SD SE SY TG TN TR GB US UY VE YE OthAfrica	AU BY BW KH CM CA CL TP CO CD EC EE FI GR HN IS IN ID IE KR LB LY LT MN MA MZ MM NO PK PE PH RO RU SN ZA LK TT TN TR TM UA AE GB US OthAfrica OthAsia
Strong decoupling	BJ BG GH GI OM PA PH PL RO SN SK ZA TZ VN ZW	AL AT BR CA CL CD CR CI CZ HU IE JM JP KP MT MA MM NL NI PE PL RO SN SK ZA TZ YE ZM OthAfrica OthLatAm ForYugosl	AL AO BH BJ CI GA MA AN NG SA SN OthLatAm OthAsia	DZ BH BJ BA CG MZ RS SD TG YE OthAsia	AZ BY CO DK ER GE IN KZ KE KG LV LB LT MT RU RS SI TJ TH AE ZM ZW	AR AM CU DK DO EG ER FR GA DE IL JP KZ MK MT NP NI CH SY TZ UZ
Recessive negative decoupling	NI	HT UY	LB NI	CD HR IQ SK UA	BG	
Weak negative decoupling	AL DZ AO AR BD BO BN CM CA CG CR CI EC EG ET FI GR HT IQ KP KR KW LY LU MX MZ MM NP NG PK PY QA ES CH AE VE YE ZM OthAfrica OthLatAm OthAsia	DZ BJ CO CY EC GA GI GR HN IS IR JO LU MY NP SD CH SY TH VN OthAsia	DZ BE BO BW BR BN BG CL TP CR CY DK DO EC EG SV ET FI FR GI GR GT HT HN HK HU IS ID IR KR LU MY MT MX MZ NP NZ NO OM PY PH PT SG SK ZA ES SD CH SY TH TG TN TR AE GB VN ZM OthAfrica	AT BD BW BR BN TP CR CI DK DO EG SV ET FR GA GI GR GT HN HK IR IT JP KR LB LY LU MT MX MA MM NP NZ NI PK PA PY PH PT QA ZA ES SE CH TZ TH TT TN TR AE UY VN ZW OthAfrica OthLatAm	AL AM AT BE BJ BR CL CG HR CY CZ DO EC SV GA GH GT HT HN HK ID IR LY LU MY NA NP NG OM PK PH PT SN SG ES CH TZ TM UZ VN OthLatAm OthAsia	AL AT AZ BH BD BE BJ BO BA BN BG CG CR CI CY CZ SV ET GE GT HU IT KE KG LV LU MX MD NA NL AN OM PA PL PT QA RS SG SK ES SD TG VE VN YE OthLatAm
Strong negative decoupling	CD SV GA IR LB NZ	BN SV ET IQ LY NG QA SA TT AE VE	AR CM IQ JO LY PA PE QA RO TT ForYugosl	AO AZ CM CZ HT MK SI TJ UZ	CD JM AN RO	HT IQ

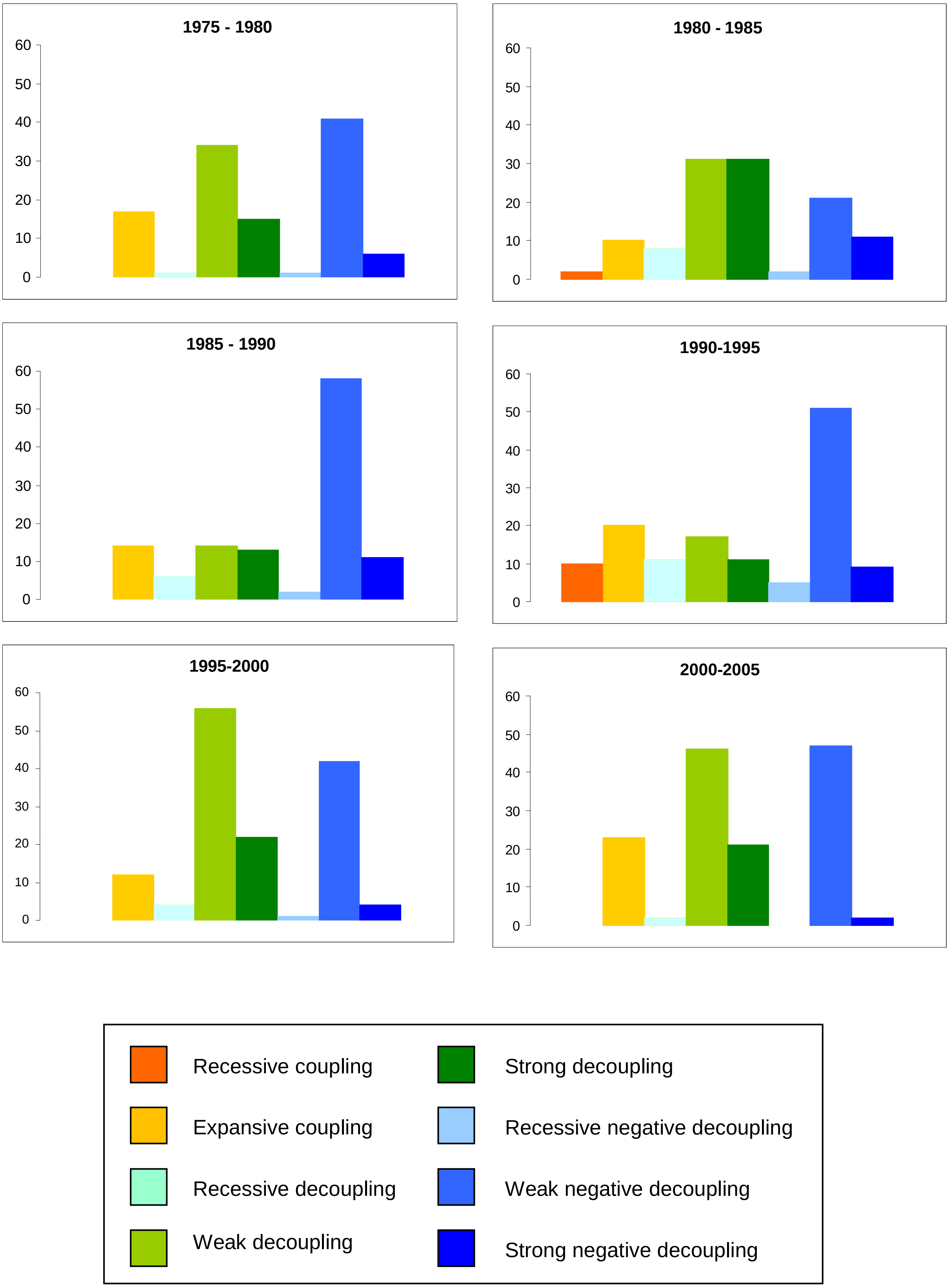

Figure 5.1. *The number of countries (shown on the vertical axis) in each form of decoupling in each 5-year period.*

The forms of decoupling vary in frequencies, that is the number of countries included in each form. The two largest forms throughout the years are weak decoupling and weak negative decoupling, meaning the groups where both emissions from transport and GDP grow. The number of countries in each form of decoupling in each 5-year period is shown in Figure 5.1.

In 1975-1980 the two largest forms were weak negative decoupling (41 countries) and weak decoupling (34 countries). In 1980-1985 weak decoupling and strong decoupling were the two largest forms (31 countries in each), followed by weak negative decoupling (21 countries). During the next two periods weak negative decoupling was the largest form (58 countries in 1985-1990 and 55 countries in 1990-1995). Some change may be observed in 1995-2000, as weak decoupling became the largest form (55 countries), followed by weak negative decoupling (42 countries). In 2000-2005 the two largest groups were weak decoupling (46 countries) and weak negative decoupling (46 countries). All in all, the forms where both emissions and GDP grew were the largest ones, except for 1980-1985 when also the strong decoupling group was large (31 countries).

The number of examined countries and groups of countries increases during the years from 115 in the period from 1975-1980 to 141 in the period from 2000-2005. This is mostly due to the collapse of the Soviet Union and the Yugoslav Republic.

5.2 Results by Groups of Countries

In total there are 141 countries examined. For the sake of clarity the countries have been grouped into six groups according to how the CO_2 emissions from transport and GDP developed in the last 5-year period, 2000-2005 to highlight the most recent development and possible seeds of change. The groups are not evenly sized. There are two very large groups (Group 3: weak decoupling and Group 5: weak negative decoupling), two medium-sized groups (Group 1: expansive coupling and Group 4: strong decoupling) and two very small groups (Group 2: recessive decoupling and Group 6: strong negative decoupling). The rest of the chapter will present the development in countries within these six groups.

5.2.1 Group 1: Expansive coupling in 2000-2005

Countries in Group 1 all ended up in the group of expansive coupling in 2000-2005. This means that both CO_2 emissions from transport and GDP grew at a similar rate. Group 1 consists of 23 countries: Algeria, Angola, Brazil, China, Croatia, Ghana, Gibraltar, Hong Kong (China), Iran, Jamaica, Jordan, Kuwait, Malaysia, New Zealand, Nigeria, Paraguay, Saudi Arabia, Slovenia, Sweden, Tajikistan, Thailand, Uruguay and Zambia.

During the time period examined, the countries in the group have experienced different kinds of decoupling development. The forms of decoupling in each country in 5-year periods from 1975 to 2005 can be seen in Table 5.2. Most of the countries in the group experienced weak decoupling and weak negative decoupling before ending up in expansive coupling.

As can be seen in Figure 5.2, the countries vary in size and location. Similar development has happened in countries that are different from one another in terms of economy, geography and demography (For more detailed information on countries, see Appendix 2). Group 1 includes countries from Africa, Asia, Europe, Oceania and South America.

Table 5.2 Forms of decoupling of Group 1 from 1975 to 2005.

