Understanding Key Drivers for Road Freight Transport Decoupling in Europe

Final report

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1. Any errors remain those of the authors. The findings, interpretations and conclusions presented in this paper are entirely those of the authors and should not be attributed in any manner to the European Investment Bank.
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1. INTRODUCTION

Transport is essential for economic development, but it also causes a wide range of externalities. As a consequence of that, one of the main challenges for policy makers in Europe over the last few decades has been to reconcile economic growth with sustainable social and environmental conditions. Emissions of greenhouse gases from transportation, especially from road transport, are contributing to cause global warming which is likely to produce more natural disasters with negative consequences for the society. This trend has been stressed by the rise of transport congestion especially in urban areas.

Past trends indicated that for decades the European transport system has been moving away from sustainability. This fact resulted crucial to emphasize the need for actions aimed at reaching certain transport sustainability targets at both national and European levels. This challenge, taken up by the European Union (EU), has been seeking to increase transport efficiency through the full internalization of negative side-effects of transport (European Commission 2001a).

With this aim in mind, the EU has been promoting some policy measures to reduce the road freight transport-related externalities (European Commission 2003) by, for instance, transferring some freight traffic volumes from the road to more competitive and efficient modes. Such type of measures are necessary because, despite certain disparities among countries, there are still common features regarding freight transport in Europe like the great modal share of the road compared to other modes.

Among the proposal of other measures, one of the key challenges for implementing this strategy has been the promotion of the decoupling of road transport growth from economic development in order to mitigate the environmental impacts of transport caused by economic growth (OECD 2006a). The concept of decoupling has been widely treated in institutional documents and discussed in the White Paper European Transport Policy for 2020: Time to
Decide (European Commission 2001b), understanding it as an opportunity for boosting sustainable development.

It is worth noting that, last decades, decoupling has increased in some countries over the last few decades due to the current transition to more service-oriented economies and the restructuring of the economies. Such structural changes could be evaluated by using an economic model like the provided by Input-Output (IO) data, as this approach makes it possible to consider both the structural relationships of production and the evolution of the economies over time.

On the other hand, as it will be seen in the contents of this document, decoupling may be also stimulated by policies that promote either improvements in logistics management or modal transfer to cleaner modes such as rail and maritime transport.

The impact of such measures and changes should be evaluated to define their importance in the promotion of decoupling trends. Therefore, this research intends to analyse the key drivers explaining decoupling between GDP and road freight transport growth across the EU and quantify how they have contributed to past road transport trends. It is clear that road transport volumes are influenced by a wide range of factors —economic, structural, functional, operational and so on— but there is still room to define the importance of each one of these factors on the final demand in each country. This knowledge is crucial to understand the potential of decoupling in the EU and of achieving sustainable development.

Thus, this project is developed to look into this question in greater depth in order to identify the most appropriate decoupling policy measures applicable in those countries where road freight transport is still growing at a pair with GDP. To that end, this has the following specific objectives:

(1) Identify the set of variables influencing road freight transport demand in European countries such as economic growth, productive structure or logistic approaches, among others.

(2) Analyse freight transport trends in some European case studies by using an IO approach together with data about freight transport by commodity. This analysis is based on the variables previously identified.

(3) Shed some light on the different levels of decoupling that have appeared among European countries by quantifying the contributions of all key drivers that should be considered in determining the road freight transport volumes.
Lay the foundations of a model that would be able to predict how some policies or economic changes would affect road freight transport evolution. This objective is achieved by establishing the observed links between the key drivers of road transport.

Use the results and conclusions obtained from the research to outline policy guidelines for promoting decoupling trends in the EU.

In order to meet these goals, this research project is developed according to a methodological framework showed in following figure. As seen, it consists of four phases subdivided in different tasks.

**Figure 1.1. Methodological framework of the Research Project**

The report is structured as follows. After this introduction, Chapter 2 contains the *State of knowledge and practice*. After conducting a review of the current transport trends and policies in Europe in Section 2.1, Section 2.2 summarizes the previous studies that have analysed the link between transport and the economy and also the decoupling issue. In the next sections
the methods and indexes used in this type of analysis are highlighted, such as the index “road freight transport intensity” —Section 2.3—, and possible policy measures that may contribute to decoupling trends are identified—Section 2.4—. After that, Chapter 3 shows a detailed description of the Input-Output model that will be used in this research. Chapter 4 describes the Methodological approach and the analysis methods that are applied to three case studies: Spain, Poland and the UK. The main graphical and numerical results are shown and also discussed. Finally, Chapter 5 summaries the main findings of this project and provide some policy guidelines to promote decoupling in the EU Member States.
2. ECONOMY AND TRANSPORT

2.1. State of play of EU transport issues

2.1.1. A brief overview about the European Transport Policy

The management of transport market involves multiple issues like rail, road, waterways, and combined transport, environment, sustainability, social costs, international transport, infrastructure needs, people with reduced mobility, road safety, traffic management, road traffic information and new communications technologies.

Within this context, for a long time European transport policy has been focused on promoting higher degrees of efficiency in the flows of transport — for both freight and passengers— for successfully developing of economies while reducing environmental threats and enhancing the social welfare.

Transport policies in the EU were assigned with a high priority through the Common Transport Policy defined in the Treaty of Rome (1957). This Treaty made clear that in transport, as in any other sector, the main concern should be to remove border charges, duties and discriminations between Member States. In that way, those measures would contribute to the free movement of individuals, enterprises and goods by the realization of a common market among Member States.

In 1992, the Treaty of Maastricht reinforced the political, institutional and budgetary foundations for transport policy, among other things. In addition, it included the concept of
the trans-European network contributing to come up with a plan for the development of transport infrastructure at European level with the help of Community funding.

In this same year, the first White Paper of the common transport policy was issued focusing on the opening-up of transport market along the lines traced in the famous 1985 White Paper “Completing the internal market”. It is worth noting that it was generally achieved except in the rail sector.

Later on, the White Paper: European transport policy for 2010: time to decide (European Commission 2001) proposed some 60 specific measures to be taken at Community Level that included an action programme with specific targets on issues like road safety, modal split and revitalization of railways (whose share – in terms of tonne-km – of the goods market fell from 21% to 8.4% between 1970 and 1998).

It is widely known that transport generates several non-negligible environmental impacts: greenhouse gases, noise, accidents, health damaging emissions (NO\textsubscript{X}, SO\textsubscript{X}, particulates, CO), and particularly road and air sectors are commonly understood as the most polluted sectors. As a consequence, one of the main goals of the 2001 White Paper was the promotion of decoupling transport growth from growth in GDP. This was also an objective of the Sustainable Development Strategy adopted in Gothenburg in June 2001, when the European Council pointed out: “a sustainable policy should tackle ... the full internalization of social and environmental costs. Action is needed to bring about a significant decoupling of transport growth and GDP growth, in particular by a shift from road to rail, water and public passenger transport”. At present, the levels of decoupling are quite differentiated by country, as countries such as Portugal, Spain, Greece, Bulgaria, Ireland, Estonia, Romania and Austria show low or zero levels, whereas Slovakia, Cyprus, Denmark, Finland, Belgium and the U.K have already started to show clear decoupling trends (Ponti et al. 2013).

The White Paper: Keep Europe moving: a transport policy for sustainable mobility ((European Commission 2006) outlines the orientation of the European Commission for the future transport policy. Together with some of the actions foreseen in the 2001 White Paper, it referred to additional instruments needed to achieve this purpose like a freight logistics action plan and an intelligent transport systems to make mobility greener and more efficient. It also promoted a debate on how to change mobility of people in urban areas; an action plan to boost inland waterways and a programme for green powering of trucks and cars.

Finally, one of the most recent documents in EU transport policy is the White paper: Roadmap to a Single European Transport Area. Towards a Competitive and Resource Efficient Transport System (European Commission 2011). This paper supported some items like the removal of
major barriers in transport systems or the cutting of carbon emissions in transport by 60% by 2050. It highlighted the necessity of developing new fuel and propulsion systems, the better use of information systems, market based incentives (like “user pays” and “polluter pays” principles) together with —once again— a modal shift from road to more friendly-environment modes.

As seen, the EU Transport Policy has provided common guidelines to the Members Sates in order to achieve a common efficient and sustainable transport system. However, it is worth noting that each member has considerable flexibility to implement these policies, so that leads to different transport patters in each one of them. This research will focus on the set of policies aimed at promoting the decoupling issue —in freight transport— and will review the state of play of some European countries in order to determine the current level of implementation of such type of policies. Within this purpose, the starting point of this task will consist on reviewing the current transport and logistics systems trends and the evidence of decoupling in Europe that have been already analysed in previous studies.

### 2.1.2. Current freight transport trends in the EU

The evolution of the freight transport market in Europe has shown different trends during last decades. Part of them has emerged after some of the treats or drafts of the institutional documents mentioned in previous section, and when looking at the most recent ones, some relevant aspects can be highlighted.

In 2008, when the economic crisis struck in the European Union, the ratio of the volume of transport relative to GDP fell cancelling the high growth recorded in previous years from 2003 to 2007. As seen in Figure 2.1, it was not until 2010 when the first increase could be observed.

![Volume of freight transport relative to GDP EU27](image)

*Source: Authors’ figure using data from Eurostat*

**Figure 2.1.** Evolution of volume of transport (tonne-kms) relative to GDE in the European Union (27 countries)
This trend is similar to the followed one by road freight transport that had accounted for a decrease of 10% between 2008 and 2009 in EU-27 and 11% fall in EU-15. In fact, the only two Member States which recorded growth in time of crisis were Poland (nearly +10%) and Bulgaria, which recorded an increase of +16% (Wrzesinska 2011).

During this period, it is important to note the notable rise in cabotage (see Figure 2.2). This was the result of a significant growth in the cabotage performed by Bulgarian hauliers, as well as the growth of Latvia’s and Poland’s. These countries have become in some of the biggest caboteurs in the EU, followed by Luxembourg, Netherlands and Germany. Thus, this suggests that the new Member States have been capable of maintaining, and even strengthening, their position on road freight market despite the global economic downturn.

![Figure 2.2. Evolution of EU-27 road freight transport (tonne-kms) between 2004 and 2009. Index 2004=100](image)

*Source: Eurostat statistics*

*Figure 2.2. Evolution of EU-27 road freight transport (tonne-kms) between 2004 and 2009. Index 2004=100*

![Figure 2.3. Modal split for inland freight transport in EU-27 between 2000 and 2012](image)

*Source: Authors’ figure based on Eurostat data*

*Figure 2.3. Modal split for inland freight transport in EU-27 between 2000 and 2012*
As Figure 2.3 shows, as a whole in last decades, road transport —that is the most energy and carbon intensive transportation mode— has become the dominant mode of transport within the European Union, accounting for a the highest share of inland freight transport (nearly 80%) compared to other modes.

However, the comparison of several countries shows some differences in the modal split (Figure 2.4):

- In some European countries road share is considerably higher than the rest of modes. This situation appears in cases like Cyprus, the UK, Ireland or Spain.
- Rail transport has a very high share in Lithuania, Latvia and Estonia and a relatively high share in other countries such as Sweden, Belgium or Germany.
- Inland navigation is very high in the Netherlands and in Bulgaria but, in contrast, there is no inland navigation at all either in countries like Sweden or in Denmark.

Source: Eurostat

Figure 2.4. Modal split for inland freight transport in 2009 by EU countries

On the other hand, looking at the importance of the different types of goods moved by road in EU, statistics show the wide differences between them depending on whether transport is measured in tonnes or tonne-kilometres. Heavy products like raw materials (sand, gravel, ores and cement) and building materials are normally transported over short distances, so they have prominence when transport is measured in tonnes. By contrast, in tonnes-kms (combining tonnage of goods with distances) food products, beverages and tobacco are the
most important groups — these products are manufactured in a limited number of production centres and then dispatched over long distances —.

It is worth noting that transport movements in all distance classes suffered a significant downturn when the crisis period arrived, with the longer distance journeys most affected, dropped by 16% below the 2006 level in 2009. Shorter distance transport also fell 9% below its 2006 level, while the middle distance transport only showed a 6% decrease of ton-kms.

In 2010, longer and middle distance transport had recovered, while on the contrary short distance transport experienced another small decline compared with 2009. This may partly due the continuing weakness of the European construction sector since 2007 that, as said before, is a major driver for transport for this distance class.

Finally, there are some aspects worth mentioning about the trends that EU Member States have followed in the use of transport resources. When the types of vehicles moved in EU countries for freight transport are analysed, it is observed that the average vehicle roads rose significantly in 2007, and began a sharp decline in 2008 which continued into early 2009 before a gradual recovery. This may be caused by, on the one hand, the general fall in construction activity in Europe, and on the other hand, the faster decrease of international transport compared to national transport in this period — overall, international transport has traditionally shown higher loads than national transport.
Moreover, there are significant differences between countries (see Figure 2.6), as higher loads has been recorded by countries with heavy products — e.g. timber for Sweden or fruits and vegetables for Spain — or with a substantial international transport performance — e.g. Lithuania.

Furthermore, the proportion of empty vehicle-kilometres in total veh-kms and its evolution over time is an important measure of the efficiency of road freight transport. In this respect, it is highlighted that for the majority of countries the rate of empty running for national transport has been twice than for international transport, and that during last years this ratio seemed to be a little lower than in the past — 24% in 2010 while 25% in 2007.

![Figure 2.6. Average vehicle loads in EU-27 countries in 2010](image-url)
2.1.3. **Main trends in European freight transport logistics**

As the demand for freight transportation services is a derived demand from production, this is strongly influenced by the organization and management of supply chains. Therefore, it is a fact that transport system evolves and adapts progressively in order to respond to the requirements imposed by the emerging new organization of logistics systems. As Woxenius and Sjöstedt (2003) argued (and it is shown in Figure 2.7), logistics and transport systems are complementary.

![Figure 2.7. Complementarity between transport and logistics systems.](image)

In recent years numerous industries have made considerable efforts to improve their logistical performance by optimizing the fleets, managing their routes, and designing logistics centres.

TRILOG-Europe project (European Commission 1999) lined out the trends initiated during 80s and 90s, which are displayed in Table 2.1. They have been driven by the combination of factors such as trade liberalisation, increase on the value of trade, trade specialisation and technology advances.

**Table 2.1. Taxonomy of logistics and supply chain trends**

<table>
<thead>
<tr>
<th>Level of logistical decision making</th>
<th>Trend</th>
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<tr>
<td>Restructuring of logistics systems</td>
<td>Spatial concentration of production and inventory</td>
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<td></td>
<td>Development of break-bulk / transhipment systems</td>
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<td></td>
<td>Creation of hub-satellite networks</td>
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*Source: Authors' figure based on Woxenius and Sjöstedt (2003)*
<table>
<thead>
<tr>
<th>Level of logistical decision making</th>
<th>Trend</th>
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<tbody>
<tr>
<td>Realignment of supply chain</td>
<td>Concentration of international trade on hub ports</td>
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<td>Rationalisation of the supply base</td>
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<td></td>
<td>Vertical disintegration of production</td>
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<td></td>
<td>Wider geographical sourcing of supplies</td>
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<td></td>
<td>Wider distribution of finished products</td>
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<td></td>
<td>Postponement / local customisation</td>
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<td></td>
<td>Increased direct delivery</td>
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<tr>
<td>Rescheduling of product flows</td>
<td>Time-compression principles applied in retail and manufacturing</td>
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<td>Increase in retailers' control over supply chain</td>
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<td>Growth of 'nominated day' deliveries and timed delivery systems</td>
</tr>
<tr>
<td>Management of distribution</td>
<td>Changes in freight modal split</td>
</tr>
<tr>
<td></td>
<td>Reduction in international transport costs</td>
</tr>
<tr>
<td></td>
<td>Impact of legislation and regulation</td>
</tr>
<tr>
<td></td>
<td>Increased use of information and communications technology</td>
</tr>
<tr>
<td></td>
<td>Developments in vehicle and handling technology</td>
</tr>
<tr>
<td>Changes in product design</td>
<td>Complexity, Packaging, Modularity</td>
</tr>
<tr>
<td></td>
<td>Globalisation, growth of E-commerce and dematerialisation of freight</td>
</tr>
</tbody>
</table>

**Source:** TRILOG-Europe project (1999)

In the last decades, a clear trend emerged aimed at concentrating production and inventory in fewer locations as a result of both a reduction in the total number of factories and greater plant specialization, based on the intensive use of economies of scale. This led to more transport-intensive logistical systems (in tonne-kms) as reducing the number of stockholding points contributed to increase the average length of haul between production and distribution centres, and between distribution centres and final consumers. This was evidenced by Kveiborg and Fosgerau (2007), who reported increasing average haulage lengths in the 1970s, 1980s and 1990s in many European countries. Nevertheless, it has been claimed that this effect is likely to have been less notable than in the past during recent years because of both the slow-down in network reconfiguration and the outsourcing of delivery processes to large companies still managing many warehouses (Crespo et al. 2006).

Furthermore, the moving to just-in-time (JIT) and quick response (QR) distribution techniques reduced the average size of deliveries. As a consequence of that, hub-satellite networks were
promoted rather than conventional systems with numerous warehouses. In this type of configuration, the hub is the focus of the system from where radial routes depart to the different geographical areas covered by the supply chain. It is worth noting that these systems may result in adding additional nodes to the supply chain increasing final tonne-kms. However, the concentration of truck flows in a determined number of routes may lead to higher load factors and vehicle size, and therefore to decreases in veh-kms.

On the other hand, the increase of direct deliveries was possible thanks to the improvements in information and communication technology (ICT), and particularly through electronic media. E-commerce has played a key role as a factor affecting new logistics systems, being supported with the centralisation of inventory mentioned above. At the same time, the electronic distribution of products like downloadable music or books is now contributing to dematerialisation and transport reductions.

Finally, worthy to mention, among the rest of things reflected in Table 2.1, that the economies of scale in terminal and vehicle operation have led to the concentration of international trade in a smaller number of hub ports and airports in Europe. The new increasing size transoceanic vessels can only operate in the largest ports such as Rotterdam, defining both the structure of international supply chain and routes of international transport in Europe.

2.2. Links between transport and the macro-economy

2.2.1. Introduction

It is widely accepted by the literature that there exist direct links between transport and the economy, and as a consequence of that belief, aggregate economic variables such as Gross Domestic Product (GDP) have been traditionally used to explain freight transport demand.

