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CO_2 Emission Reduction in Freight Transports How to Stimulate Environmental Friendly Behaviour?

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Non-technical Summary

According to the Intergovernemental Panel on Climate Change (IPCC) it is not only the energy intensive industry who should contribute to CO_2-emissions reduction. Especially the transport sector as one of the major CO_2-polluters should play a dominant role in reducing emissions. Because of the induced demand of freight transport services by economic activities of the industry and with respect to the Lisbon strategy of the EU, measures should be implemented that help to reduce emissions without cutting economic developments. The most promising measure to reach a substantial emission reduction by simultaneously allowing transport growth is to use environmental friendly modes. In practice, this means to shift transport demand from the road to rail or ship.

However, direct access of companies to the railway network or to waterways declined fast within the last two decades. Thus direct train or ship services are rare. Pre- and post-haulage by truck is needed to provide a door to door freight transport service. Hence, access to multimodal terminals and their connections to other terminals are major aspects in the discussion on modal shift. They do not only affect the quality but also the environmental performance of combined vs. unimodal truck transport. Besides the access to terminals other supply side indicators like the trip duration, reliability, flexibility or transport prices are relevant for the mode choice decision, too. Further indicators influencing the mode choice behaviour refer to demand side aspects of the transport process. Requirements of the shippers like e.g. the departure/arrival date and time at the shipper's/receiver's company have an impact on the choice decision.

The methodological framework of this analysis is an empirical survey. On the basis of interviews we assess the mode choice behaviour for a typical transport of the interviewed forwarder. The survey was carried out via computer assisted telephone interviews. The comprehensive questionnaire of this survey captures all relevant aspects of the selected transport process. Based on the explanation of the revealed mode choice we assess two policy measures aiming to shift transport demand from truck to combined transport. Based on this analysis we quantify the potential CO_2 emission reduction by the changing mode choice.

The studys show that quality and price attributes are of utmost importance for the mode choice decision. However, the demand for combined transport services is very inelastic and cannot be influenced substantially when the political measure is just marginal. Looking at the two policies analysed in this paper we see an advantage of price measures compared to structural and technical measures to improve service quality of combined services. However, both policies have just weak impacts on the emission reduction. While the road user charge increased the demand for combined transport services by about 2 percentage points, the emission reduction is just about 1%. In case of service quality the effect is even worse. A tremendous change of service quality leads to an 8 percentage point increase of combined transport demand and to a CO_2 emission reduction of just about 4 %.

Das Wichtigste in Kürze

Gemäß des Intergovernmental Panel on Climate Change (IPCC) sollen auch Sektoren, die nicht am europäischen Emissionshandelssystem beteiligt sind, vermehrt zur Reduktionen der Treibhausgasemissionen beitragen. Dem Verkehrssektor kommt dabei eine zentrale Bedeutung zu. Die Nachfrage nach Güterverkehr wird jedoch durch die Produktnachfrage der verarbeitenden und produzierenden Industrie induziert. Im Hinblick auf die Lissabon-Agenda der Europäischen Union ist eine Reduktion der Transportnachfrage ohne Berücksichtigung des Zusammenhangs mit anderen Wirtschaftsaktivitäten deshalb nicht durchsetzbar.

Eine realistische Option zur Emissionsreduktion im Verkehr stellt die Verlagerung des Verkehrs auf umweltfreundlichere Verkehrsmittel dar. Maßnahmen zur Verkehrsverlagerung ermöglichen eine steigende Wirtschaftsaktivität bei gleichzeitiger Reduktion der Verkehrsemissionen. Eine Verlagerung auf den unimodalen Schienen- oder Binnenschiffsverkehr ist jedoch kaum möglich. Eine Lösung stellt deshalb der kombinierte Verkehr dar, der gegenüber dem Lkw bei in den meisten Transportfällen ökologisch vorteilhaft ist.