	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000	2000-2005
Recessive coupling				ZM		
Expansive coupling		PY	GH JM SE	CN GH JM KW NG	GI JO SA	DZ AO BR CN HR GH GI HK IR JM JO KW MY NZ NG PY SA SI SE TJ TH UY ZM
Recessive decoupling	JM	GH KW	KW		PY	
Weak decoupling	BR CN HK JO MY SA SE TH UY	CN HK NZ SE	CN UY	JO MY SA	DZ AO CN KW NZ SE UY	
Strong decoupling	GH GI	BR JM ZM	AO NG SA	DZ	SI TJ TH ZM	
Recessive negative decoupling		UY		HR		
Weak negative decoupling	DZ AO KW NG PY ZM	DZ GI JO MY TH	DZ BR GI IR MY NZ PY TH ZM	BR GI HK IR NZ PY SE TH UY	BR HR GH HK IR MY NG	
Strong negative decoupling	IR NZ	NG SA	JO	AO SI	JM	

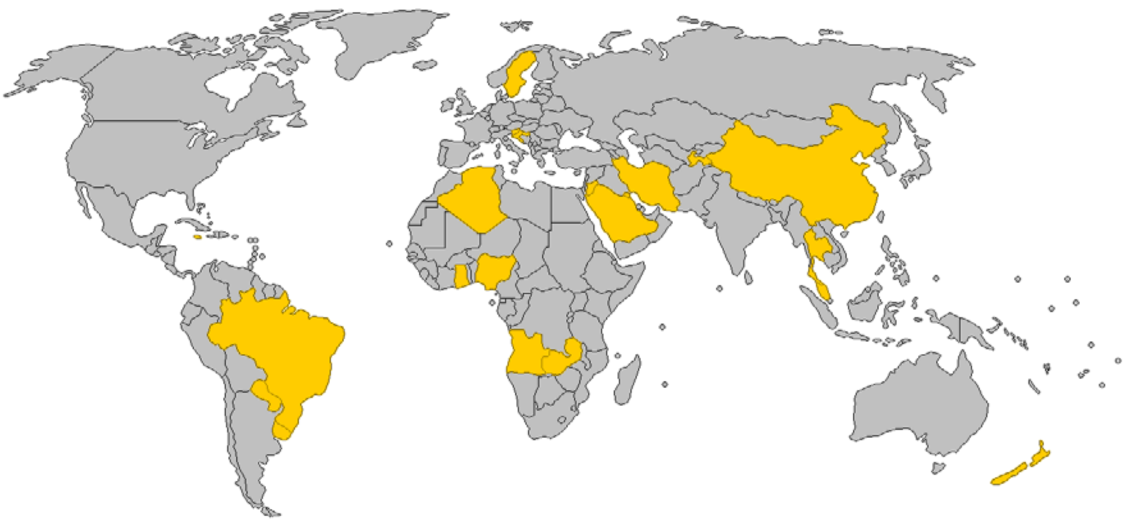

Figure 5.2 Countries in Group 1.

5.2.2 Group 2: Recessive decoupling in 2000-2005

Countries in Group 2 end up in the group of recessive decoupling in 2000-2005. This means that both CO_2 emissions and GDP have been decreasing, but the emissions have decreased relatively more than the GDP. Probably due to the global economic boom in 2000-2005, Group 2 is a tiny group and consists of only two countries, Democratic People's Republic of Korea and Zimbabwe. The forms of decoupling in each country in 5-year periods from 1975 to 2005 can be seen in Table 5.3. The countries experienced weak decoupling and strong decoupling before ending up in the group of recessive decoupling. The locations of the countries on the map can be seen in Figure 5.3.

Table 5.3 Forms of decoupling of Group 2 from 1975 to 2005.

	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000	2000-2005
Recessive coupling						
Expansive coupling						
Recessive decoupling				KP	KP	KP ZW
Weak decoupling		ZW	KP ZW			
Strong decoupling	ZW	KP			ZW	
Recessive negative decoupling						
Weak negative decoupling	KP			ZW		
Strong negative decoupling						

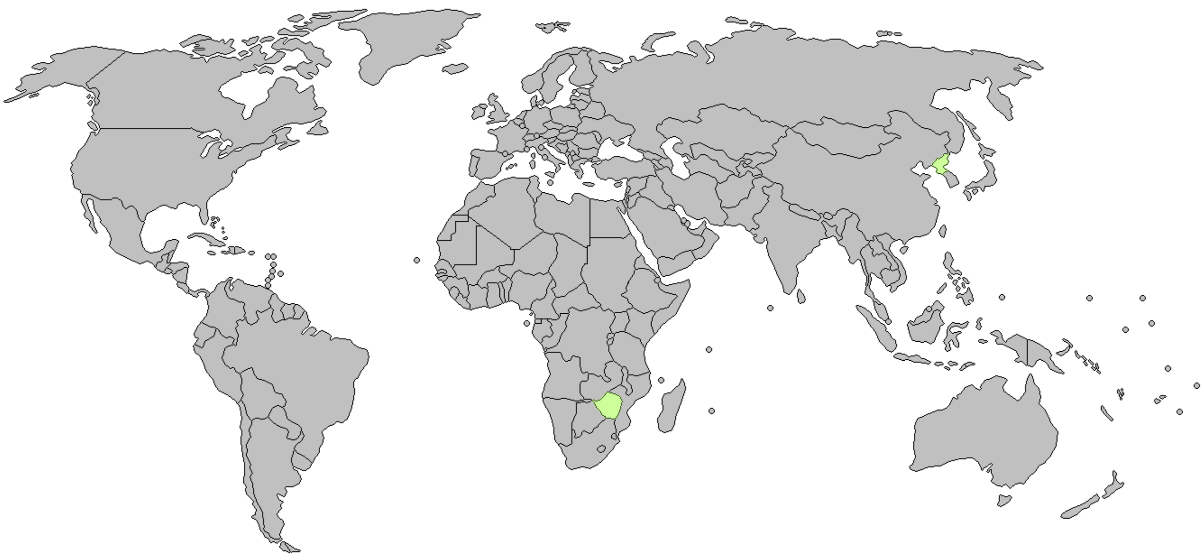

Figure 5.3 Countries in Group 2.

5.2.3 Group 3: Weak decoupling in 2000-2005

Countries in Group 3 end up in the weak decoupling group in 2000-2005. This means that both CO_2 emissions from transport and GDP have increased, but GDP has grown at a faster rate than the emissions. Relative decoupling has occurred, but the absolute amount of CO_2 emissions has still grown.

Table 5.4 Forms of decoupling of Group 3 from 1975 to 2005.

	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000	2000-2005
Recessive coupling		AR GT		AL GE KZ LV LT MD RU TM ZM ForYugosl		
Expansive coupling	AU CL TP CO ID IE MA TT TN GB	TP KR	AU PK US	CA CL CO EC IS IN ID IE PE LK	IS IE MN NI LK TT	
Recessive decoupling		MZ PH	CD MM	BY EE FI MN RO	UA	
Weak decoupling	HN IS IN NO PE LK TR US	AU CM FI IN ID LB NO PK LK TN TR GB US	CA CO IN IE MN LK	AU NO SN GB US	AU BW KH CM CA TP EE FI GR KR MA MZ MM NO PE ZA TN TR GB US OthAfrica	AU BY BW KH CM CA CL TP CO CD EC EE FI GR HN IS IN ID IE KR LB LY LT MN MA MZ MM NO PK PE PH RO RU SN ZA LK TT TN TR TM UA AE GB US OthAfrica OthAsia
Strong decoupling	PH RO SN ZA	CA CL CD IE MA MM PE RO SN ZA OthAfrica	MA SN OthAsia	MZ OthAsia	BY CO IN LB LT RU AE	
Recessive negative decoupling			LB	CD UA		
Weak negative decoupling	CM CA EC FI GR KR LY MZ MM PK AE OthAfrica OthAsia	CO EC GR HN IS OthAsia	BW CL TP EC FI GR HN IS ID KR MZ NO PH ZA TN TR AE GB OthAfrica	BW TP GR HN KR LB LY MA MM PK PH ZA TT TN TR AE OthAfrica	CL EC HN ID LY PK PH SN TM OthAsia	
Strong negative decoupling	CD LB	LY TT AE	CM LY PE RO TT	CM	CD RO	

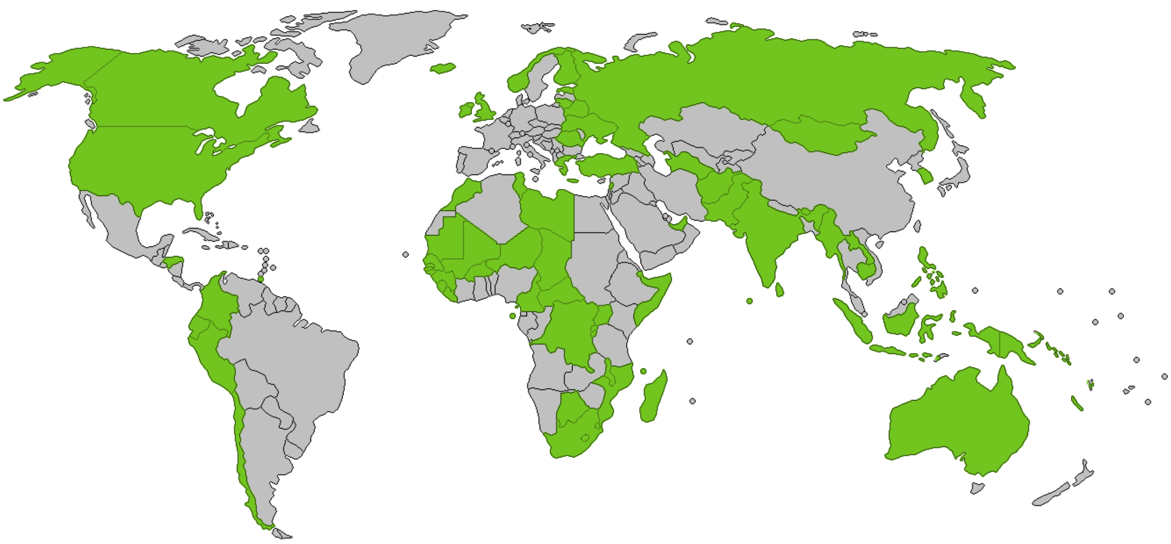

Figure 5.4 Countries in Group 3.

Group 3 is a large group, and it consists of 46 countries from all the continents: Australia, Belarus, Botswana, Cambodia, Canada, Chile, Cameroon, Chinese Taipei, Colombia, Democratic Republic of Congo, Ecuador, Estonia, Finland, Greece, Honduras, Iceland, India, Indonesia, Ireland, Korea, Lebanon, Libya, Lithuania, Mongolia, Morocco, Mozambique, Myanmar, Norway, Pakistan, Peru, Philippines, Romania, Russia, Senegal, South Africa, Sri Lanka, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, Ukraine, United Arab Emirates, United Kingdom, United States, other African countries and other Asian countries.

The forms of decoupling in each country in 5-year periods from 1975 to 2005 can be seen in Table 5.4. Many of the countries have experienced weak negative decoupling and weak decoupling, some also strong decoupling, before ending up in the group of weak decoupling. The locations of the countries in Group 3 can be seen in Figure 5.4. Group 3 contains countries of different sizes from all the different continents.