The existing methodologies applied to understand road freight transport trends look for simulating the behaviour of the multiple factors influencing transport by using mathematical models (e.g. Jong, Gunn. and Walker, 2004 and Tavasszy, 2006). However, previous studies highlight the complexity of developing such type of models, partly because of the numerous factors involved in shipping the commodities in each country (several of them explained in previous section), and partly because of that lack of available data (Elaurant and Bates, 2007).
As said before, GDP has been generally applied to forecast transport growth, and particularly road freight transport demand. This is because there has been a historical high correlation between economic development and road transport demand (Standing Advisory Comittee on Trunk Road Assessment-SACTRA, 1999). Several econometric models have proven a close correlation between tonne-kms and GDP growth in many countries (Bennathan et al., 1992). This issue, also known as coupling, has drawn a lot of attention in the literature as some countries have been gradually shown evidence of breaking this correlation during the last decades (Banister and Stead, 2002 and Gilbert and Nadeau, 2002). So, the question that arises is what is the real link between road transport demand and the economy and which are the factors driving coupling and decoupling trends.

According to Costa (1988), transport demand, particularly freight transport, is a derived demand from economic activity and the restructuring of the economy may lead to changes in the goods produced and moved, and therefore, in transport requirements. Specifically, freight activity is driven by complex and interlinked production processes and trade relationships, so analysing the freight transport in terms of both supply and demand may allow to define more realistic truck flows (Holguín-Veras and Thorson 2007).

On the other hand, recent years have seen increasing specialization, new production organization systems such as ‘just-in-time’ distribution, and an ever greater concentration of manufacturing and storage (McKinnon and Woodburn, 1996). All these factors lead to changes in transport patterns, as supply chain organization influences aspects such as transport distances or modal split (OECD, 2006).

### 2.2.2. Coupling vs. Decoupling at global level. Empirical evidence

In most industrialized countries freight transport accounts for a significant share of GDP (Crainic and Laporte, 1997), therefore GDP has been the mostly applied variable to explain freight transport trends. Indeed, the correlation between tonne-kms and GDP—that is the coupling level— is used to simulate prognosis scenarios for transport demand. However, several authors, such as McKinnon and Woodburn (1996) and Kveiborg and Fosgerau (2007), criticize this approach claiming that industrial production levels of a country define better real transport demand rather than GDP.

The subject of ‘decoupling’ has been widely treated by the literature, and particularly by institutional reports. For instance, it was the focus of the Standing Advisory Committee on Trunk Road Assessment (SACTRA) report in the United Kingdom in 1999, and has also been
discussed in political documents such as the European White Paper on transport policy in 2001 (European Commission 2001b).

Differences in national production structures and varying technological improvements in each country have led to different decoupling trends while transport demand has been growing at lower rates than GDP. It is highlighted that some countries are undergoing a transition to more service-oriented economies, and thus their economic growth has become progressively detached from road transport demand. According to Mckinnon (2007), some sectors, such as agriculture or mining, have higher transport intensities than service sectors. That is to say, they demand more tonne-kms by unit of their output. So, as services have expanded their share of total GDP, this has led to higher economic growth than in the transport sector (Åhman, 2004).

Recent studies (e.g. Banister and Stead, 2002; Gilbert y Nadeau, 2002; OECD, 2003) have analysed historical evidence for decoupling and its likely potential impact in the future. One of the most important contributions to this field has been the European programme “REIationship between DEmand for Freight-transport and Industrial Effects” – REDEFINE (NEI, 1997). This project examined road freight transport trends in five European countries between 1985 and 1995 concluding that rather than a decoupling, there had been a ‘recoupling’ of the growth of road freight transport and GDP in all but one of the case study countries (Sweden) and that these trends were likely to continue.

Other studies carried out in Japon or United States (OECD, 2003) or United Kingdom (McKinnon, 2007) showed in contrast clear decoupling trends. Banister and Stead (2002) pointed out that tonne-kms had been growing less than GDP since 1960 in US. In the UK, GDP grew by 21% between 1997 and 2005 while tonne-kms grew by only 8% in the same period (see Figure 2.1). Gilbert and Nadeau (2002) claimed that the concept of decoupling is perhaps of more concern in Europe than in North America.
A cross-sectional study of a sample of 33 countries at different stages of development undertaken by The World Bank using 1989 data demonstrated that, although the relationship between GDP and road tonne-km was extremely close (Bennathan et al., 1992), notable divergences in tonne-kms/GDP elasticity were found. For the sample of 17 developed countries (including the UK) “the partial elasticity of tonne-kms by road with respect to GDP was about 1.02, and for the rest of the sample it was about 1.28. Therefore, this research concluded that the level of development is a key factor when defining the existing link between road transport and the economy in a country.

Moreover, Schrotten and Delft (2011) argued that some important aspects explaining the differences in decoupling levels between countries or continents are the geography, the urban planning schemes, the lack of alternatives to road transport, the supply of road transport infrastructure, the fuel prices and the transport taxes.

The empirical evidence of decoupling between road freight transport and GDP has led to different studies trying to define one way of measuring the decoupling state in different countries. In that regard, one of most widespread methods, explained in detail in next section, has been the definition of the road freight transport intensity ratio.

### 2.3. A measure of the level of decoupling: Road freight transport intensity

#### 2.3.1. An essential index

Decoupling has been often studied by analysing changes in the “transport intensity” (TI) ratio since some authors, such as Banister and Stead (2002), pointed out the necessity of considering it as a measure of the “transport efficiency”.

According to Baum (2000), this may be defined, for each economic sector or industry, as a ratio that measures road transport in tonne-kilometres per unit of GDP, as is expressed in the following equation (eq. 2.1).

\[
TI_i = \frac{TK_i}{GDP_i}
\]  
(eq. 2.1)

being \( TI_i \) the transport intensity of the economic sector \( i \) in a country, \( TK_i \) the tonne-kms for the commodities produced by sector \( i \) in this country, and \( GDP_i \) the Gross Domestic Product of
that sector. It is noted that the volume of tonne-kms includes both the movement of national commodities and imported and exported goods.

The imports/exports of goods lead to an increase of transport demand, as those goods are carried along the entire supply chain network of a country from or to its borders or ports. Thus, the more accurate measure of tonne-kms for this analysis from a supply-side point of view should include commodities from national production processes together with imported goods —required all of them for intermediate industrial demand, household and government consumption and exports— (Voigtlaender, 2002).

For those cases focusing on road freight transport demand, Brunel (2005) defines “the road freight transport intensity” ratio \(\text{RFTI}\) as seen in (eq. 2.2), where \(\text{roadTK}_i\) is the number of tonne-kms made by road freight vehicles in a country.

\[
\text{RFTI}_i = \frac{\text{roadTK}_i}{\text{GDP}_i}
\]

(eq. 2.2)

Within this context, it is worth referring to different European projects that emphasize the importance of such index for analysing the link between transport and the economy. The European Union (EU) launched a strategy aimed at promoting decoupling between GDP growth and road transport demand, especially road freight transport demand, in order to reduce the negative side effects of this mode (European Commission, 2003). \(\text{RFTI}\) was then analysed to measure the decoupling level of each country.

The SACTRA report (1999) showed that road freight intensities may vary across countries. This was confirmed by Stead in 2001 after conducting a research that found out different \(\text{RFTI}\) values between 1975 and 1990 among European countries. So, he concluded that convergence of that indicator is quite unlikely in view of a number of national divergences such as economic structure, geography or land uses.

Although as seen, \(\text{RFTI}\) defined as the volume of transport related to GDP has been widely applied to analyse road freight transport demand, some authors have criticized this practice. Particularly, Banister and Stead (2002) held that although GDP provides a way of comparing economic activity in different countries, this measure has a number of limitations for explaining issues of economic restructuring. In response to this, authors such as Åhman (2004) argued that constructing sectional freight intensities based on sectors’ production —that is sectorial output— is relevant for a deeper and more accurate understanding of transport growth in an economy rather than constructing these indexes based on GDP.
This approach that uses production instead of GDP has been already applied for analysing some goods and services of the economy such as energy or water consumption (see Cosmo et al. 2012 and Alcántara and Padilla 2003). Moreover, on the basis of these examples, sectorial \( RFTI \) may be used to define global road freight transport intensity of a country as shown in (eq. 2.3.).

\[
\frac{roadTK_C}{Output_C} = \sum_{i=1}^{n} \left( \frac{roadTK_i}{Output_{i,C}} \times \frac{Output_{i,C}}{Output_C} \right)
\]  

(\text{eq. 2.3})

being \( roadTK_C \) the total tonne-kms moved in a country \( C \); \( Output_C \) the overall production in this country; \( \frac{roadTK_i}{Output_{i,C}} \) the road freight transport intensity of the sector \( i \); and finally \( \frac{Output_{i,C}}{Output_C} \) is the share of the goods produced by sector \( i \) in the total country’s production.

As said before, some sectors have higher \( RFTI \) than others, and the value of the sectorial ratios can also vary across countries and evolve over time. Such differences are due to the specific characteristics and changes of each industry or the particular features of each country. So, as the value of the sectorial \( RFTI \) partly drives the road freight transport volume in a country —and as a consequence, it partly determines the final decoupling level—, it is crucial for this research to understand the variables or factors defining both their values and their changes across the time.

In order to go further into this issue, next sections provide a detailed description of different the factors influencing both the value and the evolution of \( RFTI \)s.

\subsection*{2.3.2. Key variables driving road freight transport intensities}

When looking at the literature, different studies defining the factors driving \( RFTI \) values and their evolution across both sectors and countries are found. Nevertheless, one of the most representative works in this field has been developed by MacKinnon, together with other authors. This research is included in different reports and papers such as McKinnon and Woodburn 1996, McKinnon 2007, Piecyk and McKinnon 2009 or Piecyk and McKinnon 2010. MacKinnon identified a number of ratios, closely related to logistics, which determine \( RFTI \). Through them, it is possible to outline the amount of transport generated by a specified amount of production of an economic branch.

In case the volume of transport was measured in tonne-kms, these ratios are: the value density, the handling factor, the modal split and the average length of haul.
(1) The value density

This ratio defines the monetary value of a type of goods to their weight — i.e. \( \frac{Output_i (\$)}{tonnes_{produced,i}} \). Different categories of goods have widely different value densities — crude materials have lower value densities than manufactured products. In addition, the value density may change over time because of the emergence of new technology in production processes that may lead to increases in variety and sophistication of products — that pushes up the price of the final goods. Miniaturization and material substitution — by more durable and lighter materials — also contribute to increase value densities. Meanwhile, this ratio may be declined as a consequence of improved productivity, market liberalization, economies of scale and access to cheaper raw materials, as these factors may lead to lower prices of final products (McKinnon 2007).

(2) Handling factor

The handling factor ratio is the number of tonnes lifted per tonne produced — i.e. \( \frac{tonnes_{lifted,i}}{tonnes_{produced,i}} \) — and through it, physical weight of goods is converted into freight tonnes-lifted.

The handling requirements of goods include aspects of safety, packaging, consignment size, speed and punctuality (Steen 1998).

This ratio refers to the number of times a product is lifted between the origin and destination of the supply chain — from its production centre to the point where the good is finally consumed or used to make other manufactured product — for each type of commodity. Hence changes in the handling factor of individual goods over time are substantially influenced by logistical changes and supply chain restructuring. It is noted that the handling factor may be considered as a proxy of the number of links in a supply chain.

Complex supply chains and the need for a great flexibility in transport operations may increase the average handling factor of a country. Factors such as vertical disintegration of production, insertion of more production stages or increasing imports contribute to higher handling factors. On the contrary, developing urban-mixed areas and the reduction in warehousing, in case distribution companies chose to ship directly to customers, exert the opposite effect.

(3) Freight intensity

As Lehtonen already pointed out in 2008, there are difficulties in accessing quality, reliability and complete data about both handling factors and value densities. In view of that, it was
defined a new ratio that encompasses both of these factors. Freight intensity of a commodity group is defined as the ratio between the tonnes lifted and the value of the total production of that commodity. This is equal to the product of the inverse value density and of the handling factor for each economic sector: \( \frac{\text{tonnes}_{\text{lifted},i}}{\text{Output}_i} \) ($).

(4) Modal split

This research is focused on road freight transport, so in our case, modal split is the ratio between tonnes lifted in a commodity group that are taken by road and the total tonnes lifted by all transport modes for that commodity group — \( \frac{\text{tonnes}_{\text{lifted},\text{road},i}}{\text{tonnes}_{\text{lifted},i}} \). Differences between sectors are significant, because some commodities require greater flexibility than others, thus making shift from road to other modes, such as rail, may be more difficult. As long as customers demand more customized products, more flexible, timely and frequent carries will be necessary, hence road will be favoured. As well as more processed commodity groups within manufacturing output require more intermediate trips that are usually made by road. Instead, locating production and warehouses close to ports and railway terminals promotes the construction of intermodal freight terminals bringing competitive benefits for alternative modes of transport. Increasing road charges also contribute to change the modal split towards more sustainable transport modes.

(5) Length of haul

The average length of haul (in kms) is the ratio between tonne-kms and tonnes lifted by road for a given commodity group. It depends on the location of the different nodes of the supply chain as well as on road networks connections and their routes. Factors like spatial concentration of production and inventory and internationalization push the average length of haul up. Increasing system services and higher network densities reduce it.

On the whole, the main groups transported over longer distances are food, agricultural products, chemicals, basic metals and wood products. By contrast, products such as construction material are associated to short-distance haulages.

Thus, on the basis of these ratios, \( RFTI \), measured in \( \text{tonne} - \text{kms}_{\text{road},i} / \text{Output} \) ($), is defined through the following equation:
Understanding Key Drivers for Road Freight Transport Decoupling in Europe
State of knowledge, practice and methodology

\[
RFTI_i = \frac{\text{tonne} - \text{kms}_{\text{road},i}}{\text{Output} (\$)} =
\]

\[
= \frac{\text{tonnes}_{\text{produced},i}}{\text{Output}_i (\$)} \times \frac{\text{tonnes}_{\text{lifted},i}}{\text{tonnes}_{\text{produced},i}} \times \frac{\text{tonnes}_{\text{lifted,road},i}}{\text{tonnes}_{\text{lifted},i}} \times \frac{\text{tonne} - \text{kms}_{\text{road},i}}{\text{tonnes}_{\text{lifted,road},i}}
\]

(eq.2.4)

On the other hand, although the most usual way to express RFTI measures the relation between tonne-kms and production, this also is found in other units such as \(\text{veh} - \text{kms}_{\text{road},i}/\text{Output} (\$)\). In this case, in addition to the aforementioned ratios, RFTI depends on two extra indices related to the organization and management of transport resources.

(6) **Load factor**

This ratio defines the relation between the total tonnes carried and the loaded vehicles — \(\text{tonne}_{\text{road},i}/\text{veh}_{\text{loaded},i}\), that could also be expressed as \(\text{tonne} - \text{kms}_{\text{road},i}/\text{veh} - \text{kms}_{\text{loaded},i}\).

Loading factor depends on both the mix of vehicles (with different sizes and capacities) and the lading factor of individual vehicles, that is the ratio of actual goods moved to the maximum tonne-kms achievable if the vehicles were loaded to their maximum carrying capacity.

Spatial concentration of production and inventory may lead to higher lading factors, and thereby higher loading factor. Using larger vehicles also contribute to increase the tonnes carried with the same traffic. On the contrary, the supply of customized products may lead to lower lading factors contributing to lower the loading efficiency of road freight transport. Changes in handling systems and packaging of some products can also affect this ratio and RFTI values.

(7) **Empty running**

Empty running is the percentage of total vehicle-kilometres which are run empty. This is the ratio between total vehicle-kilometres and loaded vehicle-kilometres — \(\text{veh} - \text{kms}/\text{veh} - \text{kms}_{\text{loaded},i}\).

Reduction of empty running resulted from reasons as the improvement of load factors, that is, greater use of systems services, concentration and network design rationalization.

So, for defining \(RFTI\) in \(\text{veh} - \text{kms}_{\text{road},i}/\text{Output} (\$)\) for an economic branch, it should be considered the inverse of the load factor and the empty running value (as seen in eq. 2.5).
\[ RFTI_i = \frac{veh - km_i}{Output_i (\$)} = \frac{ton - km_{road,i}}{Output_i (\$)} \times \frac{veh - km_{loaded,i}}{ton - km_{road,i} \text{ inverse load factor}} \times \frac{veh - km_i}{veh - km_{loaded,i} \text{ empty running}} \quad (eq.2.5) \]

### 2.3.3. Factors leading to new road freight transport intensities

Figure 2.9 shows the framework that connects the economic and freight transport measures with the structural and logistics parameters described in Section 2.3.2. As already pointed out, all of these variables are influenced by a wide range of logistics-related decisions and trends, product characteristics and external factors (Piecyk and McKinnon 2010).

<table>
<thead>
<tr>
<th>Monetary value of production</th>
<th>Value density ($/tonne)</th>
<th>Product-related factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight of goods produced</td>
<td>Handling factor (tonnes_lifted/tonnes_produced)</td>
<td>Structural factors</td>
</tr>
<tr>
<td>Tonnes lifted by all modes</td>
<td>Modal split (tonnes_road_lifted/tonnes_lifted)</td>
<td>Commercial factors</td>
</tr>
<tr>
<td>Road tonnes lifted</td>
<td>Length of haul (kms)</td>
<td>Operational factors</td>
</tr>
<tr>
<td>Road tonne-kilometres</td>
<td>Load factor (tonnes/veh)</td>
<td>Functional factors</td>
</tr>
<tr>
<td>Total vehicles-kms</td>
<td>Empty running (veh_total/veh_loaded)</td>
<td>External factors</td>
</tr>
</tbody>
</table>

Source: Authors' figure based on Piecyk and McKinnon (2010)

**Figure 2.9.** Relationship between measures, key variables and determinants of road freight transport demand
Six sets of factors have a complex inter-relationship with the key freight transport variables (Piecyk and McKinnon 2010) as each set of factors exerts an influence on the key ratios driving sectorial road freight transport intensities:

- **Product-related factors** affect the nature of the transport operation and the transport requirements.
- **Structural factors** determine the number, location and capacity of factories, production and distribution centres, warehouses and other facilities in the logistics system.
- **Commercial factors** are related to supply companies’ sourcing and distribution strategies and policies that determine the way the distribution of goods is carried out.
- **Operational factors** affecting the scheduling of product flows.
- **Functional factors** are related to the management of transport resources—choice of the types of vehicle, planning of loads and routing of deliveries.
- **External factors**—such as government regulations and tax policies, macro-economic trends, market dynamics and advances/improvements in technology.

Following table provide a synthetic presentation of some examples of factors—grouped into the six aforementioned categories—affecting the key ratios related to the organization of freight operations and road freight transport demand. This reviews how those factors could vary them.