In dieser Arbeit wird auf Grundlage einer empirischen Untersuchung das Verkehrsmittelwahlverhalten von Spediteuren untersucht. Anhand ausgewählter Transporte wird das Entscheidungsverhalten der befragten Unternehmen abgebildet und mit Hilfe eines diskreten Entscheidungsmodells erklärt. Die durch den Transport emittierten CO2 Emissionen werden für die entsprechenden Verkehrsmittel über den jeweiligen Energieverbrauch und den Kohlenstoffgehalt der eingesetzten Energieträger bestimmt. Aufbauend auf den Ergebnissen zum Wahlverhalten der Spediteure werden zwei Politikmaßnahmen hinsichtlich ihres Verlagerungspotenzials zugunsten des kombinierten Verkehrs analysiert und die damit verbundenen CO_2-Emissionseinsparungen quantifiziert. Zum einen wird der Einfluss der leistungsabhängigen Schwerverkehrsabgabe und zum anderen der einer Erhöhung der Transportgeschwindigkeit auf der Schiene auf die Nachfrage nach kombinierten Verkehren bestimmt.

Generell zeigen die Ergebnisse der Untersuchung, dass die Wahlwahrscheinlichkeit des kombinierten Verkehrs relativ unelastisch ist. Eine deutliche Verlagerung zum Vorteil des kombinierten Verkehrs lässt sich somit nur durch eine substantielle Veränderung der Einflussfaktoren der Wahlentscheidung erreichen. Während Qualitätsmerkmale wie die Taktung des kombinierten Verkehrs oder die Existenz eines Direktverkehrs für die Wahlentscheidung nur von geringer Bedeutung sind, spielen die Transportkosten und die Transportdauer beider Verkehrsmittel eine zentralere Rolle. Durch eine Veränderung dieser Leistungsmerkmale lässt sich folglich die Nachfrage nach den verschiedenen Verkehrsmitteln verkehrspolitisch lenken.

Die Simulation beider Politikmaßnahmen zeigt, dass sich die Wahlwahrscheinlichkeit des kombinierten Verkehrs nur geringfügig ändert, obwohl sich die Transportdauer der kombinierten Verkehre durch die Erhöhung der Transportgeschwindigkeit im Schienenverkehr in der zweiten Simulation substantiell verringert. Dementsprechend gering sind auch die Auswirkungen beider Maßnahmen auf die CO2 Emissionsreduktionen. Die Verringerung der Transportdauer führt sogar dazu, dass Transporte nun kombiniert betrieben werden, die ökologisch unvorteilhaft sind.

CO_2 Emission Reduction in Freight Transports

How to Stimulate Environmental Friendly Behaviour?

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Abstract. *In the European Union (EU) and in Germany the transport sector is the only sector with increasing CO_2 emissions (in the EU by about 32 % and in Germany by about 1 % since 1990). Especially in road freight and air transport a further strong increase is forecasted. In the transport sector this might be impeded by avoiding transport (accepting a lower economic growth), shifting modes or in optimizing logistics. Especially the second is mentioned to be an adequate solution to meet the increasing demand for transportation and reducing CO_2 emissions simulatneously. It is often stated, that combined transport (mainly truck-train-truck) might be a very CO_2 efficient mode. In this article a Logit-Model (based on a survey of 500 German forwarders) is used to determine mode shift potentials of hauliers. The main factors of influence depending on the service provision of the transport modes are frequency of combined transport services, speed, and costs. For an estimation of the corresponding impact on the mode shift and thus potentials of CO_2 emission reductions two policy instruments are empirically tested: a further increase of the performance-based heavy vehicle fee (LSVA-Maut) and a hypothetical speeding up of the average speed in freight rail transport to 80 km per hour. Although the modal shift is rather high in the last policy simulation, the impact on CO_2 emissions is still small.*

Key Words: Freight Transports, CO2 Emissions, Mode Shift, Combined Transport
JEL classification: C53, Q54, R48

1 Introduction

The necessity of climate protection has thoroughly pointed out during the last few years. The calculated economic damage resulting from climate change will be exceedingly high if human race will not act immediately (HM Treasury, 2006). Hence, the Intergovernemental Panel on Climate Change (IPCC) amplifies the demand for complying with the emission reduction agreements in the Kyoto Protocoll. According to IPCC, all sectors (even if they do not participate in the European Emission Trading Scheme (ETS)) should contribute to reducing CO_2-emissions (IPCC, 2007). Especially the transport sector as one of the major CO_2-polluting sectors should play a dominant role in reducing emissions. About 30 % of the 2004 overall CO_2-emissions in the European Union (EU) are generated by transportation (European Commission, 2006a). Contrary to all other sectors, the emissions from the transport sector are still growing. Consequently, it is the only sector where the expulsion of CO_2 nowadays is higher than in the base year of the Kyoto agreement in 1990 (see FIGURE 1, European Commission, 2006a and Ziesing, 2007).