5.2.4 Group 4: Strong decoupling in 2000-2005

Countries in Group 4 all end up in the strong decoupling group in 2000-2005. Their GDP rose while the CO_2 emissions from transport decreased. This is the only group where absolute decoupling occurred.

Group 4 consists of 21 countries: Argentina, Armenia, Cuba, Denmark, Dominican Republic, Egypt, Eritrea, France, Gabon, Germany, Israel, Japan, Kazakhstan, FYR of Macedonia, Malta, Nepal, Nicaragua, Switzerland, Syria, United Republic of Tanzania and Uzbekistan. The forms of decoupling in each country in 5-year periods from 1975 to 2005 can be seen in Table 5.5. The countries experienced many different forms of decoupling, especially weak negative decoupling, before ending up in the group of strong decoupling.

The locations of the countries can be seen in Figure 5.5. The countries in Group 4 are located in Africa, Asia, Europe and South America. The decoupling development in the countries of Group 4 will be discussed in more detail in Chapter 5.

Table 5.5 *Forms of decoupling of group 4 from 1975 to 2005.*

	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000	2000-2005
Recessive coupling		AR		KZ		
Expansive coupling	FR DE IL SY	DK DO EG IL	DE JP	AR IL	EG FR NI	
Recessive decoupling			CU	AM CU		
Weak decoupling	CU DK DO JP MT	CU FR DE	IL TZ	DE SY	AR CU DE IL JP MK SY	
Strong decoupling	TZ	JP MT NI TZ	GA		DK ER KZ MT	AR AM CU DK DO EG ER FR GA DE IL JP KZ MK MT NP NI CH SY TZ UZ
Recessive negative decoupling	NI		NI			
Weak negative decoupling	AR EG NP CH	GA NP SD CH SY	DK DO EG FR MT NP CH SY	DK DO EG FR GA JP MT NP NI CH TZ	AM DO GA NP CH TZ UZ	
Strong negative decoupling	GA		AR	MK UZ		

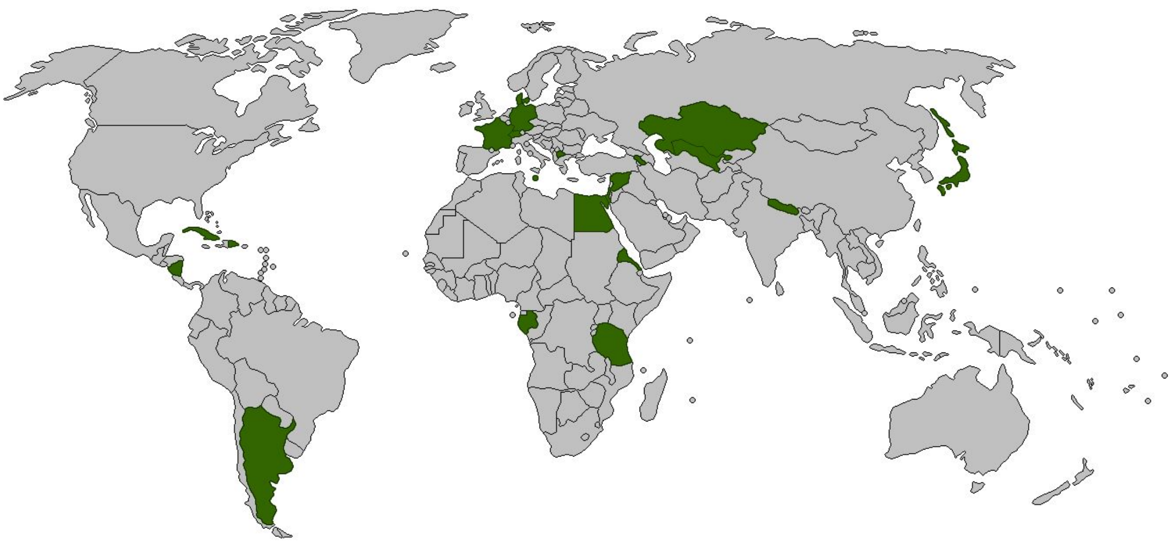

Figure 5.5 *Countries in group 4.*

5.2.5 Group 5: Weak negative decoupling in 2000-2005

Countries in Group 5 all end up in the weak negative decoupling group in 2000-2005. Both their CO_2 emissions from transport and GDP grow, but the emissions grow at a faster rate than GDP. Neither relative nor absolute decoupling occurs, hence the term negative decoupling.

Table 5.6 Forms of decoupling of Group 5 in 1975-2005.

	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000	2000-2005
Recessive coupling		GT		AL GE LV LT MD ForYugosl		
Expansive coupling	CY SG TG	BD IT PT	AT BD CZ IT NL YE	BO CY NL	HU	
Recessive decoupling		BH BO AN TG	CG PL	BG HU KG	MD	
Weak decoupling	AT BH BE CZ GT HU IT KE NL PT SD	BE BG CG KE MX OM PA SG ES	KE VE	BE KE AN OM PL SG VE	BH BD BO BA BN CR CI ET IT MX NL PA PL QA SK SD TG VE YE	
Strong decoupling	BJ BG OM PA PL SK VN	AL AT CR CI CZ HU NL PL SN SK YE OthLatAm	AL BH BJ CI AN OthLatAm	BH BJ BA CG RS TG YE	AZ GE KE KG LV RS	
Recessive negative decoupling					BG	
Weak negative decoupling	AL BD BO BN CG CR CI ET LU MX QA ES VE YE OthLatAm	BJ CY LU SD VN	BE BO BN BG CR CY SV ET GT HU LU MX OM PT SG SK ES SD TG VN	AT BD BN CR CI SV ET GT IT LU MX PA PT QA ES VN OthLatAm	AL AT BE BJ CG CY CZ SV GT LU NA OM PT SG ES VN OthLatAm	AL AT AZ BH BD BE BJ BO BA BN BG CG CR CI CY CZ SV ET GE GT HU IT KE KG LV LU MX MD NA NL AN OM PA PL PT QA RS SG SK ES SD TG VE VN YE OthLatAm
Strong negative decoupling	SV	BN SV ET QA VE	PA QA	AZ CZ	AN	

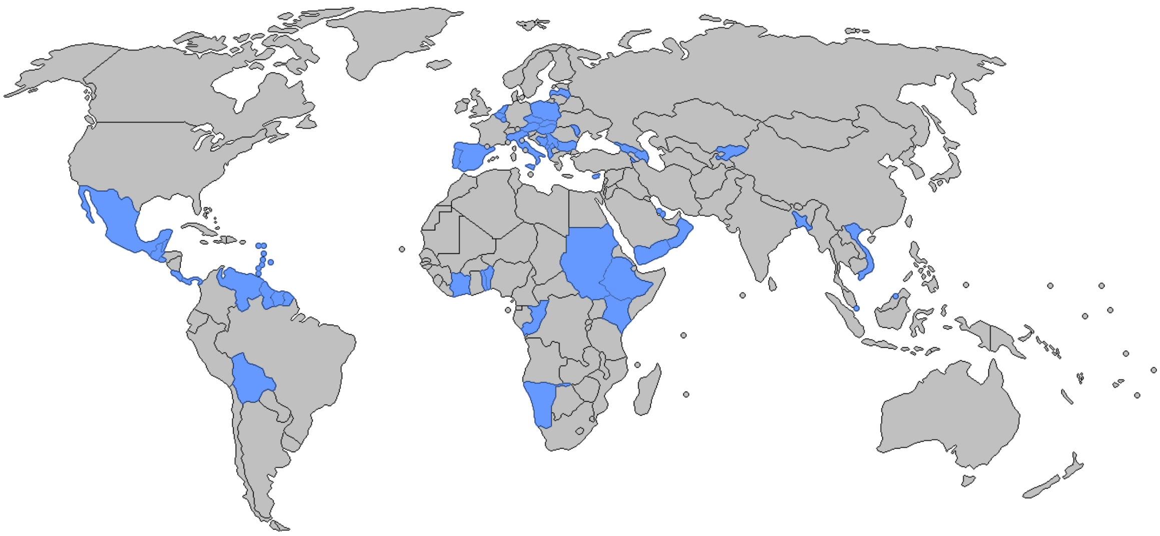

Figure 5.6 Countries in Group 5.

Group 5 is a large group, and consists of 46 countries: Albania, Austria, Azerbaijan, Bahrain, Bangladesh, Belgium, Benin, Bolivia, Bosnia-Herzegovina, Brunei Darussalam, Bulgaria, Congo, Costa Rica, Côte d'Ivoire, Cyprus, Czech Republic, El Salvador, Ethiopia, Georgia, Guatemala, Hungary, Italy, Kenya, Kyrgyzstan, Latvia, Luxembourg, Mexico, Republic of Moldova, Namibia, Netherlands, Netherlands Antilles, Oman, Panama, Poland, Portugal, Qatar, Serbia and Montenegro, Singapore, Slovak Republic, Spain, Sudan, Togo, Venezuela, Vietnam, Yemen and Other Latin American Countries.

The forms of decoupling in each country in 5-year periods from 1975 to 2005 can be seen in Table 5.6. Many of the countries in the group stayed in the weak negative decoupling group throughout the 30 years studied, but some countries experienced weak decoupling and strong decoupling before ending up in this group. The locations of the countries can be seen in Figure 5.6.

5.2.6 Group 6: Strong negative decoupling in 2000-2005

Countries in Group 6 end up in the group of strong negative decoupling in 2000-2005. This means that while GDP has decreased, CO_2 emissions from transport have increased. Group 6 is very small, and consists of two countries: Haiti and Iraq.

The forms of decoupling in each country in 5-year periods from 1975 to 2005 can be seen in Table 5.7. The countries experienced recessive negative decoupling, weak negative decoupling and strong negative decoupling during the 30 years studied. The locations of the countries can be seen in Figure 5.7.

Table 5.7 *Forms of decoupling of Group 6 in 1975-2005.*

	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000	2000-2005
Recessive coupling						
Expansive coupling						
Recessive decoupling						
Weak decoupling					IQ	
Strong decoupling						
Recessive negative decoupling		HT		IQ		
Weak negative decoupling	HT IQ		HT		HT	
Strong negative decoupling		IQ	IQ	HT		HT IQ

Figure 5.7 *Countries in Group 6.*

6. DISCUSSION

6.1 Summary and Conclusions

The amount of data used in the study was vast, including information on almost all of the countries in the world, and there are many options for analysis and comparisons of development in different countries at different times. The study acts as a general overview of the decoupling development in the transport sector in the world. Within the scope of this research, the choice has been made to focus on development in the last five year period studied, 2000-2005, and especially on the occurrence of strong decoupling. The time period 2000-2005 was chosen, because it is the most recent period. Strong decoupling, where CO_2 emissions decrease and GDP increases, was chosen as a case of special interest, because it is the kind of development that is the aim of policymakers in the EU (Commission of the European Communities, 2001) and it was not found in the study for EU15 countries (Tapio, 2005).