**Table 2.2. Factors affecting the key ratios driving road freight transport intensities**

<table>
<thead>
<tr>
<th>Product-related factors</th>
<th>Value density</th>
<th>Handling factor</th>
<th>Modal split</th>
<th>Length of haul</th>
<th>Load factor</th>
<th>Empty running</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing quality of goods</td>
<td>↑</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miniaturization of products</td>
<td>↑</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access to cheaper raw materials</td>
<td>↓</td>
<td>?(1)</td>
<td></td>
<td>?(1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of lighter materials</td>
<td>↑</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Adding more stages in the production chain</td>
<td>?</td>
<td>↑</td>
<td>↑</td>
<td></td>
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</tr>
<tr>
<td>Greater use of space-efficient packaging / handling equipment</td>
<td></td>
<td></td>
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<td>↑</td>
</tr>
<tr>
<td>Design of products adapted to logistical requirements</td>
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<td></td>
<td>↓</td>
</tr>
</tbody>
</table>
### Structural factors

<table>
<thead>
<tr>
<th></th>
<th>Value density</th>
<th>Handling factor</th>
<th>Modal split</th>
<th>Length of haul</th>
<th>Load factor</th>
<th>Empty running</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial concentration of production and inventory</td>
<td></td>
<td></td>
<td>↑</td>
<td>↑</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development of urban consolidation centres</td>
<td></td>
<td>↓</td>
<td>↓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relocation of production centres and warehouses</td>
<td></td>
<td>↓(↑)[2]</td>
<td>↓</td>
<td></td>
<td>↓(↑)</td>
<td></td>
</tr>
<tr>
<td>Load consolidation (hub-satellite networks, reduction of warehouses)</td>
<td></td>
<td>↓</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td></td>
</tr>
<tr>
<td>Concentration of international trade on hub ports</td>
<td></td>
<td>↓</td>
<td>↓</td>
<td>↑</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical disintegration of production</td>
<td>↑</td>
<td>↑</td>
<td></td>
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</tr>
</tbody>
</table>

### Commercial factors

<table>
<thead>
<tr>
<th></th>
<th>Value density</th>
<th>Handling factor</th>
<th>Modal split</th>
<th>Length of haul</th>
<th>Load factor</th>
<th>Empty running</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improving productivity</td>
<td>↓</td>
<td></td>
<td>↓?</td>
<td></td>
<td>↑</td>
<td></td>
</tr>
<tr>
<td>Increases in the volumes of goods and services traded online</td>
<td>↑</td>
<td>↑</td>
<td></td>
<td></td>
<td></td>
<td>↑</td>
</tr>
</tbody>
</table>

### Operational factors

<table>
<thead>
<tr>
<th></th>
<th>Value density</th>
<th>Handling factor</th>
<th>Modal split</th>
<th>Length of haul</th>
<th>Load factor</th>
<th>Empty running</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application of JIT — Just In Time — principle</td>
<td>↑</td>
<td>↑</td>
<td></td>
<td></td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>Increase in nominated day deliverables</td>
<td>↑</td>
<td>↑</td>
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</tbody>
</table>

### Functional factors

<table>
<thead>
<tr>
<th></th>
<th>Value density</th>
<th>Handling factor</th>
<th>Modal split</th>
<th>Length of haul</th>
<th>Load factor</th>
<th>Empty running</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase in vehicle size and weight</td>
<td></td>
<td></td>
<td>↑</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of vehicle routing and scheduling systems</td>
<td></td>
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### External factors

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Understanding Key Drivers for Road Freight Transport Decoupling in Europe
State of knowledge, practice and methodology

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<th>Value density</th>
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(1) Cheaper raw materials may be located faster/closer than traditional raw materials, and using them may involve more/less intermediate journeys as it may change production processes.

(2) Locating production and warehouses close to ports and railway terminals promotes the construction of intermodal freight terminals bringing competitive benefits for alternative modes of transport. Otherwise, road share would increase.

Source: Own elaboration partly based on Lehtonen (2008) and partly on Piecyk and McKinnon (2010)

2.4. Importance of Decoupling transport policies

As previously pointed out, the EU has backed a number of policy measures to reach transport sustainability at both the national and European levels. (European Commission 2003), and one of the key tools for accomplishing this goal is to promote the decoupling of road transport growth from economic development (OECD 2006a). After conducting the literature review contained in this chapter, it is found that these policies should be targeted to achieve an efficient transport system by modifying one or several of the variables defined throughout this chapter.

As Steen already pointed out in 1998: “Decoupling strategies are not a single, easily understandable solution. They must consist of a multiplicity of individual measures which complement each other and which will take time to be implemented”.

According to McKinnon and Woodburn (1996) there are four factors, already referred to in the previous sections, which link the transport characteristics —transport volumes, transport distances and transport efficiency —to the economic system. Then, they can be considered as key factors on the basis of which decoupling measures and strategies could be designed to decrease road freight transport demand:

- The material intensity of the economy
- The spatial structure of production and consumption
Three basic strategies, which may be put into operation through different basic policy approaches — lifestyle-oriented policies, market-oriented policies and regulation-oriented policies — allow the targeting of assistance to the specific needs of modifying one or several of these factors (Figure 2.4):

- Dematerialization of the economy
- Reduction of the spatial range of material flows
- Optimization of transport organization

Dematerialization is defined as the reduction of material resources needed per unit of GDP. It involves a shift away from economies based on the increasing consumption of raw materials. As said earlier, the shift from manufacture-oriented transport-intensive economies to service-oriented economies implies less transport demand to maintain the same economic growth. Policy measures aimed at dematerializing the economy may have a reducing effect on road freight transport demand and enhance the efficiency of the remaining production processes by decreasing transport requirements (Schleicher-Tappeser, Hey and Steen 1998). Dematerialization may be the result of both structural changes and technological innovations that can contribute to improving processes and product designs by requiring fewer amounts of certain inputs to produce articles of the same quality. Therefore policies involving investment in new techniques to upgrade manufacturing processes, and new materials — lighter and more durable —, will change both backward and forward sectorial linkages in production processes and may ultimately reduce freight transport needs.

On the other hand, decoupling can be achieved by reducing RFTI that implies the other two strategies (as explained in Sections 2.3.2 and 2.3.3): reduction of the spatial range of material flows and optimization of transport organization. This is because this ratio involves different aspects such as the average distance of the trips — based on the geographical location of production and consumption poles —, the structure of the supply chain, management of the transport system, the evolution of the modal split and the use of transport resources. RFTI can be improved by both implementing logistical changes and fostering modal split. Another policy that may play a part in reducing RFTI is encouraging land-use planners to locate production and consumption hubs closer to each other. Transport distances and modes depend on the spatial organisation of the supply chains (OECD 2006a), so spatial policies may be a means of creating mixed-use areas that bring producers — and consumers — in the chain into closer proximity, thereby decreasing derived demand. The reduction in the spatial ranges of
production networks produces fewer requirements for road transport and shorter haulage lengths.

Decoupling can also be encouraged through the organisation of transport chains, with a greater shift to more efficient modes such as rail or barge. Increased investment in intermodality would favour decoupling by transferring freight to cleaner modes while improving the efficiency of transport systems. Other measures that would make these alternatives more competitive across Europe include the harmonisation of rail regulation (OECD 2004). Finally, certain tax instruments such as emission charges or road tax reforms would have the likely effect of making other transport modes more attractive to shippers.

The way transport resources are used and transport system is organized are key factors in defining the transport efficiency of a country. Apart from the measures that have been already pointed out in this section, other aspects like, for instance, the investment in new vehicle design through bigger trucks by governments, may contribute to decouple final traffic from economic growth.
Lifestyle-oriented policies

Market-oriented policies

Regulation-oriented policies

Policy approaches

Basic strategies

Key factors for decoupling

Substitution of products by services

Miniaturization

Increased durability

Enhancement of regional consumer markets

Strengthening of regional production networks

Globalization of large companies

Slowing down “deterritorialization”

Transport market organisation

Dematerialization of the economy

Material intensity of the economy

Transport volume

Spatial structure of production

Transport distance

Handling requirements

Transport efficiency

Reduction of the spatial range of material flows

Optimisation of transport organisation

Source: Authors’ figure based on Steen (1998) and (OECD 2006b)

Figure 2.10. Strategies for decoupling freight transport from economic growth
2.5. Summary and main conclusions

There exists a clear link between transport and the economy as transport plays a key role in the entire distribution process of goods in a country. Therefore, in order to define the freight transport it is essential to analyse the level of industrial production and the transactions of goods between the different economic sectors. In that regard, it is noted that the restructuring of the economy and the changes in the level of sectorial economic activity cause different changes in freight transport demand.

A global economic growth rate does not necessary lead to the same rate of transport growth. The shift from manufacture-oriented transport-intensive economies to service-oriented economies implies less transport demand to maintain the same economic growth. So, higher decoupling levels between the volume of transport and the GDP may be expected in those countries where dematerialization trends appear.

As seen in previous sections, there are several empirical evidences of decoupling between road freight transport and GDP in the EU. The different research works aimed at analysing this issue have pointed out a wide set of variables driving the different levels observed during last decades and, in that sense, road freight transport intensity appears as an essential index to be considered.

Road freight transport intensity can be defined for each sector and country by different ratios that describe the industrial processes, the supply chain networks and the transport systems. These are the value density, the handling factor, the modal split, the average length of haul, the loading factor and the empty running. The evolution of such ratios in a different way across Europe is contributing to different decoupling levels.

The literature review developed in Chapter 2 helps to identify some different factors influencing road freight transport trends. However, there is still a need for quantifying their contributions to decoupling, in order to be able to explain the current differences among countries. To fill this gap, this research will provide a new approach to analyse in detail the issue of decoupling and its likely potential in EU countries. This approach will link two types of data:

1. Economic data, taking into account the economic growth and the inter-sector relationships over time in a country.
2. Sectorial road freight transport intensities for a country.

Economic data will be taken from Input-Output tables. As seen later, the IO model, which will be explained in detail in next chapter, will be used to design the methodology of this research.
3. INPUT-OUTPUT APPROACH

3.1. Approaches for an economic analysis of transport

There are various techniques that can be used to evaluate different systems, programmes and policies from an economic point of view. Each one of them is focused on some specific targets for carrying out the economic analysis of transport sector, depending on whether it is considered: a macro, meso or a micro economic approach.

Macroeconomic methods aim at developing an overall analysis of the economic situation in a specific country or region. These instruments deal in particular with the evolution of issues such as goods, services, assets or labour within an aggregate level of markets (Bolt et al. 2004).

Macroeconomic approaches are regularly either Keynesian or Neo-classic drawing the national accounting such as Gross Domestic Product (GDP), domestic consumption or domestic employment as a measure of welfare. Most of macroeconomic assessment approaches have been focused on overall impacts by estimating effects on productivity of public capital in general, and of transport infrastructure using production functions (see for more details in Aschauer et al. 1994). Although several criticisms to these macro approaches have been devised (see for instance Holtz-Eakin y Schwartz 1995) they have had a wide development, and moreover, other different tools have been developed using Vector Auto Regression (VAR) models or econometric approaches (Sturm, Jacobsy Groote 1999; Pereira y Andraz 2010).

On the other hand, within the context of transport systems, microeconomic tools are used to analyse specific aspects through the comparison of changes either in transport costs or
transport time. There are various approaches that have been largely used such as Cost-Benefit-Analysis (CBA) —called sometimes Benefit-Cost Analysis (BCA)— Cost-Effectiveness Analysis (CEA), Multi- Criteria Analysis (MCA), Life-Cycle Cost Analysis (LCCA), and social and environmental impact methods, among others. (Some examples can be seen in De Rus, 2011 or in Bekir Bartin, 2011).

The OECD (2002) acknowledges that microeconomic analysis is the most appropriate approach to define the optimal balance between profitability and investment in transport. By contrast, the macro level should be used to evaluate the long-term effects on the transport systems not covered by micro tools. It is worth noting that transport policy assessment procedures through traditional microeconomic and macroeconomic perspectives have been largely documented and well known. However, alternative assessment tools through the mesoeconomic framework are growing in order to evaluate effects not captured in those two conventional tools.

The mesoeconomic approach is considered as the intermediate level between macro and micro analysis (SEAGA 2003), in which the economic system is described considering the market relations and sectorial economic agents. Furthermore, this level of aggregation is flexible since it assists to move from macroeconomic to microeconomic level determining how macro level policies are translated into micro level by disaggregating down markets according to characteristics, regions and time horizons.

The mesoeconomic approach has been accepted as a valuable tool for policy analysis. In this sense, these type of analysis is another useful way to approach the assessment of infrastructure and transport policies because this analysis allows a high degree of disaggregation and representation of the economy through Input-Output (IO) analysis, and Spatial Computable General Equilibrium (SCGE) analysis (see for instance Haimesy Jiang (2001) y Bröcker y Mercenier (2009)).

This research project is focused on analysing the evolution of road freight transport demand taking into account, among other issues, the economic situation of each country. Therefore, this aim could be initially dealt from a macroeconomic perspective by using the aforementioned IO model. Ten Raa (2005) held that this model partly has a macroeconomic character but it also has a rigorous ground on micro techniques based on both production and consumption. As a consequence IO method has been sometimes defined as a mesoeconomic tool.

The IO methodology is based on the structural relationships of production over time and it allows measuring economic impacts on either a specific industry or macro level. The level of
disaggregation of the IO data provides a way to analyse road freight transport demand linking that with the economic structure of a country.

In order to provide a detailed description of this method, this chapter is structured as follows. Section 3.2 explains the sources and the conventional structure of an IO table and its main components. After that, Section 3.3 shows the alternative analysis that can be addressed through IO techniques. In Section 3.4, a description of the basic IO framework and the simplest models are provided, and finally, in Section 3.5 some extensions and more sophisticated IO methods that may be useful for carrying out this research are highlighted.

### 3.2. Source and basis of the Input-Output tables

The IO method consists on an economic model developed by Wassily Leontief in the 1930s. (Leontief 1936). This approach is aimed at analyzing the economic structure of a particular region or country by building a table that compiles economic data for a specific period of time—this is usually annual data. The fundamental information used concerns the monetary transactions between industries. These ones represent the flows of products from each sector (as producer/seller) to the rest of sectors of the economy (as a purchasers/buyers) (Pulido and Fontela 1993).

The term interindustry analysis is used within this context since the fundamental purpose of the IO framework is to analyse the interdependence of industries in an economy. The rows of such a table describe the distribution of a producer’s output ($Z$) throughout the economy. The columns describe the composition of inputs required by a particular industry to produce its output. —That is to say, each cell $z_{ij}$ shows the monetary value of the transaction from each sector $i$ that acts as a producer, to each sector $j$, as consumer sectors)—. These interindustry exchanges of goods constitute the blue portion of the table depicted in Figure 3.1.

The additional columns, labelled Final Demand ($F$), record the sales by each sector to final markets, such as personal consumption purchases and sales to the federal government. They also include the export volumes of each type of goods and services ($E$).

The additional rows are labelled Value Added ($V$) and Imports ($I$). Value Added accounts for the other (non-industrial) inputs to production, such as labour, depreciation of capital and indirect business taxes. As seen later, through this measures GDP can be calculated from an income approach.
As summary, an IO table is built through diverse statistics such as government data bases, censuses and official surveys (Eurostat 2008) and shows:

1. The structure of the costs of production and income generated in the production processes of a specific geographic area (region, country, etc.).
2. The interindustry dependences.
3. The flow of goods and services produced within the national economy.
4. The flows of goods and services with the rest of the world.

Thus, an IO table can be regarded as an accounting system of a country, since interactions between market actors (productive and purchasing sectors representing industries) are characterized as an equilibrium between total supply —national production and imports—, and total demand — intermediate consumption in the production processes, household and government consumption, investment and exports.

This rule is fulfilled not only for the overall economy, but for each one of the economic sectors. That is to say, the output $Z_i$ from a producer sector $i$ (eq. 3.1) is equal to the input $Z_j$ (eq. 3.2) of the same sector acting as a consumer sector (it means if $i = j \rightarrow Z_i = Z_j$).
\[
Z_i = \sum_{j=1}^{n} z_{ij} + f_i \quad (eq.3.1)
\]
\[
Z_j = \sum_{i=1}^{n} z_{ij} + v_j + I_j \quad (eq.3.2)
\]

The IO tables provide a picture of each economy in a specific period of time. According to Schaffer (1999) four quadrants that give essential information can be identified. Quadrant I describes consumption patterns of households and such other local final users of goods and services as private investors and governments. It also includes the export column, which shows sales to other industries and consumers outside the regional economy. Quadrant II draws the interindustry structure, showing production relationships and dependences in the economy, showing the ways raw materials and intermediate goods are used to produce final outputs for selling to other industries, to ultimate consumers and to exports. Quadrant III contains incomes of primary units of the economy, including the incomes of households, the depreciation and retained earnings of industries, and the taxes paid to the government. The quadrant also includes payments to industries outside the economy for materials and intermediate goods which are imported into the region. Finally, Quadrant IV covers nonmarket transfers of the economy, since it contains the part related to savings and taxes of households, surpluses and deficits of governments and intergovernmental transfers. The quadrant also includes purchases by final-demand sectors from industries outside the region.

Source: Authors’ figure based on Schaffer (1999)

Figure 3.2. Structure of an Input-Output table.
3.2.1. GDP measurement

GDP is a measure of the economic activity in a country and is defined, from an expenditure approach, as the sum of the total value of all services and goods produced in a country in a one-year time span. As has already been said, an IO table captures both the domestic production and final consumption in a country, while also includes imports value.

Thus, from this approach IO data enable to calculate GDP on the basis of the following values taken from the table: (1) household consumption $C$, (2) gross private domestic investment $I$, (3) public investment and sales of goods and services to governments $G$ and (4) net exports — i.e. exports from a sector less the value of imports of the same goods— $E - I$.

\[
GDP = C + I + G + (E - I) \tag{eq.3.3}
\]

On the other hand, from an income approach, GDP is defined as the sum of gross value added ($V$) by all resident producers in the economy plus any product taxes (less subsidies) not included in the valuation of output ($T - S$). These values are included in an IO table.

\[
GDP = V + (T - S) \tag{eq. 3.4}
\]

3.3. Objectives of the Input-Output analysis

At present, IO model are a widely used economic tool in much of the world. The United Nations have promoted this figure as a planning model in developed countries and have designed some common rules to standardize national accounts in order to build similar IO tables (WIOD: Word Input-Output Database project 2009-2012).

IO information has been recently understood as an essential part of an economic framework of labour and capital inputs and social and employment accounts associated to the industrial production of each country. Therefore, this model is being applied to analyse the evolution of regional and international flows of goods and services and other more specific issues such as energy consumption or pollution from industrial activity.

At the simplest level, an IO model consists on a system of linear equations accounting for the way in which each sector distributes its product through sales to other sectors and to final demand. Most of the extensions to the basic input–output framework are introduced to incorporate additional detail of economic activity, such as over time or space, to accommodate limitations of available data or to connect input–output models to other kinds of economic analysis tools.
IO method offers a wide range of techniques to address the different objectives within the economic analysis, which can be grouped in three research areas (Tarancón 2003):

- **Structural analysis:** This is focused on studying the productive structure associated with an IO table. This type of analysis looks for the reasons of changes in the tables’ variables over time.

- **Simulation/Impact assessment:** This part of the IO analysis aims at evaluating the impacts on the overall economy of certain changes in the table’s elements. These changes can be interpreted as either changes in productive structure —due to, for instance, technology improvements— or changes in exogenous variables such as household demand.

- **Forecasting analysis:** The forecasting techniques intend to estimate the IO tables corresponding to the future.

Despite of the considerable range of possibilities that IO model offers, it is worth pointing out some limitations when analysing some specific variables due to either the IO information may be insufficient or there may not be enough disaggregation in IO data for carrying on such analysis. In view of this fact, different ways to overcome such weaknesses have been proposed in previous literature (Alcántara, Del Río y Hernández 2010) either by adding complementary information to the basic IO table or by manipulating the central matrix in the model with the aim to highlight already existing information which is not liable to be captured without a specific treatment.

These suggestions have led to both extended —combining IO data with other type of data— and hybrid IO models —combining monetary and physical units in different parts of the IO table— (Bullard y Herendeen 1975). Such models have made possible to study issues like emissions and water or energy consumption (for more detail see reviewed works in Section 3.4).

### 3.4. Concepts and basic methods of the Input-Output analysis

#### 3.4.1. The Leontief model

As said before, the most basic form of an IO model consists on a linear equation system where each equation shows the way each economic branch sales its production to the rest of the
sectors and to final consumers of the country. Thus, if an economy is structured in \( n \) economic sectors —acting as producer and purchaser at the same time — a system with \( n \) equations is then defined:

\[
Z_1 = z_{11} + \cdots + z_{1j} + \cdots + z_{1n} + f_1 \\
Z_2 = z_{21} + \cdots + z_{2j} + \cdots + z_{2n} + f_2 \\
\vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \\
Z_i = z_{i1} + \cdots + z_{ij} + \cdots + z_{in} + f_i \\
\vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \\
Z_n = z_{n1} + \cdots + z_{nj} + \cdots + z_{nn} + f_n
\]

(eq.3.5)

that can be expressed in matrix form as follows in (eq.3.4) letting \( i \) be a (\( nx1 \)),

\[
Z = \begin{bmatrix} Z_1 \\ \vdots \\ Z_n \end{bmatrix}, \quad [z] = \begin{bmatrix} Z_{11} & \cdots & Z_{1n} \\ \vdots & \ddots & \vdots \\ Z_{n1} & \cdots & Z_{nn} \end{bmatrix} \quad \text{and} \quad f = \begin{bmatrix} f_1 \\ \vdots \\ f_n \end{bmatrix}
\]

\[
Z = [z] i + f
\]

(eq.3.6)

\( Z_i \) represents the total output of sector \( i \); \( z_{ij} \) is the monetary transactions between pairs of sectors (from each sector \( i \) to each sector \( j \)) — also identified as intermediate sales —; and \( f_i \) is the final demand of this sector. The equations of the above system reveal that there exist interdependencies of each sector in all the others because the level of production of a sector depends on both the production of all other sectors (as input requirements) and on the level of final demand. Also, as said before, the equilibrium between all industries is acknowledged because demand equals supply —or the industry sales equal gross output since \( Z_i = Z_j \) when \( i = j \).

The transactions value enables to identify the percentages or portions of the total inputs of a sector \( i \) needed to be purchased to produce one unit of output of the sector \( j \). Thus, technical coefficients are defined, according to Schaffer (1999), as the division of the row transactions entries by the total supply of the column sector assuming a distinctive period of time (eq. 3.7).

\[
a_{ij} = \frac{z_{ij}}{Z_j}
\]

(eq.3.7)

When these coefficients are put together the resulting matrix \( [A] \) is known as the direct requirements table. So, the system of (eq. 3.5) can be expressed as follows:
Chapter 3. Input-Output approach

\[
\begin{align*}
Z_1 &= a_{11}Z_1 + \cdots + a_{1j}Z_j + \cdots + a_{1n}Z_n + f_1 \\
Z_2 &= a_{21}Z_1 + \cdots + a_{2j}Z_j + \cdots + a_{2n}Z_n + f_2 \\
&\vdots \hspace{5cm} \vdots \\
Z_i &= a_{i1}Z_1 + \cdots + a_{ij}Z_j + \cdots + a_{in}Z_n + f_i \\
&\vdots \hspace{5cm} \vdots \\
Z_n &= a_{n1}Z_1 + \cdots + a_{nj}Z_j + \cdots + a_{nn}Z_n + f_n
\end{align*}
\]

(eq.3.8)

So, letting final demand be the independent term in each equation, the resulting expression is:

\[
\begin{align*}
(1 - a_{11})Z_1 + \cdots + a_{1j}Z_j + \cdots + a_{1n}Z_n &= f_1 \\
a_{21}Z_1 + \cdots + (1 - a_{2j})Z_j + \cdots + a_{2n}Z_n &= f_2 \\
&\vdots \hspace{5cm} \vdots \\
a_{i1}Z_1 + \cdots + (1 - a_{ij})Z_j + \cdots + a_{in}Z_n &= f_i \\
&\vdots \hspace{5cm} \vdots \\
a_{n1}Z_1 + \cdots + a_{nj}Z_j + \cdots + (1 - a_{nn})Z_n &= f_n
\end{align*}
\]

(eq.3.9)

In matrix form:

\[
(I - A)Z = f
\]

(eq.3.10)

Where I is the identity matrix — size \((n \times n)\) —, and \((I - A)^{-1}\) is called the Leontief inverse matrix \(L\), which represents structural interdependences between total both direct and indirect (and possible “induced”) requirements of any industry supplied by other industry’s sectors and by itself. In fact, this matrix is known as the total requirements table or matrix of multipliers, which measure the overall change in the economy as a result of change in final demand of a given sector.

### 3.4.2. The Ghosh Model

In classic IO model, the Leontief inverse relates sectorial gross outputs to the amount of final demand – that is, measure the impact on production of final demand changes. By contrast, Ghosh suggested in 1958 an alternative approach relating sectorial gross production to the primary inputs – that is, he proposed a supply-side IO model.
In this case, instead of dividing each column of $z_{ij}$ by the gross output of the sector associated with that column, as is made in Leontief model, each row is divided by the gross output of the sector associated with that row—that is $Z_i$. Thus, $b_{ij}$ coefficients are obtaining (eq. 3.11) representing the distribution of sector $i$’s outputs across sectors $j$, which purchase interindustry inputs from $i$. Therefore, the matrix $B$, denoted as the direct-output coefficients matrix, is defined.

$$b_{ij} = \frac{z_{ij}}{Z_i} \quad \text{(eq.3.11)}$$

So, the model results as follows:

$$Z^t = Z^t[B] + V^t \quad \text{(eq.3.12)}$$

where $V^t = [v_1, v_2 \ldots, v_n]$ is the total value-added expenditures by each sector.

Hence, it is defined the output inverse matrix $(I - B)^{-1}$ for the Ghosh model (eq. 3.13) whose terms are interpreted as measuring the total value of production that comes about in sector $j$ per unit of primary input in sector $i$.

$$Z^t = V(I - B)^{-1} \quad \text{(eq.3.13)}$$

### 3.5. Extensions of Input-Output model

#### 3.5.1. Structural changes: Demand patterns and its evolution over time.

The review of relevant literature shows different works analysing the sources and reasons that explain a specific sectorial demand structure at any given moment. For instance, Alcántara and Padilla (2009) suggested an hybrid IO subsystems model for studying the productive structure of the different sectors of an economy. The analysis carried out was aimed at decomposing the CO$_2$ emissions from services sectors in Spain—year 2000— into different components distinguishing direct and indirect emissions—induced emissions due to the strong pull effect of service activities on other activities of the economy. Other similar example is found in Cosmo et al. (2012) that adopted this approach to reveal the reasons behind sectorial water use in all EU countries.
On the other hand, there exists other group of studies intended to evaluate structural changes and, particularly, to separate the growth of some variables within certain economy over time. This set of tools facilitate the identification of the factors driving the demand patterns of goods and services and for that purpose they need consistent data sets for two or more years since technical coefficients matrix will change over time (Miller and Blair 2009). It is noted that changes in temporal gross outputs may result from either technological changes —this causes changes in the linkages and interactions between industries/sectors — or changes in final demand over time. The impact of these variations on any output, together with other ones, can be evaluated throughout different models, and one of the most applied techniques has been the Structural Decomposition Analysis (SDA). Particularly, this has been used to explain the trends of pollution in some countries and identify the factors driving the levels of emissions from their industries. See, for instance, Mukhopadhyay and Forssell (2005), Llop (2007) and Chang et al. (2008).

Although the habitual practice is to use the methodology of SDA to explain temporary changes in any factor, its own logic has been also used to analyse distinct patterns of consumption or economic structure that might have their origins in differences in one or another component. Within this context, authors such as Alcántara and Duarte (2004) adopted a spatial approach with a synchronic perspective to examine the position of the different European Union countries as consumers of final energy.

Following table (Table 3.1) compiles information regarding some reviewed references that have applied such type of structural techniques.

Table 3.2. Previous literature review on Input-Output Structural Decomposition analysis

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<th>REFERENCE</th>
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<th>FIELD</th>
<th>ISSUE</th>
<th>STUDY PERIOD</th>
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<td>Butnar and Llop (2007)</td>
<td>Spain</td>
<td>Environment</td>
<td>Environmental IO approach to quantify the changes in the levels of greenhouse emissions caused by exogenous changes in sectorial final demand.</td>
<td>2000</td>
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<tr>
<td>Alcántara and Padilla (2009)</td>
<td>Spain</td>
<td>Environment</td>
<td>Analysis of input–output subsystems to the study of the CO\textsubscript{2} emissions —direct and indirect— associated to the group of branches of the service sector.</td>
<td>2000</td>
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<tr>
<td>Cosmo, Hyland, and Llop (2012)</td>
<td>27 countries of the European Union</td>
<td>Water consumption</td>
<td>Comparison of patterns of water consumption within Europe through a subsystem input-output model that divides total water use into different income channels within the production system.</td>
<td>2005</td>
</tr>
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<tr>
<td>Llop (2007)</td>
<td>Spain</td>
<td>Environment</td>
<td>Environmental IO approach to decompose the total changes in Spanish emission multipliers into different components. Separated evaluation by applying a SDA analysis of the effects of economic structure and pollution intensity.</td>
<td>1995-2000</td>
</tr>
<tr>
<td>Chang, Lewis, and Lin (2008)</td>
<td>Taiwan</td>
<td>Environment</td>
<td>IO structural decomposition method to examine the changes in CO₂ emission over a 15-year period. Identification of the key factors causing the emission changes, as well as the most important trends regarding the industrial development process in Taiwan.</td>
<td>1989–2004</td>
</tr>
<tr>
<td>Mukhopadhyay and Forssell (2005)</td>
<td>India</td>
<td>Environment</td>
<td>Evaluation of air pollution (CO₂, SO₂, and NOₓ) from fossil fuel combustion in India. IO SDA approach is used to find out their sources of changes.</td>
<td>1973–1974, 1996–1997</td>
</tr>
<tr>
<td>Alcántara and Duarte (2004)</td>
<td>14 countries of the European Union</td>
<td>Energy</td>
<td>IO SDA-model to identify the sources of the differences in the energetic intensities of the European Union countries. Description of the role that each sector and country plays as an energy consumer.</td>
<td>1995</td>
</tr>
<tr>
<td>Wachsmann et al. (2009)</td>
<td>Brasil</td>
<td>Energy</td>
<td>Examen el origen de los cambios en el consumo de energía por parte de las industrias y de los hogares mediante SDA.</td>
<td>1970-1996</td>
</tr>
<tr>
<td>Guilhoto et al. (2001)</td>
<td>Brazil and the United States</td>
<td>Economy</td>
<td>Analysis of the changes in the economic structure of two large countries with different levels of development over time.</td>
<td>1958-1977 (US), 1959–1980 (Brazil)</td>
</tr>
</tbody>
</table>

Source: Authors’ table
3.5.2. Input-Output modelling and estimation techniques

The main advantage of forecasting IO models over other alternatives is the consideration of the inherent characteristics of the demand of some goods—or services—and the inner relation between such demand and the state of national economy systems, while these are ignored in those other alternatives (Alcántara et al. 2010).

Particularly, within transport field, numerous authors have integrated IO data into freight transport demand models (see Cascetta et al. (1996), Wang (2004) and Giuliano et al. 2007). All these authors claim that the flows of goods and services collected in the tables are equivalent to a specific number of trips between supply and demand zones (Holguín-Veras and Thorson 2007).

The commodity-based approach generates the amounts of commodity production and consumption and resulting in a more realistic and accurate freight demand models (Wisetjindawat et al. 2006). Nevertheless, certain difficulties are found when either there are not enough data to support this approach or not enough disaggregation level. That is, in an IO table supply and demand data for transport sector does not appear distinguishing between flows of passengers and freight, so this impedes developing forecasting model for any of them.

In the same way, modelling the demand of goods and services requires converting IO monetary sectorial transaction flows into physical units.

As said in Section 3.2.2, IO table can be extended or modified in order to overcome certain limitations for carrying on specific studies. When looking for analysing freight transport demand, an extended IO model could be built. In that way, gross output by commodity class could be converted to its equivalent volume of tonne-kms. According to the doctoral thesis by Voigtlaender (2002), this transformation would be possible if an additional variable, measuring the tonnes moved in a country by unit of sectorial output, is added to the basic IO model.

On the other hand, it is noted that for reasons such as technological change, development of new products or changes from domestically produced to imported inputs—or from imported to domestically produced—an economy’s technical coefficients matrix may change over time. These issues, together with changes in final demand patterns of an economy, have led to one of the most serious concerns of those who use IO models in applied work: the question of stability of IO data.

Although authors such as Marzano and Papola (2008) hold that technical coefficients show a scarce temporal variability for a time horizon of less than ten years—that implies that they can be considered as almost fixed values—, it is worth noting that most studies carried out have
generally looked for the most up to date IO data available (Miller and Blair 2009). Their possible changes in the short term as a consequence of economic factors may introduce errors in forecasting models. These have been addressed by updating IO tables through the analysis of the trends in IO coefficients and regression models run on historical data (Voigtlaender 2002). However, extrapolation of technical coefficients has been proven to provide worst results than using the most recent available IO data (Miller and Blair 2009).

Early work at updating input–output information has led to one of the most widely-used procedure: the RAS method (also known as a “biproportional” matrix balancing technique), designed under Stone’s direction (Stone and Brown 1962). This is thought to update the IO direct input coefficients table of a given year in the past to a more recent year. To that end, this needs three pieces of information of the year of interest. These are:

1. total gross outputs \((Z_i^f)\);
2. total interindustry (intermediate) sales from sector \(i\) to the rest of sectors, that is the total output of sector \(i\) less \(i\)’s sales to final demand \((U_i^f = \sum_{j=1}^n z_{ij}^f = Z_i^f - f_i^f)\); and
3. total interindustry purchases \((W_j^f = \sum_{i=1}^n z_{ij}^f = Z_j^f - v_j^f)\).

Once \(Z_i, U_i\) and \(W_j\) are known, they are applied to define two vectors \(-\hat{R}\) and \(\hat{S}\). These two multipliers can be obtained by using an iterative algorithm, displayed in Figure 2.8. Next, rows of columns of base technological matrix \([A^b]\) through the \((eq.3.11)\) for obtaining the estimated matrix \([A^f]\).

\[
[A^f] = \hat{R}[A^b]\hat{S} \quad (eq. 3.11)
\]

It is noted that the diagonalization of vectors \(R\) and \(S\) is denoted by (^).
This methodology has been already applied for developing several demand forecasting studies. For instance, Wei et al. (2006) and Fan et al. (2007) used RAS method to compute China’s energy requirements and CO$_2$ emissions in 2010 and 2020 based on the IO table of 1997. Fan and Xia also applied the RAS technique to a hybrid energy IO model (2012) to analyse energy intensity for 2020 in the same country based on the projected economic growth rates since 2010.
4. METHODOLOGICAL FRAMEWORK

4.1. Introduction

This chapter explains the methodological framework followed in this research work to analyse road freight transport demand considering the specific transport, structural and economic features of each country or region. The different analyses developed in following sections are aimed at explaining current cross-country divergences in road freight transport trends and therefore in the decoupling levels achieved. In addition, the results shown along this working paper contribute to understand the real influence of some factors on final transport volumes.

This research is developed on the basis of some case studies that will show the direction and intensity of the future road transport trends in some countries of the EU: Spain, the United Kingdom and Poland. At the same time, the analysis of these case countries, together with the numerical and graphic results obtained for each one of them, make the identification of the factors driving decoupling levels easier.

To that end, this is structured as follows. In section 4.2, based on the previous literature review, the variables influencing road freight transport demand and adopted to study decoupling trends are identified. After that, the evolution of these variables in each case study is analysed. Section 4.3 describes the proposed transportation model used to carry out this work, and finally, section 4.4 explains the analysis methods that are applied to explain quantitatively the impact of the evolution different factors on final road freight transport demand. This section will explain the way in which future likely decoupling trends in Europe could be estimated. The most relevant results are summarized in section 4.5.
4.2. Key drivers for road freight transport demand

As said previously, it has been a long-held view that transport, particularly road transport, rises according to economic growth. However, in some cases this assumption may provide erroneous results, as decoupling is now a proven fact in several countries such as in the United Kingdom.

As previous research works have already stated, transport volumes depend, on the one hand, on the levels of national economic output and consequently on the need to ship the commodities produced among different regions; and, on the other, on the organization of both the supply chains and transport systems.

The restructuring effects resulted from either technological innovations or changes in final demand clearly contribute to modify transport patterns. The necessity of knowing the influence of these changes on transport patterns over time have led to a new body of works in transport modelling. This is characterized by the development of transport IO models at urban and regional scale that combine IO data with additional information for trade and travel choices (see Ivanova 2014 for a deeper review).

The main reason for this trend is that several authors have pointed out the advantages of using these models in representing intersectorial interdependencies in production / consumption (Cascetta 2013). This is crucial to define the interchange of goods —trade flows— and therefore the movement of goods in a region.

This research project uses the information provided by the Input-Output tables to explain transport trends at the country level. This approach does not require as much information as the previously mentioned models do. However, by using aggregated information at the country level, it allows us to explain the global road freight transport trends in a certain country.

Our approach explains road freight transport volume at the country level by means of three main economic factors:

1. Sectorial linkages among activity branches of the economy of that country.

2. Final demand of that country (domestic consumption plus exports) —that is, the level of final domestic production in a country for each economic sector.