Tapio (2005) placed the EU15 countries in the decoupling framework based on their GDP and CO_2 emissions from transport between 1971 and 2001. The result was that the EU15 countries were divided into three forms of decoupling: weak negative decoupling (termed expansive negative decoupling in (Tapio, 2005)), expansive coupling and weak decoupling. Based on these results, the remaining five sectors in the Decoupling Diamond might have seemed to be only theoretical possibilities, but the results presented in Chapter 4 of this study prove that on a global scale all of the forms of decoupling have actually taken place during the 30 years examined. This means that the Decoupling Diamond is a valid tool for examining the relationship of CO_2 emissions and GDP.

Previous studies on decoupling in the transport sector agree that economic growth increases the demand for transport both in the passenger and freight sectors, e.g. Banister (1998), Lenzen et al. (2003), Schipper and Fulton (2003), Quadrelli and Peterson (2007). Travel has increased especially in the most carbon-intensive modes - private vehicles, air travel and trucking (Schipper and Fulton, 2003).

In general the results of this study support these views. In the majority of the countries studied, both GDP and emissions grew. Many countries experienced weak decoupling of the emissions and GDP, but many countries also saw emissions growing faster than GDP. Much of the weak decoupling observed can be attributed to the growth of GDP. However there were also cases where strong decoupling occurred, that is GDP growth with a simultaneous reduction of CO_2 emissions from transport. Unfortunately global data on transport volumes was not available, but since most of transport is powered by oil, the carbon dioxide emissions are a good estimate of transport volume as well.

The rates of changes of CO_2 emissions from transport and GDP have developed in different ways in different countries and at different times. In the majority of world countries, both emissions and GDP have been growing from 1975-2005, in some countries they have grown at a similar rate (expansive coupling), in some countries the rate of GDP growth has been faster than the growth of emissions (weak decoupling) and in others the CO_2 emissions have grown faster than GDP (weak negative decoupling). There are however also cases of strong decoupling, where GDP has grown and emissions have decreased. In some countries, both emissions and GDP have decreased, and in some rare cases CO_2 emissions have risen although GDP has decreased.

A detailed description of the development in each individual country is beyond the scope of this research, but a little closer look is taken at the Strong decoupling group. The group consists of 21 countries: Argentina, Armenia, Cuba, Denmark, Dominican Republic, Egypt, Eritrea, France, Gabon, Germany, Israel, Japan, Kazakhstan, FYR of Macedonia, Malta, Nepal, Nicaragua, Switzerland, Syria, United Republic of Tanzania and Uzbekistan.

The countries in the Strong decoupling group differ a lot from one another in terms of the absolute levels of GDP and emissions. They have shown similar development (decreasing of CO_2 emissions and increasing of GDP), but the absolute levels of the indicators were very different from one another. In 2005 the amounts of CO_2 emissions from transport varied between 0,2 Mt CO_2 in Eritrea and 289,5 Mt CO_2 in Japan. GDP levels ranged between 4,3 billion $US\$_{2000}$ (ppp) in Eritrea and 3473,8 billion $US\$_{2000}$ (ppp) in Japan. The differences are equally large in per capita values. CO_2 emissions from transport per capita varied between 0.036 Mt CO_2 per capita in Nepal to 3.426 Mt CO_2 per capita in Denmark. GDP per capita ranged between 986 $ per capita in Eritrea and 30800 $ per capita in Switzerland. Yet, in all these countries, in the period of 2000-2005, GDP grew and CO_2 emissions from transport decreased.

Possible reasons for the observed decoupling of GDP growth and transport CO_2 emissions in the countries of Group 4 include moving from road transport to less CO_2 intensive forms of transport, like rail, water or public transportation, the use of small cars, high fuel prices, environmental awareness, using rails as a mode of transportation, fuel shortages caused by trade embargos or political instability, restricting the free mobility of citizens, poverty (although GDP has grown, it might still be very low or incomes might not be distributed evenly), shifting to less material intensive industry, technological change, for example more efficient engines, reducing the need for transport with better logistics, using less CO_2 intensive transportation fuels (e.g. natural gas) or errors in statistics resulting from buying fuel from other countries.

6.2 Policy Implications

Minimising the harmful effects of transportation and reducing the CO_2 emissions from transport requires decisions by policymakers. Changing the energy, transportation, and urban systems takes time. The life spans of urban layouts, power plants, transportation systems and buildings are long. Decisions in land use planning and transport policy made today will affect transportation for years to come. Early planning and immediate action are needed, if reductions in global emissions are to be achieved. (Lenzen et al. 2003, Ministry of Transport and Communications Finland 2007).

In this study, all the different forms of decoupling have been examined. From the environmental point of view, there are large differences in the significance of these different forms. The most important thing is that CO_2 emissions are actually reduced, not only relatively (weak decoupling) but also in absolute terms (strong decoupling).

In the transport sector it may be easier to achieve absolute reductions in the use of energy or production of emissions than it would be to reduce the volume of transport (Banister and Stead, 2002). Possible ways to achieve reductions in transport emissions include technological changes, switching to non-fossil fuels, more efficient engines and better organised logistics. According to Johansson (2009) levels of transport as high as today could be consistent with CO_2 reductions if renewable energy sources such as wind and solar energy, combined with efficiency improvements, would be utilised. This should however be combined with measures that affect transport demand, as transportation has also other negative environmental effects besides CO_2 emissions. According to Banister (1998) "Environmental policy and transport must look for solutions which both allow movement and reduce the external costs of that movement".

The Commission and the Council of the European Union have proposed several policy tools to facilitate the breaking of the link between economic growth and transport growth and achieve sustainable mobility. Tools proposed include economic instruments, regulatory measures, infrastructure investments and new technologies. Economic instruments include congestion charging and taxation, infrastructure investments include developing and improving a trans-European rail network. Other proposed measures include reengineering of production and logistics processes and improving the connections between different transport modes. (Commission of the European Communities 2001, Commission of the European Communities 2008, Council of the European Union 2006).

6.3 Suggestions for Further Research

This study acts as a general overview on the decoupling development in the world countries between 1975-2005. Because of the lack of available global data on different modes of transport, all the fossil-fuel dependent transport modes are aggregated. Because road transport is the dominant form of transport (64% of total transport CO_2 emissions in 2005, IEA 2007), the results actually portray the decoupling of road transport emissions and GDP. Decoupling in the transport sector may differ according to different transport modes (OECD, 2006). If different modes of transport would be separated, a more detailed picture of the link between transport CO_2 emissions and GDP would emerge. For example air transport emissions are likely to have a different kind of relationship with GDP than emissions from road transportation.

Another point of view is the distinction between passenger and freight transport. In the IEA data, also these two are aggregated. According to Ballingall et al. (2003) there might be different driving forces influencing the growth of passenger and freight transport. For companies and industries transport is an input to production and therefore a cost, which gives them the incentive to minimise its use for example by making logistics more efficient. On the other hand, for individuals transport is usually a consumption good, so individuals tend to increase travelling as their income grows. The separate analysis of emissions from passenger transportation and freight transportation would also contribute to producing a more accurate picture of the relationship between transport CO_2 emissions and GDP.

Due to time restraints caused by the vast amount of countries included in the study, it was not possible to analyse the reasons for the decoupling development observed in each country. The next step for this study would be to have a more detailed look at the reasons for the observed decoupling development in different countries, especially the Strong decoupling group. Based on the analysis of reasons of good performance, policy recommendations could be given. Other countries could learn from the success of the countries that have managed to combine economic growth and decreasing CO_2 emissions from transport. It would also be interesting to find out how the current global recession has affected emissions and decoupling in 2005-2010.

ACKNOWLEDGEMENTS

This work is part of the SIGHT project (Sustainability Foresight of Global Transport CO_2 Emissions). The Academy of Finland is greatly acknowledged for financial support.

REFERENCES

Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C.S., Jansson, B., Levin, S., Mäler, K., Perrings, C. and Pimentel, D. (1995) 'Economic Growth, Carrying Capacity and the Environment', Science, vol. 268.

Ayres, R.U. (1995) 'Economic growth: politically necessary but not environmentally friendly', Ecological Economics , vol. 15, pp. 97-99.

Ballingall, J., Steel, D. and Briggs, P. (2003) 'Decoupling economic activity and transport growth: the state of play in New Zealand', Ministry of Transport. AT RF 03.

Banister, D. (1998) 'Introduction: Transport policy and the environment', in Banister, D. Transport policy and the environment, London.

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

Banister, D., Stead, D., Steen, P., Åkerman, J., Dreborg, K., Nijkamp, P. and Schleider-Tappeser, R. (2000) European Transport Policy and Sustainable Mobility, Suffolk: Spon Press.

Binswanger, M. (2001) 'Technological progress and sustainable development: what about the rebound effect?', Ecological Economics , vol. 36, pp. 119-132.

Carlsson-Kanyama, A. and Lindén, A. (1999) 'Travel patterns and environmental effects now and in the future: implications of differences in energy consumption among socio-economic groups', Ecological Economics, vol. 30, pp. 405-417.

Cole, M.A., Rayner, A.J. and Bates, J.M. (1997) 'The environmental Kuznets curve: an empirical analysis', Environment and Development Economics, vol. 2, pp. 401-416.

Commission of the European Communities (2001) 'White Paper - European transport policy for 2010: time to decide', http://ec.europa.eu/transport/white_paper/documents/doc/lb_com_2001_0370_en.pdf.

Commission of the European Communities (2008) 'Communication from the Commission to the European Parliament and the Council. Greening Transport.'.

Corbett, J.J. and Köhler, H.W. (2003) 'Updated emissions from ocean shipping', Journal of Geophysical Research, vol. 108.

Council of the European Union (2006) 'Review of the EU Sustainable Development Strategy (EU SDS) - Renewed Strategy'.

Daly, H.E. (1997) 'Georgescu-Roegen versus Solow/Stiglitz', Ecological Economics, vol. 22, pp. 261-266.

de Bruyn, S. (1997) 'Explaining the environmental Kuznets curve: structural change and international agreements in reducing sulphur emissions', Environment and Development Economics, vol. 2, pp. 485-503.