3. Imports necessary to meet the final demand.
The availability of IO tables for consecutive years in certain countries allows to study the evolution of the factors previously mentioned and therefore to analyse how they influence road freight transport trends.

The IO approach —that has been reviewed in chapter 3— has been used to conduct several analyses at the macro level for planning processes and policy design in sectors such as the energy sector. It is noted that this type of studies has never been conducted for transportation field.

On the other hand, countries are characterized by road freight transport intensities (RFTIs), which in their turn can be decomposed into several ratios that evolve according to industrial, logistics and transportation systems changes (see Chapter 2). Annual RFTIs can be calculated as long as the information about national production and transport volumes is available. RFTIs can be explained in terms of other variables insofar as data such as modal split or length of haul is available at the national level.

In order to achieve the main goal of this research project that consists of identifying the key drivers of decoupling, an extended Input-Output model that connects all the aforementioned variables —that is IO information along with road freight transport intensities data— is proposed. This methodological framework is schematized in the figure 4.1.

![Figure 4.1. Methodological framework scheme to define the IO transportation model](Image)
The first phase of the analysis carried out in this research will consist of a detailed description of the evolution of the variables included in the proposed model. To that end, the following items will be analysed:

- Key sectors driving economic activity and economic growth
- Final demand and GDP growth/restructuring
- Imports/Exports evolution
- Freight intensity evolution
- Modal split evolution
- Changes in the average lengths of haul
- Averages vehicles loads and empty running evolution

4.2.1. Evolution of decoupling trends and key drivers: the cases of Spain, Poland and the UK

Next sections analyse the evolution of the above identified key variables from 1999 to 2011, since this is the latest year with available both IO and transport data.

Particularly, in the case of Poland the period covered by the study is 2004-2011, due to no previous transport data have been found.

4.2.1.1 Economic variables
As seen previously, the evolution of the economy is a key factor to determine whether transport demand growths or decreases in a certain country.

Focusing on the case studies of this research project, some economic aspects can be highlighted in all of them.

Firstly, regarding to their macro-economic indexes evolution, Graph 4.1 shows a comparative analysis of the evolution of GDP growth, import and export volumes for the three countries from 1999 to 2011.
Graph 4.1. Evolution of key macro-economic measures in Spain, the UK and Poland (Index 2004=100)

Spain shows a continuous growth of the three macroeconomic figures until 2008, with an annual average growth rate higher than the UK and lower than Poland. This country has a strong and diverse manufacturing industry and is one of the biggest tourist destinations in the world. Spain is part of the European Union since 1986 and the Euro Area since 1999. As a result, it became one of the world’s leading destinations for foreign direct investment and its economy grew on average of 0.9 percent every quarter from 1994 through 2008. However, in the third quarter of 2008, following the burst of a housing market bubble the country plunged into recession and has been striving to recover ever since.

Poland has pursued a policy of economic liberalization since 1990 and today stands out as a success story among transition economies. In 2008, its GDP grew by an estimated 4.8%, based on the rise of private consumption, an increase in corporate investment, and inflows of European Union funds inflows. Since 2004, EU membership and access to EU structural funds have provided a major boost to the economy, as seen in the figure.

Meanwhile, the United Kingdom is recognized as one of the largest economy in the world. UK’s economy has been structurally changing since the 1970s with a movement away from heavy primary and secondary industries such as coal and steel. These industries couldn’t compete with the lower costs and better quality imports and as a consequence, industrial regions like South Wales and Newcastle in north east England fell into social and economic decline.
Successive governments pushed the tertiary industry. Consequently, last decades the service sector has become the biggest sector of the economy and accounts for more than 75 percent of total GDP. The key segments within services are Distribution, Transport, Hotels and Restaurants (18 percent of total GDP), Government, Health and Education (20 percent); Professional and Support (11 percent); Financial and Insurance (9 percent) and Real Estate (9 percent). Although the UK is still one of the biggest manufacturers in the world, production constitutes only 10 per cent of its GDP. Last big component of the GDP is Construction, which accounts for around 7 percent of total output (see graph 4.2).

It is clear that the economic development of the three case studies has gone hand in hand with economic restructuring processes. Within these changes some sectors have expanded causing other economic branches losing their previous weight in the whole economy of each country.

Graph 4.2, 4.3 and 4.4 show the evolution of annual sectorial weight over the period of study for Spain, Poland and the UK. In this figure we show the global economy organized into 8 sectors. The first 7 sectors are transport-intensive industries, while the last one includes all service-oriented activities. As seen, it is possible to point out some clear differences among them.

In the case of Spain, according to the graph 4.2, it is highlighted that Construction and Mining increasingly gained sectorial importance accounting for more than 16 percent of GDP at the end of 2007. That trend ended with the advent of the economic crisis when Construction activity dramatically fell and Services therefore gain increased importance in the Spanish economy.

![Graph 4.2. Evolution of the sectorial weights (%) in the national GDP of Spain between 1999 and 2011](image-url)
In regard to the UK’s economy, it has been previously mentioned that the shift away from agriculture and manufacturing towards services has been its most notable trend over all the study period (graph 4.4). And finally, it is observed that Poland is the most dependent country on non-services activities, and its economic structure has barely changed after the economic downturn. Mining, construction and food industries play an important role in the whole production of the country (graph 4.3).

**Graph 4.3.** Evolution of the sectorial weights (%) in the national GDP of Poland between 1999 and 2011

**Graph 4.4.** Evolution of the sectorial weights (%) in the national GDP of the UK between 1999 and 2011
As we have noted before, certain economic sectors generate more exchange of goods, and therefore, have more transport requirements per unit of output than others. Specifically, service activities generate fewer road transport volumes relative to their output than non-service activities such as manufacturing, agriculture or construction, which show higher road freight transport intensities. Therefore, it is essential to look at the economic structure of a country in order to identify the key sectors driving road freight transport demand.

The transition to service economies, while shifting away from agriculture and manufacturing, is a worldwide trend that has accelerated in the last decade in many countries. Services was the largest growing sector in the world, between 2000 and 2009, whilst manufacturing declined globally, on average, by around 2.5% over the same period of time. In is remarkable that the largest decline happened in the EU.

4.2.1.2 Transport volumes
Road transport has become the dominant mode of transport within Europe, recording the highest share of inland freight transport in 2007 with nearly 80% tonne-kms in the EU-27. This importance has been relatively unchanged since 2002 until today.

After a slight recovery of traffic after 2009, European road freight transport declined again in 2011 in terms of tonne-kms. The major components, national and international transport, declined. In constrast, the smaller components, share cross-trade and cabotage transport, recorded substantial increases during this period.

Transport of construction related products fell as a result of the difficulties faced in the construction sector. However, construction industry products remained the major group in tonnage terms, while food sector dominates transport in tonne-kms.

Focusing on the case studies of this project, graph 4.5 shows the trends followed by tonne, tonne-kms as well as vehicles-km between 1999 and 2011.
Chapter 4. Methodological framework

Graph 4.5. Evolution of key transport measures in Spain, the UK and Poland (Index 2004=100)

As seen, in the UK, after a continuous decline observed of both tonnes and tonne-kms between 1999 and 2004, there was a slight upward trend in goods moved from 2004 until mid-2007. This was followed by continuing significant decreases until 2009, most likely as a result of the economic recession.

From graph 4.1 and these last transport data, it is concluded that in this country changes in GDP have not always mirrored changes in road freight statistics for the same years.

In the case of Spain, it is noted a strong growth in the pre-recession period — particularly in terms of tonnes— but a much steeper fall once the recession began, mainly in national transport (graph 4.6). Unlike in the other two countries there was not yet evidence of a recovery in Spanish national road freight activity by 2011.

Finally it is highlighted a much faster growth of freight movements in Poland, which has made this country one of the largest road freight transport industry in Europe. From graph 4.6 it can be said that this trend was mostly caused by the rapid increase in international transport in this country during these years. Moreover, it is seen how the crisis has had no significant effect on road activity since no decreases in the transport volumes —either tonnes, tonne-kms or veh-km— have been recorded. Even more striking was the evolution of cabotage in this
country recording extremely high growth rates after 2008 (see graph 4.7). It is noted that this situation was partly caused by Regulation (EC) No. 1072/2009, which provides new clear common cabotage rules in the EU.

Graph 4.6. Evolution of both national and international transport —tonne-kms— in Spain, the UK and Poland (Index 2004=100)

Graph 4.7. Evolution of cabotage in terms of tonne-kms reported by Spain, the UK and Poland (Index 2004=100)
4.2.1.3 Road freight transport intensity evolution

As previously said, road freight transport intensity (RFTI) is an index that measures the volume of transport generated per unit of monetary production in a country. So, this can be expressed in either tonnes/output, tonne-kms/output or veh-km/output.

This is another key variable to define transport volumes since this index is obtained through several ratios that measure different aspects of the logistics systems as well as the transport networks and resources state in a country.

As the methodological approach of this research implies to introduce this variable in the IO model, it is worth analysing the evolution of RFTI together with the evolution of related ratios in the actual scenario for each case study.

Next graph shows the evolution of global RFTI figures in each country over the period of study. As seen the most significant differences are found between Spain and the UK in the first years, when RFTIs experienced high decreases in the UK while positive growth rates were observed in Spain until 2002. After that, a similar behaviour was found during the period of before the crisis for the three countries. However, it is noted that during the last four years, there are several divergences between the case studies.

Graph 4.8. Road freight transport intensities evolution in Spain, the UK and Poland (Index 2004=100)
The different trends can be explained by the evolution of the related ratios in each country (that were defined in section 2.3.2.). This is displayed in graphs 4.9, 4.10 and 4.11.

**Graph 4.9.** Evolution of key ratios related to road freight transport intensity in Spain from 1999 to 2011 (Index 2004=100)

**Graph 4.10.** Evolution of key ratios related to road freight transport intensity in Poland from 2004 to 2011 (Index 2004=100)

**Graph 4.11.** Evolution of key ratios related to road freight transport intensity in the UK from 1999 to 2011 (Index 2004=100)
Looking at the graphs, it is notable how during the period before 2004 there were clear differences in the evolution of the amount of tonnes lifted by unit of monetary production — that is freight intensity — in Spain and the UK. Whereas in the UK it has been continuously decreasing since 1999, in Spain this significantly increased in 2002 and no lower values had been recorded after the base year until the arrival of the crisis. Table 4.1 contains the main values of all key ratios and RFTIs figures in each country during the period of analysis. It is seen how, in this regard, the main value of the freight intensity is 68% higher in Spain than in the UK.

The service activity growth in the UK led to fewer trips across the country. By contrast, the main reason for the trends observed in Spain was the expansion of the construction activity, since mining and construction goods are low value materials and generate numerous as well as short length trips. This is also the explanation of the remarkable reduction of the average length of haul recorded in Spain between 2001 and 2002.

The evolution of freight intensity in Poland was marked by a continuous decline (similarity to the other two countries) until 2008. Although this trend led to lower values than in the base year, it is worth pointing out that freight intensities in Poland have been much higher in comparison with the other two cases (even more than twice the freight intensity in the UK as seen in Table 4.1). Such differences are similar in the lengths of haul as the average value per trip is also higher in Poland. The main reason might be the notable increase in international transport for this country.

Regarding to the modal share of road transport it is noted the growing trend in Poland while this share has remained fairly stable in both the UK and Spain. However, table 4.1 shows that the weight of road in island transport is greater in these last two cases.

Finally, regarding to the use of transport resources, the higher load factors have been recorded in Spain, although it is seen how Poland and the UK have improved this ratio during the last few years. Poland has also made progress in doing transport more efficient by diminishing empty running. The opposite trend has been recorded in the UK while this factor has remained stable in Spain.

Table 4.1. Mean values of RFTI and related key ratios in Spain and the UK in the period 1999-2011 and for Poland between 2004 and 2011

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</tr>
</thead>
<tbody>
<tr>
<td>Spain</td>
<td>861.4</td>
<td>94.7</td>
<td>122.5</td>
<td>10292.1</td>
<td>27.4%</td>
<td>15.8</td>
<td>7011</td>
</tr>
<tr>
<td>Poland</td>
<td>1269.1</td>
<td>74.4</td>
<td>149.4</td>
<td>18890.1</td>
<td>27.5%</td>
<td>13.1</td>
<td>16420</td>
</tr>
<tr>
<td>UK</td>
<td>511.5</td>
<td>88.8</td>
<td>95.0</td>
<td>4659.7</td>
<td>22.1%</td>
<td>9.2</td>
<td>6013</td>
</tr>
</tbody>
</table>
Anyway, one the main conclusions that can be obtained from this analysis is that there are clear divergences between the evolutions of transport related key ratios in each country. Furthermore, an important finding for this research is that, with the exception of load factor, all the rest of key ratios have shown more efficient values in the UK, promoting a highest reduction of traffic in that country. As a consequence, RFTIs have been much lower in the UK, followed by Spain. Poland has shown values much less stable. That will partly explain both the volumes and the evolution of road traffic in each country.

4.2.1.4 Coupling vs. Decoupling trends

As explained in the introduction of this working paper, one of the main objectives of this research consists of explaining the reasons behind the different decoupling trends between road transport and GDP growth in EU countries.

Looking at the previous research work of Tapio (Tapio, 2005), this cited a weak relative decoupling between freight traffic (and also for passengers) and GDP during the 1990s in five countries: Finland, Sweden, the UK, Ireland and Luxembourg. By contrast, in the Netherlands and Portugal, he identified an expansive negative decoupling while transport volumes grew at higher rates than this GDP. In all the other countries of the EU-15, GDP decreased during that decade while transport continued to grow. Tapio emphasized the exceptionally high elasticity values observed in Germany in that period. According to Leonardi, some drivers of that trend were the globalisation and the opening of Eastern European markets. This growth was only absorbed by the road mode due to the low competitiveness of German freight rail (Leonardi 2006).

Focusing on the case studies of this research project, we can characterize them based on the degrees of coupling and decoupling of transport volume growth from economic growth given by Tapio in the above mentioned study.

By comparing the graphs 4.12, 4.13 and 4.14, it is found that the UK is the clearest case of decoupling with positive growth rates of GDP while both tonne-kms and veh-km have been decreasing. In this country Tapio noted a situation of weak decoupling in the 90s (which meant that the relation of $\Delta\text{tonne-km}/\Delta\text{GDP}$ remained between 0 and 0.8). In the light of the trends observed in the graph 4.14, this decoupling trend became clearly more marked during the pre-crisis years as the UK achieved a strong decoupling level (being $\Delta\text{tonne-km}/\Delta\text{GDP}<0$).

In contrast, the opposite situation is observed in Poland, whose transport volume is still coupled to economic development (it shows an expansive coupling situation
where $0.8 < \frac{\Delta \text{tonne-km}}{\Delta \text{GDP}} < 1.2$). Spain could be defined as an intermediate scenario as this country tended to a weak decoupling situation since 2004.

**Graph 4.12.** Growth of real GDP, road tonnes, road tonne-kms and veh-km in Spain (index 1999=100): 1999–2011

**Graph 4.13.** Growth of real GDP, road tonnes, road tonne-kms and veh-km in Poland (index 2004=100): 2004–2011

**Graph 4.14.** Growth of real GDP, road tonnes, road tonne-kms and veh-km in the UK (index 2004=100): 2004–2011
In the first part of this chapter, it has been carried out a deep analysis of the evolution of the variables identified as key drivers of road traffic. After that, next sections are aimed at quantifying their real impact on road transportation during the period of analysis. In that way, the main causes of the observed trends in each country will be explained. In addition a simulation exercise and also a forecasting analysis is developed in order to provide a better understanding of the most likely future trends in each country.

These analyses are developed by using an extended Input-Output model that links all of the variables previously analysed. The method is presented in more detail bellow.

### 4.3. Extended Input-Output model

As explained earlier in this report, in the basic IO model, interactions between both productive and purchasing sectors representing industries are characterized as an equilibrium between total supply and total demand. This can be expressed by the equilibrium equation of Leontief model \( x = (I - A)^{-1}f \), where \( x \) represents the production vector — that is, the total output corresponding to the sectors of the economy—, \( f \) is the final demand vector and \( (I - A)^{-1} \) is the Leontief inverse matrix \([L]\) — which reflects the requirements of any industry supplied by the rest of sectors and by itself—.

Since the first IO research works, some economic analyses based on an IO approach have added complementary information to the basic IO model structure to overcome the limitations of the information provided by the IO tables. The methodological framework proposed in this research follows this approach in order to identify the key factors explaining road freight transport demand in each of the countries analysed.

To that end, the logistical and structural variables defining the industrial and transport systems are to be included. This can be done by adding a vector to the conventional IO model expressing the transport volumes generated in the sectorial production processes, which depend on such variables.

In the following equations the economy is supposed to be structured in \( n \) economic sectors and in the following the diagonalization and the transposition will be denoted by \(^\wedge\) and \('{\prime}\) respectively.

\( T \) is as a vector \((n \times 1)\) that contains the road transport demand by commodity class. Thus, other vector whose elements express the road transport volume linked to each unit of sectorial output can be defined, that is to say, the road freight transport intensity vector (in the following \(RFTI^*\)): 
\[ RFTI^* = T'(x)^{-1} \]  

(eq. 4.1)

Thus, we can obtain the road transport volume in that way:

\[ T = \overline{RFTI}^* x \]  

(eq. 4.2)

Taking the value of \( x \) from the Leontief model it leads to:

\[ T = \overline{RFTI}^* (I - A)^{-1} f \]  

(eq. 4.3)

On the other hand, in an IO model the final demand is equal to the sum of the GDP plus the volume of imports. So, the vector \( f \) can be expressed by other two vectors (\( n \times 1 \)) that contain these components sorted by sector.

\[ T = \overline{RFTI}^* (I - A)^{-1} (GDP + Imp) \]  

(eq. 4.4)

Let \( \overline{s} = (\overline{s}_1, \overline{s}_2, ..., \overline{s}_n) \) be a vector of the sectorial shares of GDP of the \( n \) productive sectors, so that \( \sum_i \overline{s}_i = 1 \). Therefore, the road freight transport demand can be explained by five components: the road freight transport intensity, the production structure—that is to say, the technological linkages—, the GDP structure, the aggregate GDP value and the volume of imports, as is shown in expression (eq. 4.5).

\[ T = \overline{RFTI}^* (I - A)^{-1} f = \overline{t} L(\overline{s} \sum_i GDP + Imp) \]  

(eq. 4.5)

The matrix \([L]\) and the vectors used —\( t, \overline{s} \) and \( Imp \)— in this transport model must reflect an identical disaggregation in the \( n \) activity branches considered. To that end IO data and the transport data that will be used have to be homogenized in the same number of sectors when applying this formulation.