Galeotti, M. and Lanza, A. (2005) 'Desperately seeking environmental Kuznets', Environmental Modelling & Software, vol. 20, pp. 1379-1388.

Gilbert, R. and Nadeau, K. (2002) 'Decoupling economic growth and transport demand: A requirement for sustainability', Paper presented at the Conference on Transportation and Economic Development, Transportation Research Board, Portland Oregon, May.

Greening, L.A. (2004) 'Effects of human behavior on aggregate carbon intensity of personal transportation: comparison of 10 OECD countries for the period 1970-1993', Energy Economics, vol. 26, pp. 1-30.

Grossman, G.M. and Krueger, A.B. (1991) 'Environmental impacts of a North American Free Trade Agreement', National Bureau of Economic Research Working Paper 3914, NBER, Cambridge MA.

Grossman, G.M. and Krueger, A.B. (1995) 'Economic Growth and the Environment', The Quarterly Journal of Economics, vol. 110, pp. 353-377.

Holm, S. and Englund, G. (2009) 'Increased ecoefficiency and gross rebound effect: Evidence from USA and six European countries 1960 - 2002', Ecological Economics, vol. 68, pp. 879-887.

Huang, W.M., Lee, G.W.M. and Wu, C.C. (2008) 'GHG emissions, GDP growth and the Kyoto Protocol: A revisit of Environmental Kuznets Curve hypothesis', Energy Policy, vol. 36, pp. 239-247.

IEA (2007) 'CO2 emissions from fuel combustion 1971-2005. 2007 edition'.

IEA (2008) 'Worldwide Trends in Energy Use and Efficiency. Key Insights from IEA Indicator Analysis'.

IMO (2009) 'Second IMO GHG Study', International Maritime Organisation.

IPCC (2007) 'Climate Change 2007: Synthesis Report', pp. 36-37.

Johansson, B. (2009) 'Will restrictions on CO2 emissions require reductions in transport demand?', Energy Policy, vol. 37, pp. 3212-3220.

Kamakaté, F. and Schipper, L. (2009) 'Trends in truck freight energy use and carbon emissions in selected OECD countries from 1973 to 2005', Energy Policy, vol. 37, pp. 3743-3751.

Kuznets, S. (1955) 'Economic growth and income inequality', American Economic Review, vol. 49, pp. 1-28.

Lenzen, M., Dey, C. and Hamilton, C. (2003) 'Climate Change', in Hensher, D.A. and Button, K.J. Handbooks in Transport 4. Handbook of transport and the environment, Elsevier.

Lu, I.J., Lin, S.J. and Lewis, C. (2007) 'Decomposition and decoupling effects of carbon dioxide emission from highway transportation in Taiwan, Germany, Japan and South Korea', Energy Policy, vol. 35, pp. 3226-3235.

Luukkanen, J., Vehmas, J., Kinnunen, V., Kuntsi-Reunanen, E. and Kaivo-oja, J. (2005) 'Converging CO2 emission to equal per capita levels. Mission possible?', FFRC-Publications 2/2005, p. 139.

Marland, G., Brenkert, A. and Olivier, J. (1999) 'CO2 from fossil fuel burning: a comparison of ORNL and EDGAR estimates of national emissions', Environmental Science and Policy, vol. 2, pp. 265-273.

Ministry of Transport and Communications Finland (2007) 'Tranport 2030. Major challenges, new directions', Programmes and Strategies 2/2007.

Moomaw, W.R. and Unruh, G.C. (1997) 'Are environmental Kuznets curves misleading us? The case of CO2 emissions', Environment and Development Economics, vol. 2, pp. 451-463.

O Gallachoir, B.P., Howley, M., Cunningham, S. and Bazilian, M. (2009) 'How private car purchasing trends offset efficiency gains and the successful energy policy response', Energy Policy, vol. 37, pp. 3790-3802.

OECD (2002) 'General Secretariat: Sustainable Development: Indicators to Measure Decoupling of Environmental Pressure from Economic Growth', SG/SD (2002) 1/FINAL.

OECD (2006) 'Decoupling the Environmental Impacts of Transport from Economic Growth'.

Olivier, J.G.J. and Peters, J.A.H.W. (2005) 'CO2 from the non-energy use of fuels: A global, regional and national perspective based on the IPCC Tier 1 approach', Recources, Conservation and Recycling, vol. 45, pp. 210-225.

Panayotou, T. (1997) 'Demystifying the environmental Kuznets curve: turning a black box into a policy tool', Environment and Development Economics, vol. 2, pp. 465-484.

Peake, S. (1994) Transport in Transition. Lessons from the History of Energy, London: Earthscan Publications.

Quadrelli, R. and Peterson, S. (2007) 'The energy-climate challenge: Recent trends in CO2 emissions from fuel combustion', Energy Policy, vol. 35, pp. 5938-5952.

Schipper, L.J. and Fulton, L. (2003) 'Carbon dioxide emissions from transportation: Trends, driving factors and forces for change', in Hensher, D.A. and Button, K.J. Handbooks in transport 4. Handbook of transport and the environment, Elsevier.

Song, T., Zheng, T. and Tong, L. (2008) 'An empirical test of the environmental Kuznets curve in China: A panel cointegration approach', China Economic Review, vol. 19, pp. 381-392.

Stead, D. (2001) 'Transport intensity in Europe - Indicators and trends', Transport Policy, no. 8, pp. 29-46.

Stern, D.I. (2004) 'The Rise and Fall of the Environmental Kuznets Curve', World Development, vol. 32, pp. 1419-1439.

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, vol. 35, pp. 137-151.

Tapio, P., Banister, D., Luukkanen, J., Vehmas, J. and Willamo, R. (2007) 'Energy and transport in comparison: Immaterialisation, dematerialisation and decarbonisation in the EU15 between 1970 and 2000', Energy Policy, no. 35, pp. 433-451.

van den Bergh, J.C.J.M. (2009) 'The GDP paradox', Journal of Economic Psychology , vol. 30, p. 117–135.

van den Brink, J.C.J.M. and van Wee, B. (2001) 'Why has car-fleet specific fuel consumption not shown any decrease since 1990? Quantative analysis of Dutch passenger car-fleet specific fuel consumption', Transportation Research Part D, vol. 6, pp. 75-93.

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

Vehmas, J., Malaska, P., Luukkanen, J., Kaivo-oja, J., Hietanen, O., Vinnari, M. and Iivonen, J. (2003) 'Europe in Global Battle of Sustainability: Rebound Strikes Back? Advanced Sustainability Analysis', Series Discussion and Working Papers. Publications of the Turku School of Economics and Business Administrations, vol. 7.

World Bank (1992) 'World Development Report 1992 Development and the Environment', p. 308.

Appendix 1.
Country codes used in the study

Albania	AL	Gibraltar	GI	Panama	PA
Algeria	DZ	Greece	GR	Paraguay	PY
Angola	AO	Guatemala	GT	Peru	PE
Argentina	AR	Haiti	HT	Philippines	PH
Armenia	AM	Honduras	HN	Poland	PL
Australia	AU	Hong Kong (China)	HK	Portugal	PT
Austria	AT	Hungary	HU	Qatar	QA
Azerbaijan	AZ	Iceland	IS	Romania	RO
Bahrain	BH	India	IN	Russia	RU
Bangladesh	BD	Indonesia	ID	Saudi Arabia	SA
Belarus	BY	Islamic Republic of Iran	IR	Senegal	SN
Belgium	BE	Iraq	IQ	Serbia and Montenegro	RS
Benin	BJ	Ireland	IE	Singapore	SG
Bolivia	BO	Israel	IL	Slovak Republic	SK
Bosnia-Herzegovina	BA	Italy	IT	Slovenia	SI
Botswana	BW	Jamaica	JM	South Africa	ZA
Brazil	BR	Japan	JP	Spain	ES
Brunei Darussalam	BN	Jordan	JO	Sri Lanka	LK
Bulgaria	BG	Kazakhstan	KZ	Sudan	SD
Cambodia	KH	Kenya	KE	Sweden	SE
Cameroon	CM	Dem. People's Republic of Korea	KP	Switzerland	CH
Canada	CA	Korea	KR	Syria	SY
Chile	CL	Kuwait	KW	Tajikistan	TJ
China	CN	Kyrgyzstan	KG	United Republic of Tanzania	TZ
Chinese Taipei	TP	Latvia	LV	Thailand	TH
Colombia	CO	Lebanon	LB	Togo	TG
Congo	CG	Libya	LY	Trinidad and Tobago	TT
Democratic Republic of Congo	CD	Lithuania	LT	Tunisia	TN
Costa Rica	CR	Luxembourg	LU	Turkey	TR
Côte d'Ivoire	CI	FYR of Macedonia	MK	Turkmenistan	TM
Croatia	HR	Malaysia	MY	Ukraine	UA
Cuba	CU	Malta	MT	United Arab Emirates	AE
Cyprus	CY	Mexico	MX	United Kingdom	GB
Czech Republic	CZ	Republic of Moldova	MD	United States	US
Denmark	DK	Mongolia	MN	Uruguay	UY
Dominican Republic	DO	Morocco	MA	Uzbekistan	UZ
Ecuador	EC	Mozambique	MZ	Venezuela	VE
Egypt	EG	Myanmar	MM	Vietnam	VN
El Salvador	SV	Namibia	NA	Yemen	YE
Eritrea	ER	Nepal	NP	Zambia	ZM
Estonia	EE	Netherlands	NL	Zimbabwe	ZW
Ethiopia	ET	Netherlands Antilles	AN	Other Africa	OthAfr
Finland	FI	New Zealand	NZ	Other Latin America	OthLAm
France	FR	Nicaragua	NI	Other Asia	OthAsia
Gabon	GA	Nigeria	NG	Former Yugoslavia	ForYug
Georgia	GE	Norway	NO		
Germany	DE	Oman	OM		
Ghana	GH	Pakistan	PK		

Appendix 2.
The coverage of the study – individual, grouped and excluded countries