This model has been proposed to explain road freight transport and explain it as a derived demand from countries’ own economic activity. That is to say, the model measures the volume of transport that is observed in each country as a consequence of national production and consumption, imports and exports of that country as all of those values are measured by IO tables.

However, it is important to note that this model is not able to explain complete traffic changes in the countries as it does not capture the amounts of cross-country traffic that come from the economic activity of neighbouring countries.

As it will be seen in following stages of this research, the statistical data on transport volumes in a country provided by databases only include transport operations made by its own domestic hauliers. This means that the foreign hauliers’ activity is left out of the picture of this analysis. Nevertheless, in our two case studies this part of the transport volume only accounts...
for about 1% of the total road transport demand — between 0.6 and 0.8% in Spain, 0.3 and 0.5 in Poland and 0.9 and 1.1% in the UK according to EUROSTAT data series — so the distortion of the results is expected to be negligible.

4.4. Analytical methods

4.4.1. Input-Output Structural Decomposition Analysis

The structural decomposition analysis (SDA) has been widely used in the economic literature to identify the driving factors for changes in key variables over time. All variants of SDA are static comparative methods that examine time series of either sector-level and/or country-level data. In essence, SDA formulates an explained variable, such as energy use, as a sum or product of explanatory determinants like energy efficiency, technology, per-capita consumption and population. A pair-wise comparison of changes at two points in time is undertaken by each determinant and explanatory variable.

According to Dietzenbacher and Los (1997), if any factor $y$ can be expressed by the product of $n$ variables $x_1, x_2, ..., x_n$, the observed changes over the period 0-1 leads to the following decomposition:

$$
\Delta y = \left(\frac{1}{2}\right) (\Delta x_1) [(x_2^0 ... x_n^0) + (x_2^1 ... x_n^1)] \\
+ \left(\frac{1}{2}\right) [x_1^0 (\Delta x_2) (x_3^0 ... x_n^0) + x_1^1 (\Delta x_2) (x_3^1 ... x_n^1)] + ... \\
+ \left(\frac{1}{2}\right) [(x_1^0 ... x_{n-2}^0) (\Delta x_{n-1}) x_n^1 + (x_1^1 ... x_{n-2}^1) (\Delta x_{n-1}) x_n^0] \\
+ \left(\frac{1}{2}\right) [(x_1^0 ... x_{n-1}^0) + (x_1^1 ... x_{n-1}^1)] (\Delta x_n) 
$$

(eq. 4.6)

4.4.1.1 Explaining road freight transport trends

Following the previous approach, the SDA can be applied to explain road freight changes over time. The aim here is to study the factors that motivate the differences, in terms of aggregate road transport demand, between two years — from the base year expressed by superscripts 0 and each one of the following years in the study period expressed by superscripts 1 — along a temporary period. This means that the objective is to explain $\Delta T^{0-1} = T^1 - T^0$. 
Therefore, by applying this rule to the equation 4.5 that define the transport IO model previously proposed it is possible to write the expression to carry out the SDA on road transport demand:

\[
\Delta T_{0-1} = \frac{1}{2} (\Delta RFTI^0)^{0-1} \left[ L^0 (s^0 \sum GDP + Imp^0) + L^1 (s^1 \sum GDP^1 + Imp^1) \right] \\
+ \frac{1}{2} \left[ RFTI^0 (\Delta L)^{0-1} (s^0 \sum GDP + Imp^1) + RFTI^1 (\Delta L)^{0-1} (s^0 \sum GDP^0 + Imp^0) \right] \\
+ \frac{1}{2} \left[ RFTI^0 L^0 (\Delta S)^{0-1} \sum GDP^1 + RFTI^1 L^1 (\Delta S)^{0-1} \sum GDP^0 \right] \\
+ \frac{1}{2} \left[ \left( RFTI^0 L^0 \Delta S^0 \right) + \left( RFTI^1 L^1 \Delta S^1 \right) \right] (\Delta GDP)^{0-1} \\
+ \frac{1}{2} \left[ \left( RFTI^0 L^0 \Delta Imp \right) + \left( RFTI^1 L^1 \Delta Imp \right) \right] (\Delta Imp)^{0-1} 
\]

(eq. 4.7)

Thus, the SDA technique enables to break down the aggregate changes in road freight transport demand in a particular economy into the contributions of five main factors, —C\(^1\), C\(^2\), C\(^3\), C\(^4\) and C\(^5\)— which are each individually contained in separated lines of equation 4.7.

The first term C\(^1\) captures how much of the increase or decrease in traffic volumes can be attributed to changes in road freight transport intensity values in the economic sectors. The second component, C\(^2\), is the “production linkages effect”, and shows the effect on the aggregate road freight transport volume of the different use of inputs in the production processes between year 0 and 1 depending on the changes in the interrelationships between sectors. This effect is caused by technological changes in the economy. C\(^3\) reflects how the GDP restructuring modifies road freight transport demand —the “GDP structure effect”; and finally C\(^4\) and C\(^5\) quantify the contributions of GDP growth and the changes in import volumes to the increase/decrease in aggregate transport volumes respectively in a country.

This analysis allows a cross-country comparison of our case studies to be conducted in order to:

1. Identify the variables influencing European road freight trends in the last few decades.
2. Identify the countries that have achieved significant decoupling.
Determine which factors have played the greatest role in decreasing road transport volume in each one.

4.4.1.1 Empirical results: Spain, Poland and the UK

In this subsection the methodological framework defined above is implemented in the three case studies—Spain, the United Kingdom (UK) and Poland—using data from 1999 to 2011 for the two first cases and from 2004 to 2011 for Poland.

The information on road freight transport demand—data series of tonne, tonnes-kms and veh-km sorted by commodity group in each country—was obtained from Eurostat. Economic data were collected from the Input-Output (IO) tables compiled by the World Input-Output Database (WIOD). This dataset provides the IO tables at current prices in US$ according to the national accounts of 35 economic branches.

As it is necessary to integrate both transport and economic data in our methodology, the information from the two databases has to be homogenised. To that end, the original IO tables are aggregated into eight sectors representing the main areas of economic activity. This aggregation is made according to the commodity groups of the transport dataset. Transport data series from EUROSTAT shows different classification of goods until 2007 (NST/R classification) and for the years after 2008 (the new NST 2007), so we have also to homogenize the series of transport for all the years of our period of study. Finally, we consider these groups: (1) food, beverage and tobacco, (2) mining and construction, (3) textile sector, (4) energy: fuel and power products, (5) chemical products, (6) machinery and transport equipment, (7) manufacturing products and (8) services. The first seven sectors include the eighteen transport-intensive industries from the IO tables.

In order to calculate the impact of the evolution of road transport intensity, production structure, GDP structure, growth in GDP and import volumes on the annual aggregate road freight transport demand, we apply (eq.4.7). According to the method, by aggregating these five contributions we obtain the global change in road freight transport between the base year 1999 and the other years in the study period.

The final contribution of each factor explaining road transport demand is obtained as the summation of each economic sector’s contributions. It is important to keep in mind that the way industries contribute to increasing/decreasing road freight transport volumes across the European countries is largely dependent on the weight of each sector in their economy, the evolution of their sectorial linkages, and the performance of the supply chain. These are the
reasons why there are major asymmetries in the final contribution of each economic sector to modify road freight transport trends.

Next graphs below show the aggregate results per country explaining the evolution of tonnes, tonne-kms and veh-km volumes.

Each figure contains three different graphs providing a quantitative measure of the impacts exerted by the evolution of the key drivers on the transport volumes of each case study. As seen, there exist significant differences in the contributions from each factor to increase/decrease the total tonnes, tonne-kms or veh-km in the same region. The reason of such divergences is that each one of these transport measures depends on the considered factors in different degrees. It stands to reason that economic variables influence more directly to the evolution of, firstly, tonnes, and secondly, to tonne-kms rather than veh-km. This is because the latest measures are also defined by more logistical variables. Tonne-kms depend on lengths oh haul and veh-km on this measure and also on both load factor and empty running values.

**NOTE:** The contributions are measured in % of increase/decrease of units of transport with respect to base year 1999

**Graph 4.15.** Contribution of all effects to changes in road freight transport from 1999 to 2011 in Spain
Overall, looking at all the graphs (4.15, 4.16 and 4.17), it is seen as the growth in both GDP and imports contributed to increasing transport volumes in the three countries. As a consequence of that trend, transport volumes should have expanded practically uninterruptedly at rates closely matching economic growth. However, in some cases, mostly in the UK, it is observed how road transport remained stable or even declined under economic growth scenarios. This effect is mostly explained by changes in RFTI, with moderate contributions from sector production linkages and GDP structure effects.
NOTE: The contributions are measured in % of increase/decrease of units of transport with respect to base year 1999

Graph 4.17. Contribution of all effects to changes in road freight transport from 1999 to 2011 in the United Kingdom

After analysing case by case, it is possible to provide an explanation of the different road freight transport trends observed during THE last years.

In the case of Spain, the remarkable increase of freight intensity between 2001 and 2002 contributed to boost the movement of tonnes across this country. This was caused by the construction boom. This is the reason why economic structure effects led to positive contributions. The Spanish economy became hugely dependant on road transport intensive sectors (in terms of tonnes/output) such as mining industry. By contrast, this same situation tended to restrain the growth of both tonne-kms and veh-km. The reason was that mining and construction goods, in addition of being low value materials and generate numerous trips, are associated with short-length haulages.

After the beginning of the economic recession, it is seen that the effect was exactly the opposite. Construction industry was particularly affected with the arrival of the
crisis while services gain increased importance. Therefore, the Spanish economy became less dependent on transport activities, so tonnes considerably decreased. However, this decline was not so sharp for tonne-kms or veh-kms since the average of lengths of haul tended to increase during that period.

In the case of Poland, it is highlighted that this was the only country with a positive growth rate of transport volumes in 2009, not only compared with the two other case studies, but also with all the Member States (+1.1% vs. an average -4.8 % in the EU). Since its entry into the European Union in May 2004, the Polish road freight transport sector rapidly opened up to the European market. This country takes advantage of its geographical location between Eastern and Western Europe, and therefore, most of the Polish road freight transport activity is international and greatly increased between 2004 and 2010. In this country, imports growth exerted a most notable positive contribution to transport growth compared to the other two ones. Moreover, it is worth noting that construction activities also gained importance in Poland after 2004, which led to positive contributions to increase tonnes lifted across the country while the growth rates of final tonne-kms were moderately constrained (as average length of haul tended to decrease).

One of the most highlighted findings of our results, showed in figure 4.16., is the observed change in the level of contribution of road freight transport intensities between 2008 and 2009. After 2008, the freight intensity of this country notably increased (as also seen in graph 4.10.). Conceptually this means that its economic sectors needed for more shipping of commodities by road for the same level of economic output. However, this trend might be a consequence of the extremely high growth rates of cabotage activities between 2008 and 2010 performed by Polish haulers (see Graph 4.7.). This also caused that after 2008 road modal share and the average of the length of haul increased, contributing to tonne-kms growth rates. In contrast, the notable improvement in the efficiency of load factors contributed to limit the growth of veh-kms reported by Poland.

Finally, regarding to the UK, it is seen that the positive contributions to increase transport volumes have been hardly offset by the road freight transport intensity, the production linkages and the GDP structure effects. That means that, on the one hand, the economy of this country has evolved towards a non-transport dependent economy —since the GDP growth in the UK from 1999 to 2007 was mostly concentrated in service-oriented sectors. On the other hand, road freight activity in the UK has become more sustainable during last years, especially before the arrival of the crisis. Until 2007, freight intensity, the average of the length of haul as well as load factor evolution has prompted a greater reduction of freight traffic volume in the
UK. All of these trends has caused that the UK is the most notable case of decoupling in the
UK.

4.4.1.2 The impact of key drivers on road freight transport demand

After quantifying the actual level of influence on road freight transport volumes by different
explanatory variables, the SDA technique may also allow to evaluate the potential impact such
variables on the final output —road freight transport— by simulating alternative scenarios.

To quantify these impacts a specific hypothetic trend is assigned to one of the explanatory
variables while keeping the actual values for the rest of the variables. This way, the impact of
this variable on road freight transport demand evolution will be known.

Specifically, four different alternative scenarios will be simulated for each case study. In the
first two ones the impact of the restructuring of the national economy on road transport will
be analysed, and the last two ones will look at the importance of logistical and transport
systems organization by modifying the actual trends of road freight transport intensities in
each case study.

In scenarios 1 and 2 the actual values of the global GDP, the road freight transport intensities,
the sectorial linkages and the volumes of imports are kept for all the study period. By contrast,
the structure of GDP is varied.

- **Scenario 1 (full materialization).** All the GDP growth is absorbed by transport intensive
  sectors. According to this scenario it is supposed that service-oriented branches of the GDP
  no longer grow after the base year. Consequently, intensive sectors experience a higher
  increase in their GDP compared to the actual scenario. The growth across intensive sectors
  is allocated according to their weight in the GDP of the base year.

- **Scenario 2 (full dematerialization).** All the GDP growth in a country is absorbed by service-
  oriented sectors. In this case it is assumed that the economic growth of each country
  results from service-oriented sectors. Consequently transport intensive sectors no longer
  grow after the base year.

It is noted that the economy of each one of the case studies has evolved according to an
average economic scenario.

The third and fourth scenarios are aimed at analysing the importance of some aspects related
to the organization of transport operations. In that sense, the sectorial road freight transport
intensity values are varied keeping the actual values of the economic data.
In scenario 3, the analysis is focused on the impact of modal split. It is highlighted that this has been one of the most notable concerns for European transport policy since road—one of the less energy-efficient transport modes—has become the dominant mode for inland transport. Therefore, Scenario 3 simulates what had happened if island freight transport would have been shifted from road to more environmentally-friendly modes in the case studies.

Finally, scenario 4 is focused on evaluating the importance in decoupling trends of increasing the efficiency when using transport resources. In this case, vehicles loads and empty running ratios are modified in order to evaluate their impact on final veh-kms per country.

- **Scenario 3:** Road share is decreased at a rate of 2% per year. It is supposed an annual decrease of 2% in the modal share of the road mode (in all commodity classes) between the base year and the final year of the study period. In this scenario the actual values of road freight transport intensities are changed.

- **Scenario 4:** Average vehicles loads increase annually at a 1% rate and empty running decreases at 1%. In this scenario the impact on final veh-kms of these changes will be evaluated.

With this approach, equation 4.8 is used to simulate the different scenarios and obtain the trend that the road freight traffic had followed in each country for each hypothetic situation.

\[
\Delta T = \left( \frac{1}{2} \right) (\Delta RTT^1) \cdot 0^{-1} [ (L^0 (PIB^0 + Imp^0)) + (L^1 (PIB^1 + Imp^1))] \\
+ \left( \frac{1}{2} \right) [ \text{RTT}^0 (\Delta L)^{0-1} (PIB^1 + Imp^1) + \text{RTT}^1 (\Delta L)^{0-1} (PIB^0 + Imp^0)] \\
+ \left( \frac{1}{2} \right) [ \left( \text{RTT}^0 L^0 \right) + \left( \tilde{T}^1 L^1 \right)] (\Delta PIB)^{0-1} \\
+ \left( \frac{1}{2} \right) [ \left( \text{RTT}^0 L^0 \right) + \left( \text{RTT}^1 L^1 \right)] (\Delta Imp)^{0-1} \quad (eq.4.8)
\]

In scenarios 3 and 4, the variations of road freight transport intensities — that is \( \Delta t \) — will be firstly calculated to be used in equation above.

The following table summarises the characteristics of the four scenarios and defines the variables that will be adopted in equation 4.8 for each one of them.
### Table 4.2. Description of the different scenarios simulated

<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>Description</th>
<th>Variables used in the model</th>
</tr>
</thead>
</table>
| **SCENARIO 1** | - ACTUAL evolution of road freight transport intensities  
- ACTUAL evolution of sectorial linkages  
- ACTUAL global GDP growth  
- Services’ GDP growth is shared between transport intensive sectors according to their share of GDP  
- ACTUAL evolution of imports volume | **ACTUAL VARIABLES**  
\(RF_{TI}^{0}, RF_{TI}^{1}, \Delta RF_{TI}^{0-1}, L^0, L^1, \Delta L^{0-1}, \text{Imp}^0, \text{Imp}^1, \Delta \text{Imp}^{0-1}\)  
\(\text{GDP}^0, \Delta \text{GDP}^{0-1}, \sum_{i=1}^{n} \text{GDP}_i^1\)  
**MODIFIED VARIABLES**  
\(\text{GDP}^1, \Delta \text{GDP}_i^{0-1}\)  
\(\Delta \text{GDP}^{0-1}_{\text{services}} = 0\)  
\(P_{(\text{intensive})}^{i-1(+) = \Delta \text{GDP}_{(\text{intensive})}^{i-1(+) = \Delta \text{GDP}^0} + \frac{\text{GDP}^0_i}{\sum_{\text{intensive}} \text{GDP}_i^0} \Delta \text{GDP}^{0-1}_{\text{serv}}\)  
\(\text{GDP}_i^1 = \text{GDP}_i^0 + \Delta \text{GDP}_i^{0-1(+) + \Delta \text{GDP}^{0-1}_{\text{intensive}}}\) |
| **SCENARIO 2** | - ACTUAL evolution of road freight transport intensities  
- ACTUAL evolution of sectorial linkages  
- ACTUAL global GDP growth  
- Global GDP growth is only derived from service GDP  
- ACTUAL evolution of imports volume | **ACTUAL VARIABLES**  
\(RF_{TI}^{0}, RF_{TI}^{1}, \Delta RF_{TI}^{0-1}, L^0, L^1, \Delta L^{0-1}, \text{Imp}^0, \text{Imp}^1, \Delta \text{Imp}^{0-1}\)  
\(\text{GDP}^0, \Delta \text{GDP}^{0-1}, \sum_{i=1}^{n} \text{GDP}_i^1\)  
**MODIFIED VARIABLES**  
\(\text{GDP}^1, \Delta \text{GDP}_{i}^{0-1}\)  
\(\Delta \text{GDP}^{0-1}_{\text{intensive}} = 0\)  
\(\Delta \text{GDP}^{0-1}_{\text{services}} = \Delta \text{GDP}^{0-1}_{\text{services}} + \Delta \text{GDP}^{0-1}_{\text{intensive}}\)  
\(\text{GDP}_i^1 = \text{GDP}_i^0 + \Delta \text{GDP}_i^{0-1(+) + \Delta \text{GDP}^{0-1}_{\text{intensive}}}\) |
| **SCENARIO 3** | - Road freight transport intensities (\(\tilde{\epsilon}\)) evolve driven by an annual decrease of 2% of modal share. The rest of ratios that define \(\tilde{\epsilon}\) follow the actual trends  
- ACTUAL evolution of sectorial linkages  
- ACTUAL global GDP growth  
- ACTUAL evolution of the GDP structure  
- ACTUAL evolution of imports volume | **ACTUAL VARIABLES**  
\(L^0, L^1, \Delta L^{0-1}, \text{Imp}^0, \text{Imp}^1, \Delta \text{Imp}^{0-1}\)  
\(\text{GDP}^0, \Delta \text{GDP}_{i}^{0-1}\)  
\(\sum_{i=1}^{n} \text{GDP}_i^1\)  
\(RF_{TI}^{0}\)  
\(\Delta RF_{TI}^{0-1}\)  
\(\text{Annual decrease (-2%) in \(\text{tons}\) in \(\text{tons}\)}\)  
**MODIFIED VARIABLES**  
\(RF_{TI}^{1}, \Delta RF_{TI}^{0-1}\)  
\(\text{Annual decrease (-2%) in \(\text{tons}\) in \(\text{tons}\)}\) |
Understanding Key Drivers for Road Freight Transport Decoupling in Europe
State of knowledge, practice and methodology

<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>Description</th>
<th>Variables used in the model</th>
</tr>
</thead>
</table>
| SCENARIO 4 | - Road freight transport intensities evolve driven by both an annual increase of 1% in average vehicles loads and an annual decrease of 1% of empty running. The rest of ratios that define \( t \) follow the actual trends | \[ \text{ACTUAL VARIABLES} \]
| | | \[ L^0, L^1, \Delta L^{0-1}, \text{Imp}^0, \text{Imp}^1, \Delta \text{Imp}^{0-1}, \sum_{i=1}^{n} \text{GDP}_i^1, \Delta \text{GDP}_i^{0-1} \] |
| | | \[ \text{MODIFIED VARIABLES} \]
| | | \[ \text{RFTI}_1 - \text{RFTI}_0 \] |
| | | Annual increase (+1%) in \[ \frac{\text{con}_i}{\text{veh}_i} \] \text{veh}-\text{km}_i |
| | | Annual decrease (-1%) in \[ \frac{\text{veh}-\text{km}_i}{\text{veh}-\text{km}_{\text{loaded},i}} \] |

Notes: \( \text{RFTI}_0 \) and \( \text{RFTI}_1 \) are the road freight transport intensity vectors in year 0 and 1 and \( \Delta \text{RFTI}^{0-1} \) is their difference. 
\( L^0 \) and \( L^1 \) are the Leontief matrixes corresponding to years 0 and 1 and \( \Delta L^{0-1} \) is the difference between them. 
\( \text{Imp}^0 \) and \( \text{Imp}^1 \) are the import vectors of the years 0 and 1 and \( \Delta \text{Imp}^{0-1} \) is their difference. 
\( \text{GDP}^0 \) and \( \text{GDP}^1 \) are the vectors of sectorial GDP in the base year 0 and in the year 1 respectively. When it appears \( \text{GDP}^0_i \) or \( \text{GDP}^1_i \) we referred to the GDP value of a specific sector \( i \) in each year. When it appears \( \sum_{i=1}^{n} \text{GDP}^1_i \) we refer to the global value of the GDP in the year 1. 
\( \Delta \text{GDP}_i^{0-1}(+) \) and \( \Delta \text{GDP}_i^{0-1}(-) \) mean the increase and decrease of sector \( i \)'s GDP between year 0 and 1 respectively. These values appear sometimes with the subscript “intensive” or “services” based on whether we refer to transport-intensive sectors or service-oriented sectors.

4.4.1.2.1 Empirical results: Spain, Poland and the UK

In this subsection, the afore-explained simulation analysis is applied to the three case studies of this research work. This analysis is aimed at studying in detail how road freight traffic would behave under similar hypothetic situations in these three countries.

Firstly, S1 and S2 reflect two opposite economic scenarios covering the full range of economic impacts on road freight transport. By means of their simulation it is possible to define a range where road freight transport could have fluctuated depending on the evolution of the structure of the economy within each country.

Secondly, through S3 and S4 it is studied the possible effect of some of the ratios defining road freight transport intensities such as modal split, empty running or length of haul. That is to say, their simulation allows to analyse the impact of some measures promoting a sustainable transformation of transport systems.
Following graphs (4.18., 4.19. and 4.20.) shows the road freight traffic trends—in terms of vehicles-km—obtained for each country. It is noted that the closer the actual trend is to any of the simulated trends, this means that the assumed situation is similar to what actually happened in the country.

Graph 4.18. Actual GDP growth and road freight transport trends $-\Delta$ veh-kms (%)—under different economic scenarios in Spain from 1999 to 2011

The growth of intensive-transport sectors in S1 implies a greater road freight transport increase. This trend is associated with elasticity values higher than one in the case of Spain. For S2, when service GDP share is expanded, road freight transport is progressively detached from GDP, which leads to a clear decoupling trend with elasticity values around 0.1. The actual trend, as it was expected, remains within the band delimited by the two scenarios previously mentioned.

Both S3 and S4 assumptions lead to lower traffic volumes than in the Spanish actual case. As seen in previous graph 4.9 the three ratios—road modal share, load factor as well as empty running—remained more or less stable during the period of study, while in these simulations they are supposed to evolve prompting traffic declines. Therefore, more remarkable decoupling trends might have been enhanced by improving the efficiency of transport activities in these aspects.

However, one of the main conclusions is that in Spain the lower traffic volumes are reached in the S2 scenario. This implies that a progressive dematerialization of the Spanish economy—rather the experienced construction boom—could have led to the most notable effect of decoupling in the country.

Graph 4.18 draws the attention to the fact that road transport volume was above GDP in the three scenarios during the three first years of the study period. The reason explaining the
similarity in all the scenarios is that in this period the GDP growth of all the economic sectors was rather small. Along with that fact, in this period road freight intensity in Spain grew a lot compared to the base year leading to positive road transport growths when global GDP decreased in all situations (see graph 4.9.).

Regarding to the case of Poland, shown in graph 4.19., it is noted that the actual scenario is closer of S1 than in the previous country. This is because the Polish economy still largely depends on transport intensive activities. The results show that if services gain importance in the future, it could be expected much lower traffic volumes.

Unlike Spain, the simulation of S4 has led to higher veh-kms than in the actual scenario. Since 2004 Poland has been greatly improving the efficiency in the use of transport resources by means of notable reductions in empty running —with an average annual rate of -1.7%— and increasing load factors —by +3.2% as an annual average—. As seen, these changes are greater than the simulated in the scenario.

Finally, it is shown that the lower traffic volumes are reached in S3. This implies that one of the main factors that have caused the traffic growth in Poland has been its increasing road modal share, which rose by an annual average growth rate of almost 3% in the period 2004-2011. Therefore, the shifting toward more sustainable means of transportation may be a measure that would in fact effectively promote decoupling trends in this country.

The same analysis for the UK is shown in graph 4.20. As previously seen, in this case road freight traffic growth began to separate from economic growth ever since 2003, accounting for traffic losses of nearly 15% after this year and elasticity values around -0.30. This trend was
even more pronounced after 2007. During the economic crisis period traffic reductions of more than 20% are observed compared to the base year.

Graph 4.20. Actual GDP growth and road freight transport trends —Δ veh-kms (%)— under different economic scenarios in the UK from 1999 to 2011

In this country, the actual trend is close to both S2 and S3, particularly in the years preceding the economic recession. This means that, on the one hand, the dematerialization process of this economy was almost complete, and, on the other, road modal share also followed a downward trend, although only by -0.2% annually. This leads to conclude that minor reductions in modal split do not are decisive to reduce significantly traffic volumes.

In contrast, S4 has led to notable divergences compared to actual trends in the UK. For S4 it has been supposed an average annual increase of 1% in average vehicles loads and an annual decrease of -1% of empty running compared with an average annual growth of 0.2% of load factor and annual increase of 2,5% in the UK. So, contrary to the effect of modal split, minor differences in the efficiency when using transport resources, seems to be crucial to achieve decreases in the final traffic in a country.

4.4.1.3 Forecasting of future decoupling trends

The analyses carried out in previous sections have allowed, on the one hand, to define the factors that have mostly contribute to either coupling or decoupling in the three case studies, and on the other, to determine the potential impact of this factors on final transport volumes.

The final analysis that is carried out in this research work aims at estimating future levels of decoupling in the European case studies. To that end, this research will follow the methodical framework displayed in Figure 4.2, which implies different tasks:
(1) **Identification of the trends of key variables:** The previous analysis on the evolution of the key variables explaining road freight transport demand in each European country will be used to define the current trends.

(2) **Determination of possible levels of trend changes:** Taking into account the factors influencing decoupling, such as the logistics innovations or the proposal of some transport policies mentioned in Chapter 2, it will be highlighted the alternative ways in which the key variables may evolve in the future.

(3) **Estimation of the relative importance of factors influencing the trends development:** Looking at the past impacts exerted by the factors influencing road freight trends on the key variables (estimated from results obtained in the analysis in the section 4.4.1.2.), the future likely contributions of such factors will be explained.

(4) **Assessment of expected level of development of the key variables trends:** Expected future trends of the key variables analysed will be defined according the conclusions obtained from previous tasks.

(5) **Definition of the variables in a future scenario:** In this task the estimated values of the variables defining road freight transport demand will be provided. To that end, the RAS method —explained in section 3.5.2— will be applied to obtain expected IO tables. The expected values of the ratios related with road freight transport intensities are obtained by defining Auto-Regressive Moving Average models.

(6) **Estimation of future decoupling trends:** On the basis of the suggestion made in previous tasks, the likely future decoupling trends in each case study will be defined by applying the transport model used in this research (eq. 4.4).
Chapter 4. Methodological framework

**Figure 4.2.** Methodical framework for estimating future decoupling trends in European case studies
4.4.1.3.1 Economic variables: expected trends in Spain, Poland and the UK

As said along this chapter, there are two types of variables that should be taken into account in order to define expected level of road freight volumes. Firstly, it is necessary to establish the most likely scenario for the economic activity. Therefore, this section tries to identify the expected trends of both sectorial and global economic growth in the case studies in order to define the most likely IO tables in the future.

- National economic growth

After the widespread recession suffered by EU countries, Europe's economic recovery, which began in the second quarter of 2013, is expected to continue in the following years as seen in graph 4.21. (European Commission 2015). However, the consequences of the crisis are still constraining the economic growth in some countries.

Economic growth has been identified as a key driver of road transport volumes, so in order to carry out a forecast analysis of road traffic in a country; it is necessary to establish its expected future GDP growth rates.

Based on the expectations provided by economic experts — http://es.tradingeconomics.com/ —, the following table shows the GDP growth rates that will be adopted for each case study in the RAS simulation analysis.

It is noted that this analysis is developed with a 2020 horizon.
Table 4.3. Expected GDP growth rates in Spain, Poland and the UK

<table>
<thead>
<tr>
<th></th>
<th>(\Delta GDP^{2014–2015})</th>
<th>(\Delta GDP^{2015–2016})</th>
<th>(\Delta GDP^{2016–2020})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spain</td>
<td>+ 2%</td>
<td>+ 2.75%</td>
<td>+1.62%</td>
</tr>
<tr>
<td>Poland</td>
<td>+3.3%</td>
<td>+4%</td>
<td>+3.75%</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>+2.70%</td>
<td>+3%</td>
<td>+2.75%</td>
</tr>
</tbody>
</table>

Source: data provided by Trading Economics

- Sectorial growth

As seen in the previous sections, economic restructuring processes play a key role in defining road freight volumes. So in order to forecast future road traffic trends it is essential to establish what are the economic sectors most likely to gain importance in the future.

It is difficult to assess the full impact of the economic crisis on EU industries. However it is possible to provide some common patterns and trends, based on the previous results of this work and also on specialized studies such as the EU Industrial Structure Report (European Commission 2013).

In general, since the arrival of the crisis, some sectors such as food, beverage and tobacco, transport equipment, chemistry or pharmaceutical sectors or high-technology manufacturing industries were not so affected as others. During last years some medium-high-technology industries have lost large levels of productivity as capital goods and intermediate goods industries are more sensitive to business-cycle fluctuations than consumer goods. However, manufacturing, as a whole, were not as hard-hit as mining and construction that have been on the decline over the last years, and this last trend is even expected to persist in next years. This downturn has been also seen in some manufacturing sectors such as furniture, clothing and textiles.

It is noted that interlinkages between manufacturing and services are increasing since manufacturing firms include service activities in their business — R&D, engineering design, software design, market research, marketing, organisational design and after-sales training, maintenance and support services.

Overall, services have not suffered from the financial crisis to the same extent as construction, manufacturing and mining industries, and most specifically, information and communication and financial and insurance activities. Furthermore, after analysing the evolution of the economic structures, it was found that, as a whole, the shift away from primary and secondary sectors towards services is a widespread trend, which has accelerated in the last decade in emerging markets as well.
On the basis of the information provided by EU business surveys, the positive development in both manufacturing output and services in last years over the rest of economic sectors is expected to continue.

The evolution of growth in value added of some sectors mentioned above is shown in graph 4.22. The data show that the high-technology and service industries are those helping the EU to recover from the economic crisis. In contrast, it is seen that construction has been continuously deceasing since 2008.

This sectorial analysis can be refined using a lower level of aggregation. Studying production growth rates at three-digit NACE level offers a more detailed view of EU sectors as seen in graph 4.23.

Source: Eurostat data. EU Industrial Structure Report 2013
Graph 4.22. Growth value added, by sector in the EU (2000-2012)
Taking into account the previous discussion and graphs, the forecast exercise of road traffic is made based on a series of assumptions about sectorial weight in the economies of Spain, Poland and the UK. Concretely, it is assumed that mining, construction and textile, clothing and leather outputs are constrained until 2015. After that, these will remain stable. Food, beverage and tobacco, energy and chemistry industries weight will remain stable along all the period, until 2020. Machinery, manufacturing and services will continuously gain importance and this last one at higher rate than the others.

On this basis, the sectorial growth rates over the period of study have been established through the following equation:

Source: Eurostat data. EU Industrial Structure Report 2013

Graph 4.23. Average annual value-added growth in the EU sectors between 2001 and 2011 (%).
\[ \Delta GDP_{i,c}^{0-1} = \frac{1 + \alpha_i}{\sum_{i=1}^{n} W_i^0 \times \alpha_i} \times \Delta GDP_{c}^{0-1} \quad (eq.4.9) \]

Being \( \Delta GDP_{i,c}^{0-1} \) the GDP growth rate of sector \( i \) in the country \( C \) between years 0 and 1; \( W_i^0 \) is the GDP share of sector \( i \) in the initial year 0; \( \Delta GDP_{c}^{0-1} \) is the global GDP growth rate in this country between years 0 and 1 — taken from table 4.8, depending upon the country and the years. —; and \( \alpha_i \) is a fixed coefficient for each sector \( i \) that takes the values of the table 4.4, depending upon the sector and the years.

The most recent data about sectorial activity have been found for 2013, so the forecasting process explained in this section is applied from 2013 to 2020 for each country.

**Table 4.4.** Auxiliary fixed coefficient (\( \alpha \)) to establish the future sectorial GDP growth rates

<table>
<thead>
<tr>
<th>Sector</th>
<th>2013-2015</th>
<th>2015-2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food, beverage and tobacco</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mining and construction</td>
<td>-0.01</td>
<td>0</td>
</tr>
<tr>
<td>Textile, clothing and leather</td>
<td>-0.01</td>
<td>0</td>
</tr>
<tr>
<td>Energy</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chemistry</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Machinery and transport equ.</td>
<td>+0.01</td>
<td>+0.01</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>+0.01</td>
<td>+0.01</td>
</tr>
<tr>
<td>Services</td>
<td>+0.015</td>
<td>+0.015</td>
</tr>
</tbody>
</table>

Under this approach, the evolution of the future sectorial outputs has been estimated for each case study. Following figures (graphs 4.24., 4.25. and 4.26.) show the final forecasted trends obtained for Spain, Poland and the UK. By using these data, the next phase of this analysis consists on the definition of the expected IO tables for the following years, which is addressed by means of the RAS method that was explained in detail in section 3.5.2.
Graph 4.24. Output growth by sector in Spain from 2007 to 2020. (Index 2007=100)

Graph 4.25. Output growth by sector in Poland from 2007 to 2020. (Index 2007=100)
As a reminder, the RAS method is thought to update the IO direct input coefficients on the basis of three pieces of information for the horizon period: total gross outputs, total interindustry (intermediate) sales from sector $i$ to the rest of sectors and total interindustry purchases. In order to apply this methodology, this research work assumes that the expected future trends of these three types of data are the result of multiplying the sectorial data in 2013 by the growth rates obtained through equation 4.9, which are shown in the following table.
### Table 4.5. Forecast sectorial growth rates in Spain, Poland and the UK, from 2013 and 2020

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SPAIN</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food, beverage and tobacco</td>
<td>1,0083</td>
<td>1,0196</td>
<td>1,0025</td>
</tr>
<tr>
<td>Mining and construction</td>
<td>0,9982</td>
<td>1,0094</td>
<td>1,0025</td>
</tr>
<tr>
<td>Textile, clothing and leather</td>
<td>0,9982</td>
<td>1,0094</td>
<td>1,0025</td>
</tr>
<tr>
<td>Energy</td>
<td>1,0083</td>
<td>1,0196</td>
<td>1,0025</td>
</tr>
<tr>
<td>Chemistry</td>
<td>1,0083</td>
<td>1,0196</td>
<td>1,0025</td>
</tr>
<tr>
<td>Machinery and transport equipment</td>
<td>1,0184</td>
<td>1,0298</td>
<td>1,0126</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>1,0184</td>
<td>1,0298</td>
<td>1,0126</td>
</tr>
<tr>
<td>Services</td>
<td>1,0234</td>
<td>1,0349</td>
<td>1,0176</td>
</tr>
<tr>
<td><strong>POLAND</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food, beverage and tobacco</td>
<td>1,0261</td>
<td>1,0339</td>
<td>1,0287</td>
</tr>
<tr>
<td>Mining and construction</td>
<td>1,0158</td>
<td>1,0236</td>
<td>1,0287</td>
</tr>
<tr>
<td>Textile, clothing and leather</td>
<td>1,0158</td>
<td>1,0236</td>
<td>1,0287</td>
</tr>
<tr>
<td>Energy</td>
<td>1,0261</td>
<td>1,0339</td>
<td>1,0287</td>
</tr>
<tr>
<td>Chemistry</td>
<td>1,0261</td>
<td>1,0339</td>
<td>1,0287</td>
</tr>
<tr>
<td>Machinery and transport equipment</td>
<td>1,0363</td>
<td>1,0443</td>
<td>1,0390</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>1,0363</td>
<td>1,0443</td>
<td>1,0390</td>
</tr>
<tr>
<td>Services</td>
<td>1,0415</td>
<td>1,0494</td>
<td>1,0441</td>
</tr>
<tr>
<td><strong>UNITED KINGDOM</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food, beverage and tobacco</td>
<td>1,0085</td>
<td>1,0214</td>
<td>1,0180</td>
</tr>
<tr>
<td>Mining and construction</td>
<td>0,9984</td>
<td>1,0112</td>
<td>1,0180</td>
</tr>
<tr>
<td>Textile, clothing and leather</td>
<td>0,9984</td>
<td>1,0112</td>
<td>1,0180</td>
</tr>
<tr>
<td>Energy</td>
<td>1,0085</td>
<td>1,0214</td>
<td>1,0180</td>
</tr>
<tr>
<td>Chemistry</td>
<td>1,0085</td>
<td>1,0214</td>
<td>1,0180</td>
</tr>
<tr>
<td>Machinery and transport equipment</td>
<td>1,0186</td>
<td>1,0317</td>
<td>1,0282</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>1,0186</td>
<td>1,0317</td>
<td>1,0282</td>
</tr>
<tr>
<td>Services</td>
<td>1,0388</td>
<td>1,0419</td>
<td>1,0384</td>
</tr>
</tbody>
</table>

### 4.4.1.3.2 Road freight transport intensities: expected trends in Spain, Poland and the UK

According to the transport model proposed in this research work, in addition to the IO tables, the estimation of future transport volumes requires data on the expected road freight transport intensities values.
As seen in previous chapters of this work, road freight transport intensity depends on the evolution of a set of key variables that vary across countries depending on the evolution of logistics, technology and the use of transport resources.