Individual countries (137)	
Africa	Algeria, Angola, Benin, Botswana, Cameroon, Congo, Democratic Republic of Congo, Côte d'Ivoire, Egypt, Eritrea, Ethiopia, Gabon, Ghana, Kenya, Libya, Morocco, Mozambique, Namibia, Nigeria, Senegal, South Africa, Sudan, United Republic of Tanzania, Togo, Tunisia, Zambia and Zimbabwe.
America	Argentina, Bolivia, Brazil, Canada, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Mexico, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, the United States, Uruguay and Venezuela.
Asia	Bahrain, Bangladesh, Brunei Darussalam, Cambodia, China (including Hong Kong), Chinese Taipei, India, Indonesia, Islamic Republic of Iran, Iraq, , Israel, Japan, Jordan, Korea, DPR of Korea, Kuwait, Lebanon, Malaysia, Mongolia, Myanmar, Nepal, Oman, Pakistan, Qatar, Philippines, Saudi Arabia, Singapore, Sri Lanka, Syria, Thailand, United Arab Emirates, Vietnam and Yemen.
Oceania	Australia and New Zealand.
Europe (excluding former USSR and Yugoslavia)	Albania, Austria, Belgium, Bulgaria, the Czech Republic, Cyprus, Denmark, Finland, France, Germany, Gibraltar, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Spain, Sweden, Switzerland, Turkey and the United Kingdom.
Former Yugoslavia[a]	Bosnia-Herzegovina, Croatia, Former Yugoslav Republic of Macedonia, Slovenia, and Serbia/Montenegro.
Former USSR[a]	Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Republic of Moldova, Russia, Tajikistan, Turkmenistan, Ukraine and Uzbekistan
Grouped countries (3 groups)	
Other Asia (17)	Afghanistan, Bhutan, Cambodia, Fiji, French Polynesia, Kiribati, Laos, Macau, Maldives, Mongolia, New Caledonia, Papua New Guinea, Samoa, Solomon Islands, Tonga and Vanuatu.
Other Latin America (17)	Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, Bermuda, Dominica, French Guyana, Grenada, Guadeloupe, Guyana, Martinique, St. Kitts and Nevis, Anguilla, Saint Lucia, St. Vincent and Grenadines, and Surinam.
Other Africa (37)	Burkina-Faso, Burundi, Cape Verde, Central African Republic, Chad, Comoros, Djibouti, Equatorial Guinea, Gambia, Guinea, Guinea-Bissau, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Niger, Reunion, Rwanda, Sao Tome and Principe, Seychelles, Sierra Leone, Somalia, Swaziland and Uganda.
No data, not included (15 countries)	
Africa	Saint Helena and Western Sahara.
America	Anguilla, British Virgin Islands, Cayman Islands, Falkland Islands, Montserrat, Saint Pierre-Miquelon and Turks and Caicos Islands.
Asia and Oceania	Christmas Island, Cook Islands, Nauru, Niue and Palau.
Europe	Liechtenstein.

[a]Grouped together 1975-1990, treated as individual countries 1990-2005.

Appendix 3. Relative change of GDPppp and CO_2 emissions from transport 1975-2000 in five-year intervals, and GDP elasticity of transport CO_2

Country	1975–1980			1980–1985			1985–1990			1990–1995			1995–2000			2000–2005		
	CO2%	GDP%	CO2/GDP	CO2%	GDP %	CO2/GDP	CO2%	GDP%	CO2/GDP	CO2%	GDP%	CO2/GDP	CO2%	GDP%	CO2/GDP	CO2%	GDP%	CO2/GDP
Albania	73,3	32,0	2,3	-26,8	10,6	-2,5	-34,9	2,6	-13,5	-11,3	-12,1	0,9	156	30,4	5,1	64,0	30,1	2,1
Algeria	65,7	35,0	1,9	32,3	26,5	1,2	28,5	3,9	7,4	-2,1	1,3	-1,6	10,4	16,7	0,6	30,8	27,2	1,1
Angola	10,6	0,3	31,7	1,9	7,0	0,3	-2,8	17,2	-0,2	9,7	-20,9	-0,5	9,7	36,3	0,3	52,4	63,6	0,8
Argentina	27,2	14,9	1,8	-13,1	-12,1	1,1	8,6	-2,3	-3,7	36,2	37,3	1,0	9,3	13,6	0,7	-4,6	10,4	-0,4
Armenia										-93,9	-47,2	2,0	246	28,4	8,6	-6,6	78,1	-0,1
Australia	17,2	16,0	1,1	7,7	16,0	0,5	14,6	15,3	0,9	11,1	17,5	0,6	12,0	21,1	0,6	6,7	17,6	0,4
Austria	12,2	17,5	0,7	-1,5	7,6	-0,2	13,4	16,3	0,8	13,8	11,3	1,2	19,0	15,6	1,2	29,7	7,5	4,0
Azerbaijan										3,3	-58,1	-0,1	-44,0	40,7	-1,1	179	88,0	2,0
Bahrain	15,9	63,1	0,3	-25,5	-6,9	3,7	-11,0	25,3	-0,4	-1,7	38,8	0,0	10,9	23,6	0,5	65,5	33,0	2,0
Bangladesh	76,0	22,7	3,3	23,5	20,0	1,2	21,5	20,1	1,1	54,0	24,0	2,3	14,8	28,9	0,5	54,9	30,3	1,8
Belarus										-43,2	-34,7	1,2	-7,5	35,8	-0,2	1,1	43,4	0,0
Belgium	7,0	16,9	0,4	2,9	4,8	0,6	41,4	16,4	2,5	5,0	8,2	0,6	21,7	14,1	1,5	17,8	7,5	2,4
Benin	-19,4	22,1	-0,9	44,8	24,9	1,8	-50,0	4,3	-11,7	-9,5	23,2	-0,4	416	29,6	14,1	50,0	22,1	2,3
Bolivia	40,3	10,7	3,8	-20,6	-9,3	2,2	28,9	11,6	2,5	25,7	22,2	1,2	4,1	18,4	0,2	27,1	16,0	1,7
Bosnia-Herzegovina										-51,1	19,1	-2,7	60,7	234	0,3	42,8	27,5	1,6
Botswana							100	74,6	1,3	33,8	21,9	1,5	35,2	49,3	0,7	24,4	32,8	0,7
Brazil	12,0	38,1	0,3	-4,4	5,5	-0,8	17,6	10,5	1,7	29,0	16,7	1,7	26,8	11,7	2,3	10,5	11,4	0,9
Brunei Darussalam	150	62,3	2,4	25,0	-16,9	-1,5	32,0	1,9	16,5	48,5	8,4	5,8	3,1	6,0	0,5	17,8	12,3	1,5
Bulgaria	-2,7	34,8	-0,1	10,0	17,9	0,6	31,9	7,8	4,1	-17,7	-12,4	1,4	-2,8	-4,1	0,7	43,4	27,3	1,6

Cambodia													9,5	42,5	0,2	40,2	54,8	0,7
Cameroon	71,4	36,4	2,0	31,9	56,2	0,6	1,6	-11,2	-0,1	1,0	-9,1	-0,1	6,7	26,1	0,3	12,0	19,7	0,6
Canada	24,2	20,0	1,2	-13,7	14,5	-0,9	12,0	15,2	0,8	9,6	8,9	1,1	9,5	22,4	0,4	5,7	13,4	0,4
Chile	34,4	42,0	0,8	-4,1	4,5	-0,9	47,3	38,5	1,2	54,7	51,7	1,1	29,8	22,6	1,3	14,3	23,9	0,6
China	22,3	37,2	0,6	24,6	66,4	0,4	18,9	46,0	0,4	30,6	78,3	0,4	46,2	51,2	0,9	56,2	57,7	1,0
Chinese Taipei	64,5	65,5	1,0	36,8	38,4	1,0	83,2	54,8	1,5	51,3	41,0	1,3	23,4	31,2	0,7	2,9	15,5	0,2
Colombia	25,2	29,9	0,8	15,5	11,7	1,3	20,7	27,3	0,8	23,5	22,4	1,0	-8,1	4,7	-1,7	7,4	18,3	0,4
Congo	41,3	26,6	1,6	4,6	62,6	0,1	-19,1	-1,9	10,1	-30,9	3,2	-9,6	28,9	13,1	2,2	79,6	23,7	3,4
Democratic Republic of Congo	2,0	-7,3	-0,3	-1,0	9,6	-0,1	-4,9	-0,3	14,5	-17,3	-31,4	0,6	1,2	-18,2	-0,1	1,2	21,6	0,1
Costa Rica	37,6	29,1	1,3	-12,2	0,1	####	39,3	28,1	1,4	72,4	30,9	2,3	15,0	27,2	0,6	37,1	22,1	1,7
Côte d'Ivoire	159	22,5	7,1	-30,4	1,3	-23,0	-28,6	6,0	-4,8	11,5	7,6	1,5	10,9	16,7	0,7	10,3	0,5	21,0
Croatia										-14,5	-27,6	0,5	26,7	18,3	1,5	25,8	25,6	1,0
Cuba	1,2	17,5	0,1	39,3	50,7	0,8	-33,1	-1,0	32,8	-58,3	-30,6	1,9	12,0	25,6	0,5	-4,8	6,2	-0,8
Cyprus	73,6	75,4	1,0	47,8	31,0	1,5	53,7	39,9	1,3	20,1	24,6	0,8	27,5	20,4	1,4	20,6	16,2	1,3
Czech Republic	2,7	11,3	0,2	-2,5	5,0	-0,5	7,9	8,2	1,0	2,1	-4,7	-0,5	73,4	7,6	9,6	40,6	19,6	2,1
Denmark	0,0	14,6	0,0	15,4	14,3	1,1	9,8	7,3	1,3	23,0	12,2	1,9	-0,7	15,1	0,0	-0,2	6,9	0,0
Dominican Republic	6,0	29,2	0,2	8,8	9,9	0,9	34,1	15,0	2,3	44,2	22,5	2,0	68,1	45,6	1,5	-12,8	18,3	-0,7
Ecuador	71,1	29,3	2,4	32,1	7,1	4,5	24,3	14,4	1,7	15,6	14,1	1,1	20,5	4,8	4,3	12,6	28,6	0,4
Egypt	99,7	59,6	1,7	43,3	38,5	1,1	27,7	22,9	1,2	36,0	18,0	2,0	32,8	29,0	1,1	-1,1	20,4	-0,1
El Salvador	12,5	-0,2	-79,8	16,7	-13,1	-1,3	29,5	10,7	2,8	65,4	35,0	1,9	20,9	16,2	1,3	15,1	11,4	1,3
Eritrea													-70,1	4,3	-16,3	-8,7	19,2	-0,5
Estonia										-43,3	-29,7	1,5	18,4	31,1	0,6	24,8	44,2	0,6
Ethiopia	21,7	11,5	1,9	20,2	-6,0	-3,3	47,5	25,8	1,8	30,9	0,3	107	3,6	25,4	0,1	63,9	27,7	2,3
Finland	28,7	16,1	1,8	7,6	14,3	0,5	26,7	17,8	1,5	-8,3	-3,7	2,2	14,9	26,2	0,6	4,9	13,1	0,4

France	13,7	17,2	0,8	0,2	10,5	0,0	22,0	17,1	1,3	8,5	6,3	1,3	12,3	14,8	0,8	-0,3	7,7	0,0
Gabon	127	-7,3	-17,4	24,0	12,9	1,9	-3,2	6,0	-0,5	61,7	16,2	3,8	16,5	8,7	1,9	-8,0	8,9	-0,9
Georgia										-72,9	-71,8	1,0	-15,8	32,8	-0,5	61,4	42,1	1,5
Germany	18,7	18,0	1,0	2,1	7,0	0,3	19,0	17,6	1,1	5,6	11,5	0,5	5,1	10,4	0,5	-7,5	3,2	-2,3
Ghana	-2,0	4,8	-0,4	-8,2	-2,1	3,8	28,9	26,5	1,1	27,0	23,3	1,2	43,9	23,5	1,9	23,0	27,9	0,8
Gibraltar	-28,1	9,4	-3,0	102,2	11,4	8,9	59,1	15,4	3,8	97,3	8,9	10,9	19,9	18,4	1,1	13,1	12,1	1,1
Greece	57,7	22,7	2,5	22,4	0,7	32,7	44,6	6,4	7,0	19,3	6,4	3,0	7,6	18,5	0,4	1,1	23,6	0,0
Guatemala	23,0	32,1	0,7	-5,9	-5,5	1,1	27,3	15,4	1,8	49,6	23,3	2,1	37,0	21,4	1,7	16,1	13,3	1,2
Haiti	52,2	31,9	1,6	-2,9	-4,9	0,6	44,1	0,9	49,3	16,3	-22,2	-0,7	38,6	12,6	3,1	13,9	-1,8	-7,8
Honduras	21,8	41,5	0,5	31,3	8,8	3,5	23,9	16,7	1,4	55,0	19,0	2,9	20,1	16,1	1,2	4,9	19,2	0,3
Hong Kong (China)	55,2	76,2	0,7	9,4	31,3	0,3	73,5	41,5	1,8	62,4	31,2	2,0	27,4	18,7	1,5	24,5	23,2	1,1
Hungary	12,8	19,2	0,7	-7,1	9,1	-0,8	8,7	2,6	3,3	-13,9	-11,3	1,2	24,8	21,7	1,1	30,4	23,6	1,3
Iceland	7,7	35,7	0,2	26,8	11,9	2,2	33,8	17,1	2,0	1,1	1,3	0,8	31,3	26,3	1,2	2,4	22,8	0,1
India	10,6	16,6	0,6	19,2	29,8	0,6	22,8	35,3	0,6	28,1	28,9	1,0	-11,2	32,5	-0,3	8,4	40,0	0,2
Indonesia	48,4	46,4	1,0	15,8	31,5	0,5	55,2	41,1	1,3	50,1	46,0	1,1	25,8	3,5	7,3	18,5	25,9	0,7
Islamic Republic of Iran	6,1	-13,4	-0,5	50,7	21,1	2,4	11,7	1,3	9,0	42,0	18,2	2,3	28,9	21,9	1,3	37,2	30,9	1,2
Iraq	110	50,4	2,2	55,9	-36,0	-1,6	23,6	-46,7	-0,5	-0,2	-61,7	0,0	12,9	105	0,1	30,0	-26,3	-1,1
Ireland	22,8	24,9	0,9	-4,7	13,4	-0,4	16,8	25,9	0,6	22,2	25,4	0,9	69,9	58,9	1,2	22,1	28,8	0,8
Israel	16,5	20,6	0,8	14,9	15,7	1,0	16,3	23,5	0,7	33,5	37,0	0,9	14,2	24,7	0,6	-2,7	10,1	-0,3
Italy	17,4	24,3	0,7	7,5	8,7	0,9	16,2	16,7	1,0	10,2	6,5	1,6	7,6	9,9	0,8	6,8	3,2	2,1
Jamaica	-28,8	-15,2	1,9	-1,6	2,0	-0,8	29,0	27,6	1,1	23,1	21,4	1,1	27,4	-0,1	####	8,8	8,8	1,0
Japan	3,9	23,9	0,2	-4,2	16,5	-0,3	27,5	26,4	1,0	18,6	7,8	2,4	2,8	4,9	0,6	-1,5	7,4	-0,2
Jordan	76,0	108	0,7	35,5	28,9	1,2	13,1	-5,5	-2,4	11,3	40,9	0,3	17,9	17,1	1,0	36,0	34,9	1,0
Kazakhstan										-42,0	-38,6	1,1	-44,4	13,1	-3,4	-25,2	63,8	-0,4
Kenya	3,8	35,9	0,1	0,8	13,2	0,1	12,8	31,5	0,4	0,2	8,2	0,0	-3,4	11,2	-0,3	27,8	19,2	1,4

Dem. People's Republic of Korea	97,8	72,4	1,4	-17,3	60,0	-0,3	2,0	19,2	0,1	-46,1	-21,5	2,1	-32,4	-11,2	2,9	-23,7	-3,0	7,9
Korea	103	39,8	2,6	44,4	45,7	1,0	120	58,4	2,0	92,3	45,6	2,0	14,7	23,9	0,6	15,5	24,7	0,6
Kuwait	26,0	5,8	4,5	-27,0	-21,0	1,3	-38,1	-15,2	2,5	75,4	83,8	0,9	2,9	9,9	0,3	35,3	38,3	0,9
Kyrgyzstan										-75,4	-49,3	1,5	-29,5	31,3	-0,9	93,6	20,0	4,7
Latvia										-46,4	-42,9	1,1	-12,3	31,8	-0,4	69,7	47,7	1,5
Lebanon	6,6	-15,1	-0,4	10,0	39,9	0,2	-23,4	-43,1	0,5	138	77,9	1,8	-9,3	12,5	-0,7	2,1	20,6	0,1
Libya	75,6	57,2	1,3	24,7	-34,8	-0,7	1,3	-26,0	0,0	51,4	14,1	3,6	15,2	6,7	2,3	3,7	25,8	0,1
Lithuania										-43,4	-42,0	1,0	-2,5	22,8	-0,1	36,7	44,4	0,8
Luxembourg	46,1	11,9	3,9	20,8	13,1	1,6	69,4	43,4	1,6	29,8	21,4	1,4	44,4	34,7	1,3	46,0	16,3	2,8
FYR of Macedonia										25,3	-21,2	-1,2	10,1	15,7	0,6	-3,7	7,2	-0,5
Malaysia	21,9	50,6	0,4	41,0	28,2	1,5	58,1	39,3	1,5	42,4	57,2	0,7	54,2	26,4	2,1	24,9	24,5	1,0
Malta	30,4	72,5	0,4	-41,7	8,7	-4,8	117	34,8	3,4	40,8	30,6	1,3	-19,6	24,9	-0,8	-4,7	0,1	-32,0
Mexico	60,1	38,0	1,6	5,4	10,1	0,5	22,6	8,7	2,6	11,7	7,9	1,5	9,8	30,4	0,3	23,0	9,5	2,4
Republic of Moldova										-58,4	-59,9	1,0	-48,6	-11,3	4,3	59,6	40,4	1,5
Mongolia							24,2	44,3	0,5	-42,9	-13,3	3,2	15,9	15,0	1,1	19,6	30,5	0,6
Morocco	29,0	30,5	1,0	-6,7	17,6	-0,4	-39,2	24,1	-1,6	19,3	4,7	4,1	13,3	19,2	0,7	10,6	22,7	0,5
Mozambique	12,3	2,3	5,4	-51,6	-22,2	2,3	165	30,5	5,4	-3,7	13,1	-0,3	21,5	46,5	0,5	21,9	52,8	0,4
Myanmar	39,9	35,9	1,1	-1,0	26,6	0,0	-29,3	-10,2	2,9	102	32,1	3,2	30,1	50,2	0,6	13,8	55,6	0,2
Namibia													63,9	18,8	3,4	44,9	24,0	1,9
Nepal	122	12,3	9,9	35,0	27,0	1,3	44,4	24,6	1,8	87,2	29,2	3,0	35,6	26,5	1,3	-2,0	15,6	-0,1
Netherlands	0,1	13,7	0,0	-1,6	5,8	-0,3	21,0	17,9	1,2	11,5	10,9	1,1	16,8	21,9	0,8	16,8	5,9	2,8
Netherlands Antilles				-17,9	-5,2	3,4	-16,0	6,0	-2,7	7,6	16,5	0,5	0,9	-1,2	-0,7	6,9	4,9	1,4
New Zealand	6,1	-2,9	-2,1	2,3	17,0	0,1	27,9	2,9	9,5	22,1	16,5	1,3	10,4	13,5	0,8	16,4	19,0	0,9
Nicaragua	-2,1	-19,2	0,1	-8,6	3,2	-2,7	-3,5	-15,5	0,2	41,5	9,2	4,5	31,0	26,8	1,2	-3,3	10,0	-0,3