The past evolution of these ratios in the three case studies—which are freight intensity, modal split, length of haul, empty running and load factor—has been analysed in section 4.2.1.3. After that, this section tries to provide an estimation of the most likely behaviour of such variables in the future years in Spain, Poland and the UK.

To that end, it is taken into account that the future values depend on the recent trends followed by each one of these ratios. In addition, along this work, it has been emphasize that the implementation of new policy measures—e.g. those aimed at shifting away from road to rail—together with the development and innovation of new production processes or new transport systems may contribute to change the expected trends.

Within this context, to carry out the forecasting exercise of road freight transport intensity values, it is proposed a time series analysis method in the form of an Auto-Regressive Moving Average (ARMA) model. The boundary conditions of this analysis are based on two general assumptions: (1) after the period of economic recovery lived in EU countries, road freight transport intensity will tend to stabilise in both the UK and Spain; and (2) road freight transport intensity will experience the greatest changes in Poland following the most recent past trends. This last assumption is motivated by the idea that Poland, as an emerging country, will seek more efficiency in transport activities. At the same time, length of haul will continue to increase as international transport is likely to gain more importance in the future (partly due to globalization trends).

In the statistical analysis of time series, autoregressive–moving-average (ARMA) models provide a description of a (weakly) stationary stochastic process in terms of two polynomials, one for the autoregression and the second for the moving average. An Auto-Regressive (AR) component is able to exploit relevant information related to the autocorrelated nature of the time series—that means that the output variable depends linearly on its own previous values—, and a Moving Average (MA) model which is able to incorporate information from additional sources of information generally denominated “inputs”.

The notation ARMA(p, q) refers to the model with p autoregressive terms and q moving-average terms. This model contains the AR(p) and MA(q) models. ARMA models are trained by means of an optimization procedure aiming at minimizing the fitting error within selected training data set. A general form for an ARMA estimator is as follows:
where $X$ is the time series to be predicted, $p$ and $q$ are the orders of the auto-regressive and moving average models, respectively, $t$ is the time index for each time series, and $\varphi_i$ and $\theta_i$ re the model coefficients that have to be computed during the training phase, $c$ is a constant and $\epsilon_t$ is an error term.

In this analysis, each one of the ratios related with road freight transport intensities has been described by an ARMA model by using the history data for training the models. At this way, the estimations of future trends are shown in following graphs:

**Graph 4.27.** Historic and forecasted trends of the key ratios related to road freight transport intensities in Spain from 1999 to 2020 (Index 2004=100)

**Graph 4.28.** Historic and forecasted trends of the key ratios related to road freight transport intensities in Poland from 1999 to 2020 (Index 2004=100)
4.4.1.3.3 Future road freight transport volumes in Spain, Poland and the UK

After estimating the expected trends of all the key drivers of road freight transport volumes until the horizon year 2020, it is possible to define the future transport volumes by applying the proposed extended IO model for each case study. That is, future annual volumes of tonnes, tonne-kms and veh-kms in Spain, Poland and the UK are calculated by means of the formulation $T = RFTI^* (I - A)^{-1} f$.

For each year—from 2013 to 2020—$f$ is the final output estimated in this section as the sum of sectorial output described above, $(I - A)^{-1}$ is the Leontief matrix that has been calculated by applying the RAS method and $t$ is the estimated RFTI value, that depending on the type of transport unit analyzed it is calculated in the following way:

- $RFTI^* = \frac{\text{tonnes}_{\text{road}}}{\text{output} (\$)} = [\text{freight intensity} \times \text{modal share}]$ for tonnes estimations.

- $RFTI^* = \frac{\text{tonnes-\text{kms}_{\text{road}}}}{\text{output} (\$)} = [\text{freight intensity} \times \text{modal share} \times \text{average length of haul}]$ for tonne-kms estimations.

- $RFTI^* = \frac{\text{veh-\text{km}_{\text{road}}}}{\text{output} (\$)} = [\text{freight intensity} \times \text{modal share} \times \text{average length of haul} \times \text{load factor} \times \text{empty running}]$ for vehicles-km estimations.

With this approach, next graphs (4.30., 4.31. and 4.32.) show the expected trends obtained in each one of the case studies.
According to these results it is seen that, as a whole, road freight transport volumes are expected to grow during the following years driven mostly by the forecasted economic recovery. In the cases of Spain and the UK, the expected growth of tonnes is no so marked as for tonne-kms due to the forecasted freight intensity and modal share decline slightly. In contrast the increase in the average length of haul causes greater growth rates of tonne-kms and veh-kms.

The case of Poland show different trends. In this country the forecasting analysis leads to positive growth rates only for tonne-kms while both tonnes and veh-kms remain stable or even slightly decline in final years. This is a consequence of, on the one hand, the expected services expansion, and, on the other, the expected improvement in the efficiency when using transport resources in this country.

Graph 4.30. Historic and forecasted trends of real GDP and transport volumes in Spain from 1999 to 2020. (Index 1999=100)

Graph 4.31. Historic and forecasted trends of real GDP and transport volumes in Poland from 1999 to 2020. (Index 2004=100)
4.5. Summary of the results

This chapter has described different analyses aimed at understanding the potential of decoupling. Concretely, these have been applied to three EU countries: Spain, Poland and the UK, based on which it is possible to highlight different issues.

Firstly, it has been seen that there exist significant differences between the road transport trends observed across European countries. According to the analysis, the UK has been the most notable case of decoupling, partly due to the fact that its economic growth has been mostly concentrated in service sectors, and partly, to the progressive sustainable transformation of its transport system.

These trends have not been so identified in the other cases. The construction boom in Spain has been the main cause of the increase of traffic observed in this country. In Poland, its dependence on primary sectors along with the increase of international haulages have prompted high growth rates recorded of transport volumes.

On the other hand, the results show the effectiveness of different measures or structural changes in modifying coupling trends. For instance, it has been shown that the dematerialization of the economies play a key role prompting decoupling levels.

Minor improvements in the reduction of empty running or the increase of load factors have been noted to be essential to achieve decreases in the final traffic in a country. In contrast, minor reductions in road share are not decisive to reduce traffic volumes. To succeed in limiting road transport growth by these last types of split measures, the shift away from road
to other modes should be significant enough, higher than 2% per year. However, it is noted that if road mode continues to gain importance, veh-km may be expected to greatly increase (as has been proven in the case of Poland).

Finally the forecasting analysis carried out led to conclude that transport volumes are expected to grow in the next years, mainly due to the economic recovery of EU countries. However this growth will be modest compared with the economic expansion as a consequence of the progressive dematerialization of the EU economies. In addition different improvements in logistics and transport operations could also contribute to constrain traffic levels in the future.
5. CONCLUSIONS AND POLICY GUIDELINES

After the development of this research work, this final section aims at providing a set of concluding remarks along with some policy recommendations to the EU Member States.

To that end, the first section of this chapter lists the main findings of this project and draws the main conclusions from both the literature review process and from the set of analysis carried out in chapter 4. Finally, the second section explains the policy implications of coupling and decoupling trends in order to suggest some possible actions that could be taken by EU countries. These actions are thought to promote the economic development while limiting the road freight transport growth.

5.1. Main findings

This research project has intended to identify the key drivers of road freight trends and also to measure their potential effect over time. The ultimate goal of this study is to determine the most effective policy measures to promote the decoupling between road freight transport and economic growth in EU countries. To that end, it has been developed a new methodology on the basis of the Input-Output (IO) model. This approach allows to analyse the influence of the evolution of the economies on road freight transport volumes. That is to say, IO method allows to analyse how the expansion or the economic downturn of different sectors contributes to increase/decrease road freight volumes in a country.

As seen throughout this study, IO information can be combined with logistical and modal indexes to analyse also how the evolution of this aspects modifies transport patterns.
The literature review and the results obtained in previous sections by means of the methodology adopted have led to the highlights listed below:

(1) The global volumes of road freight transport recorded in a country depend on the volumes of gross outputs exchanged among its economic sectors and with other countries. New technological innovations, new production processes and variations of the goods demanded in a country between two periods can cause restructuring processes of the economy that may increase/decrease these gross outputs. These effects contribute to modify national and international transport patterns.

(2) Among all the economic sectors of an economy, it is possible to distinguish between transport-intensive sectors like agriculture or mining—that is, sectors that require many exchanges of goods with other sectors for their production processes, and therefore many shipments of commodities— and non-transport-intensive sectors like services. Within this context, economic sectors can be characterized by means of the “road freight transport intensity” index, that provides a measurement of the volume of road transport related to sectorial production, i.e., tonne-kms or veh-km per unit of sectorial output.

(3) Those countries evolving to service-oriented economies show higher levels of decoupling between freight transport growth and economic growth. That is to say, freight traffic grows at lower rates than economy. In contrast, in those economies predominantly based on primary and secondary sectors, such as agriculture, construction or manufacturing, freight transport demand usually couples with economic expansions.

(4) The value of sectorial road freight transport intensities in a country depends on several technological, logistical and organizational factors of production processes and transport operations. For instance, it depends on the mix and value of produced goods, the design of the supply chains, the location of production and consumption centres, the modal split and the effectiveness in using transport resources. The divergences among countries together with the temporal evolution of these factors lead to very different sectorial road freight transport intensities values across countries and over time.

(5) In order to define global road freight transport volumes in a country it is necessary to take into account two types of information: (i) the levels of national economic output and the needs for exchange of goods between sectors and with other countries—that is, the level of economic activity and the economic structure, which can be known from Input-Output tables —; and (ii) the sectorial road freight transport intensities.
The analysis of the coupling and decoupling contributions of different factors on road freight transport allows to identify several common patterns and also several divergences across the EU case studies of this work:

- As a whole, the growth of GDP and imports in Europe has contributed to increasing road freight transport demand. This is reasonable in view of the fact that the greater the economic activity and trade, the higher the freight transport volumes. However, the positive decoupling trends can be explained by several factors: technological changes are prompting new sector linkages in production processes, thus reducing road transport needs; the transition to more service-oriented economies has also led to a decline in road freight traffic; and the pursuit of transport efficiency has had the effect of reducing total road freight transport volumes in Europe.

- The expansion of international transport and cabotage during the last few years has played a key role in increasing road freight volumes reported by countries like Poland. In addition to increase the number of tonnes moved across Europe, this trend has also caused higher levels of the road share.

- Among all the decoupling contributions found in this work, it is highlighted that the most effective one in constraining road freight traffic growth during last years has come from the evolution of road freight transport intensities in the EU countries, mainly due to the new distribution of supply chains and to increased efficiency in transport resources. However, this effect has been proven to be more effective in some countries like the United Kingdom than in others like Poland.

The simulation analysis of alternative scenarios developed in this work has allowed to check the effectiveness of different economic, structural and logistical changes on the promotion of decoupling between road freight transport and economic development:

- The economic restructuring processes in national economies play a significant role in determining final road freight transport volumes. For the same global GDP growth, very different road transport volumes could be expected depending on the type of economic activity in a certain country. In this respect, the progressive dematerialization of the economies thought the expansion of service activities seems to be a key driver of decoupling trends, even leading to negative elasticity values of traffic to GDP in some EU countries.

- Prompting efficiency in transport operations is essential for achieving reductions of final traffic levels in a country. Even small improvements when using transport
resources—whether by raising the load capacity of trucks or by reducing empty running—can lead to notable reductions of road freight traffic.

Certain measures, such as modal shift actions, could be ineffective for decoupling unless significant volumes of transport can be shifted from road to other modes.

This project has helped to lay the basis for developing a transportation model to predict how some policies or economic changes would affect road freight transport evolution. Looking ahead to the near future, the expected economic recovery in EU countries is likely to contribute to increase final transport volumes across Europe. However, it is highlighted that the progressive dematerialization of the economies of developed countries, even experienced today by emerging countries, may constrain the road transport growth rates. This decoupling trend can be also encouraged by improving the efficiency in transport operations both within and outside EU countries.

5.2. Policy Implications of Coupling and Decoupling

From the point of view of sustainability, one of the serious concerns for the EU countries is that the predominance of road mode in inland transport continues to cause large adverse impacts on environment and human health due to greenhouse gas emissions, local air pollution, noise and congestion. The road transport activity also involves significant externalities associated with accidents, as well as high depletion rates of non-renewable resources (mainly fossil fuel).

Within this context, it is important to note that there are certain factors that can influence the final road freight traffic trends. All of these factors can be defined in the contexts of coupling or decoupling relationships between road growth and economic development.

Road charges, investment in new technologies as well as decisions in land use and transport planning have notable impacts on the mobility patterns of goods, and therefore in the final levels of transport externalities. As a consequence of this, improving the efficiency of transport operations, by reducing the road traffic levels requires the attention of governments authorities and investors, particularly in developing countries.

This section suggests some policy options aimed at reducing the effects of the coupling factors and improving the decoupling effects. As shown in this working paper, from decomposing analysis, it became possible to identify the main contributors of decoupling trends, named key drivers of decoupling—which are mainly the dematerialization trends of the economies and
the reduction of sectorial road freight transport intensities—. Thus, several practices are suggested in order to provide some sustainable policy guidelines for increasing the effect of these drivers in the EU countries.

- **Economic structure changes.** Increasing the share of the service sector in the GDP can reduce transport intensity. When the economic growth is driven by tertiary sectors, the number of trips necessary to satisfying the demand of economic growth in term of transportation can be reduced. Therefore, further investment in service activities could promote the economic development of a country without necessarily leading to increase transport volumes.

- **Investment in new production processes and technologies.** The introduction of new technologies may contribute dematerialize production processes. Dematerialization may be the result of structural changes, but also of technological innovations that can contribute to improving processes and product designs by requiring fewer amounts of certain inputs to produce articles of the same quality. Policies involving investment in new techniques to upgrade production processes and new materials may change both backward and forward sector linkages and may ultimately reduce freight transport needs. On the other hand, it is noted that the introduction of certain innovations such as 3D printing in the industry of EU countries may have a profound effect on the demand for transport, as this type of technologies avoid trips to the final consumers, which are usually made by road. In the future, such technology could also contribute in the future to decrease international transport of those goods produced only by specific countries.

- **Logistic solutions.** The increasing use of logistic data and ICT solutions by the Member States’ industries may contribute to optimize the transport management of the entire transportation chain by using freight travel information. This may serve to reschedule the transport operations, to better manage cargo and capacity management, and also to promote intermodal transport. Other logistic solutions like the optimized relocation of production units may reduce the final travelling distances across Europe.

- **Modal shift actions.** These actions are aimed at shifting freight traffic from road to other more environmentally-friendly modes like railway. To that end, as it has been promoting by the European Commission during last decades, some measures could be applied in the European Member States. Some of them may be: reinforce the rail infrastructure and international freight rail market, further investment in the improvement of the technologies of alternative modes, and apply road charges, among others. Within this context it is worth noting that the European focus has recently changes from intermodal transport to the concept of co-modality. The promotion of transport hubs where all
transport modes are offered alongside one another may contribute to the best use of each one of these modes depending on the destination, the type of goods and on the turn-around time. The proper management of these centres may facilitate that some transport volumes could be shift away from road.

The development of this research project has shown that these types of modal shift measures have not been effective enough to promote the decoupling trends in any European country. The results of this work suggest that in order to change this situation it is necessary to fulfil many of the proposed actions to considerably reduce the road market share.

**Land-use and transport planning.** Another policy that may play a role in reducing road freight transport intensity is encouraging land-use planners to locate production and consumption hubs closer to each other. Transport distances and modes depend on the spatial organisation of the supply chains, so spatial policies may be a means of creating mixed-use areas that bring producers —and consumers— in the chain into closer proximity, thereby decreasing derived demand. The reduction in the spatial ranges of production networks entails fewer requirements for road transport and shorter haulage lengths. In addition, the promotion of co-modal hubs mentioned above could aid to share traffic efficiently between modes. In that sense, planning properly the transport network connecting these hubs with production and consumption centres is essential.

**Fiscal and economic instruments.** They can be used to shift traffic to other modes. In addition, taxes for road freight transport could encourage the companies to promote the use of vehicle with high capacities or reduce empty running. These taxes could be applied along with subsidies given to companies that use alternative modes. This measures may lead to a reduction of road freight intensity and therefore to higher decoupling levels.

**Regulatory instruments.** Restrictions or prohibitions of truck traffic in some highways may promote the use of alternative modes in some corridors. Other restrictions could be applied to avoid the traffic of trucks with low load capacity.

**Technological improvements in the road transport sector.** One of the findings of this research is that minor improvements in the use of transport resources —by means, e.g., of increasing the trucks’ capacity— can highly promote decoupling trends. So, research and development to promote higher trucks and new handling systems to use the load-capacity is essential to make more efficient the haulage off freight by road.
Different aspects characterize the main points related to the potential of decoupling and therefore to sustainable freight transportation. They encompass the efficient use of transport resources and modes, the planning of supply chains and transport infrastructure and the improvement of the existing ones by defining their role in the EU Corridors. In this regard, the set of measures and actions mentioned above are aimed to providing guidelines to EU Member States to promoting decoupling trends in the near future.
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References