Nigeria	139	21,2	6,6	3,0	-14,3	-0,2	-13,2	29,8	-0,4	12,5	13,1	1,0	55,8	16,3	3,4	26,1	31,4	0,8
Norway	0,3	25,3	0,0	11,9	16,8	0,7	21,2	8,9	2,4	9,0	20,8	0,4	5,9	19,3	0,3	6,3	10,7	0,6
Oman	-41,5	29,7	-1,4	24,4	103	0,2	24,3	16,5	1,5	1,9	33,0	0,1	26,9	18,1	1,5	40,4	15,4	2,6
Pakistan	73,0	35,1	2,1	27,3	38,8	0,7	34,6	32,5	1,1	43,9	25,4	1,7	25,4	17,4	1,5	8,3	26,5	0,3
Panama	-4,7	19,2	-0,2	5,0	18,5	0,3	9,4	-3,3	-2,9	50,0	30,6	1,6	19,5	25,5	0,8	29,8	22,5	1,3
Paraguay	122	69,0	1,8	9,7	8,6	1,1	31,5	21,0	1,5	79,8	19,8	4,0	-4,1	-2,6	1,6	9,3	11,3	0,8
Peru	5,8	12,0	0,5	-4,2	1,6	-2,6	9,4	-9,2	-1,0	28,0	30,6	0,9	7,8	13,1	0,6	8,9	22,6	0,4
Philippines	-12,1	34,2	-0,4	-10,5	-6,2	1,7	45,4	26,0	1,7	144	11,3	12,7	30,0	21,3	1,4	19,2	24,3	0,8
Poland	-7,6	4,3	-1,8	-14,3	0,9	-16,4	-14,0	-1,5	9,1	4,8	11,4	0,4	22,1	30,1	0,7	26,1	15,7	1,7
Portugal	10,7	28,2	0,4	4,5	4,5	1,0	38,9	31,8	1,2	22,6	8,8	2,6	34,9	22,2	1,6	6,1	3,3	1,9
Qatar	112	16,3	6,8	16,5	-15,7	-1,1	21,6	-1,4	-15,1	31,7	15,3	2,1	24,9	74,5	0,3	107	33,0	3,3
Romania	-20,6	44,1	-0,5	-37,8	17,6	-2,1	190	-8,7	-21,9	-29,6	-10,2	2,9	13,6	-6,2	-2,2	25,0	31,9	0,8
Russia										-38,2	-37,9	1,0	-1,2	8,3	-0,1	16,6	34,7	0,5
Saudi Arabia	9,7	39,7	0,2	111	-20,8	-5,3	-20,9	18,4	-1,1	6,8	14,1	0,5	11,2	10,2	1,1	21,5	18,9	1,1
Senegal	-29,0	5,4	-5,3	-29,6	16,0	-1,9	-14,7	17,1	-0,9	3,1	7,7	0,4	67,4	24,0	2,8	15,4	25,9	0,6
Serbia and Montenegro										-42,1	0,3	####	-15,0	0,3	-53,9	174	30,2	5,8
Singapore	50,8	50,3	1,0	5,9	36,2	0,2	101	50,2	2,0	11,8	52,8	0,2	48,1	35,7	1,3	31,5	21,0	1,5
Slovak Republic	-13,7	11,3	-1,2	-25,7	8,1	-3,2	51,5	7,2	7,2	-4,4	-8,7	0,5	5,8	19,8	0,3	59,7	25,2	2,4
Slovenia										44,5	-3,3	-13,5	-7,6	24,0	-0,3	21,8	18,4	1,2
South Africa	-19,1	16,5	-1,2	-2,9	7,0	-0,4	19,1	8,6	2,2	28,6	4,4	6,5	0,6	14,7	0,0	14,0	20,2	0,7
Spain	24,0	10,2	2,3	2,0	7,2	0,3	45,6	24,6	1,9	12,6	7,8	1,6	33,6	22,3	1,5	22,2	17,2	1,3
Sri Lanka	22,0	29,2	0,8	8,2	27,4	0,3	7,6	18,4	0,4	29,1	30,1	1,0	28,6	27,8	1,0	4,9	20,4	0,2
Sudan	7,9	12,4	0,6	19,4	3,4	5,7	36,6	23,6	1,6	-28,0	28,3	-1,0	6,2	35,8	0,2	55,5	35,4	1,6
Sweden	3,3	6,8	0,5	3,0	9,8	0,3	12,5	13,2	0,9	10,2	3,4	3,0	9,1	17,2	0,5	10,3	12,3	0,8
Switzerland	14,3	8,7	1,6	14,3	7,8	1,8	24,2	15,4	1,6	2,7	0,4	6,8	17,2	10,5	1,6	-5,4	5,5	-1,0

Syria	42,8	38,2	1,1	33,3	15,5	2,2	23,8	7,5	3,2	18,7	46,6	0,4	9,2	12,0	0,8	-10,1	21,4	-0,5
Tajikistan										94,9	-62,0	-1,5	-32,5	0,2	####	66,3	57,6	1,2
United Republic of Tanzania	-1,0	15,5	-0,1	-13,3	5,0	-2,7	16,5	31,9	0,5	16,2	9,3	1,7	28,7	22,1	1,3	-13,5	39,3	-0,3
Thailand	33,3	46,8	0,7	45,7	30,4	1,5	90,3	63,3	1,4	65,4	51,2	1,3	-4,3	2,3	-1,9	30,8	27,7	1,1
Togo	29,2	26,3	1,1	-25,8	-1,7	15,1	126	13,1	9,6	-1,9	0,3	-5,6	0,0	23,6	0,0	37,3	13,0	2,9
Trinidad and Tobago	50,2	46,2	1,1	23,8	-10,8	-2,2	3,1	-10,7	-0,3	16,1	7,1	2,3	25,2	27,3	0,9	15,9	44,5	0,4
Tunisia	42,1	36,0	1,2	9,0	22,8	0,4	22,4	15,6	1,4	27,3	20,9	1,3	23,0	31,4	0,7	7,2	24,4	0,3
Turkey	0,6	12,4	0,0	19,8	26,8	0,7	43,7	31,1	1,4	27,3	17,1	1,6	3,2	21,4	0,1	16,2	23,6	0,7
Turkmenistan										-43,5	-37,7	1,2	41,7	22,4	1,9	18,3	93,9	0,2
Ukraine										-45,7	-52,0	0,9	-18,1	-9,5	1,9	16,6	44,5	0,4
United Arab Emirates	571,6	108	5,3	57,2	-12,8	-4,5	92,1	12,4	7,4	40,7	18,2	2,2	-3,2	28,8	-0,1	17,4	47,5	0,4
United Kingdom	10,0	9,0	1,1	6,8	10,3	0,7	25,7	17,3	1,5	3,0	8,6	0,4	10,3	17,0	0,6	5,6	12,8	0,4
United States	8,8	19,9	0,4	1,3	17,2	0,1	13,9	17,4	0,8	7,5	13,0	0,6	11,3	22,5	0,5	4,7	12,6	0,4
Uruguay	2,2	24,9	0,1	-13,8	-17,5	0,8	14,7	20,9	0,7	79,7	21,3	3,7	0,9	11,0	0,1	3,8	4,6	0,8
Uzbekistan										26,5	-18,9	-1,4	42,3	20,8	2,0	-13,0	30,1	-0,4
Venezuela	21,2	12,8	1,7	1,1	-4,6	-0,2	6,8	13,7	0,5	14,7	18,5	0,8	0,9	3,8	0,2	29,1	12,1	2,4
Vietnam	-59,7	5,7	-10,5	48,0	37,9	1,3	45,2	26,3	1,7	79,1	48,3	1,6	48,8	39,9	1,2	87,6	43,4	2,0
Yemen	121	75,3	1,6	-1,5	42,9	0,0	17,7	18,0	1,0	-16,2	31,0	-0,5	11,8	30,8	0,4	36,7	17,8	2,1
Zambia	25,3	1,9	13,5	-21,1	2,4	-8,8	11,6	8,3	1,4	-6,2	-6,9	0,9	-5,6	14,9	-0,4	25,9	26,3	1,0
Zimbabwe	-10,8	7,6	-1,4	7,3	23,1	0,3	5,0	25,0	0,2	7,8	6,1	1,3	-9,2	3,5	-2,6	-42,7	-25,0	1,7
Other African countries	45,7	13,0	3,5	-7,2	7,7	-0,9	43,3	7,7	5,6	10,6	4,5	2,3	21,4	28,9	0,7	11,1	24,3	0,5
Other Latin American countries	45,4	26,3	1,7	-19,9	5,5	-3,6	-10,4	33,2	-0,3	10,0	6,1	1,6	75,4	21,2	3,6	12,8	10,4	1,2
Other Asian countries	34,0	12,5	2,7	36,0	15,1	2,4	-4,9	15,5	-0,3	-13,6	1,5	-9,1	17,5	8,7	2,0	8,1	20,5	0,4
Former Yugoslavian countries	6,9	34,6	0,2	-0,9	1,8	-0,5	5,9	-8,7	-0,7	-16,3	-14,2	1,1	8,2	29,8	0,3	50,9	22,9	2,2

Recent FFRC eBOOKS

15/2011	Lakkala, Hanna & Vehmas, Jarmo (eds): Trends and Future of Sustainable Development. Proceedings of the Conference "Trends and Future of Sustainable Development", 9–10 June 2011, Tampere, Finland.
14/2011	Heinonen, Sirkka – Kurki, Sofi & Ruotsalainen, Juho: Kohtaamisten kuunsillalta voimaantumisen valtamerelle. Luova tulevaisuustila -pilotti Helsingin kaupunginkirjastossa.
13/2011	Heinonen, Sirkka – Hietanen Olli & Ruotsalainen, Juho: Mustat joutsenet Turun kulttuuripääkaupungissa. 27.5.2011 ja 3.11.2011 pidettyjen Tulevaisuusklinikoiden raportti.
12/2011	Heinonen, Sirkka – Kurki, Sofi – Laurén, Leena-Maija & Ruotsalainen, Juho: Elämykselliseen yhteisöllisyyteen. Elävä esikaupunki -hankkeen tulevaisuusklinikka "Perspective" 27.10.2011.
11/2011	Kauppinen, Veli-Matti – Kaivo-oja, Jari & Aho, Samuli: Building The Future Of European Life-Long Learning Strategies and Policies: Defining Critical Key Drivers Of Lifelong Learning In Europe.
10/2011	Myllylä, Yrjö – Sajeva, Maurizio - Kaivo-oja, Jari & Aho, Samuli: iKnow Delphi 2.0/National Survey – Country Report Finland. iKnow Project – Word Package 5. www.iknowfutures.eu.
9/2011	Nurmi, Timo – Vähätalo, Mikko & Saarimaa, Riikka: Magneettiteknologiaklusteri 2020.
8/2011	Kaivo-oja, Jari: Futures of Innovation Systems: Towards Better Innovation Quality With New Innovation Management Tools.
7/2011	Lauttamäki, Ville (ed./toim.): Peeks into the Future – Kurkistuksia tulevaisuuteen. Stories of Possible Futures Written for massidea.org. Kooste massidea.org sivustolle syötetyistä tulevaisuustarinoista.
6/2011	Hoffrén, Jukka – Kaivo-oja, Jari & Aho, Samuli: Erään keskeisen tulevaisuuden yhteiskuntapoliittisen päätöksenteon ja seurantamittarin lähtökohdat. Yhteenveto BKT:n käsitteellisestä ja teoreettisesta kritiikistä.
5/2011	Auffermann, Burkhard & Kaskinen, Juha (editors): Security in Futures – Security in Change. Proceedings of the Conference "Security in Futures – Security in Change", 3–4 June 2010, Turku, Finland.
4/2011	Heinonen, Sirkka – Keskinen, Auli & Ruotsalainen, Juho: RIIHI – radikaalit innovaatiot ilmastonmuutoksen hillitsemiseksi. RIIHI-tulevaisuusklinikan tulokset.

FFRC eBOOK 1/2012

Nufar Finel & Petri Tapio

DECOUPLING TRANSPORT CO_2 FROM GDP

ISBN 978-952-249-135-0
ISSN 1797-1322

FINLAND FUTURES RESEARCH CENTRE

Turun yliopisto
University of Turku