The growth in emissions results from an increasing demand for transport activities in passenger and especially in freight transport. Between 1990 and 2005, freight transport in Europe rose by 90 %. In the same period the demand for road freight transport as the major polluter of all land based transport modes increased even more (by 138 %). Consequently, the contribution of road freight transport to the direct CO_2-emissions is 20 % (BMVBS, 2007 and European Commission, 2007).

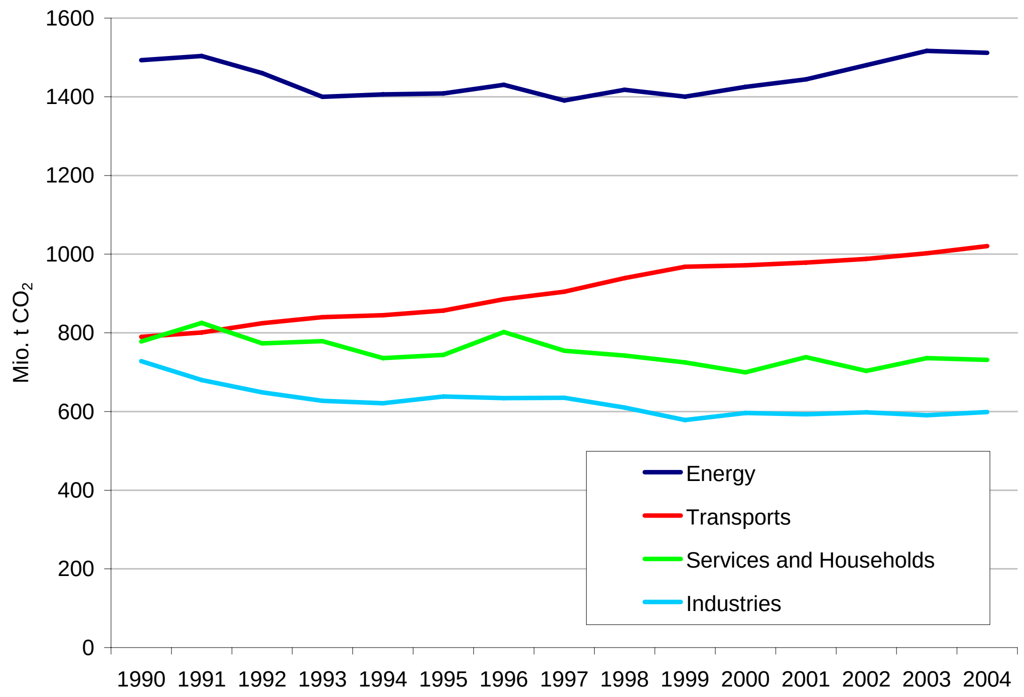

FIGURE 1 Sectoral development of the greenhous gas emissions in the EU25 between 1990 and 2004 (3).

For the coming years a further rapid growth in freight transport demand is predicted (ProgTrans, 2007). Nevertheless the Federation of German Industries sees a high reduction potential in the transport sector (BDI, 2007). Given economic effectiveness of measures and a price of 20 Euro/t CO2 the transport sector can cut down emissions substantially by 28 million tons (European Commission, 2001). Even the road freight transport can cut down emissions by 9 million tons in 2020 just by carrying out economically reasonable investments.

In order to stipulate this reduction potential, politics want to take measures to develop an environmental friendly transport sector. Because of the correlation between transport demand and economic performance (Rommerskirchen, 1999) and with respect to the Lisbon strategy of the EU, measures should be implemented that help to reduce emissions without influencing economic developments. According to the revised White Paper of the European Commission on the transport policy for 2010 (European Commission, 2006b) effectiveness and efficiency of policy measures should be assessed before implementing them into practice.

According to the targeted linkage, environmental measures can be classified into two categories. Firstly, there are instruments decoupling economic and transport activities. Secondly, instruments aim at decoupling transport activities and their environmental load (see Figure 2). Within the second group of instruments another classification can be made. One solution is to shift demand from very polluting to less polluting transport modes. The other solution is to reduce emissions by being more energy efficient in the use of the respective modes. Instruments belonging to latter category are the purchase of energy efficient vehicles, the increase of load factors or the optimisation of the route choice. The following graph illustrates the approaches.

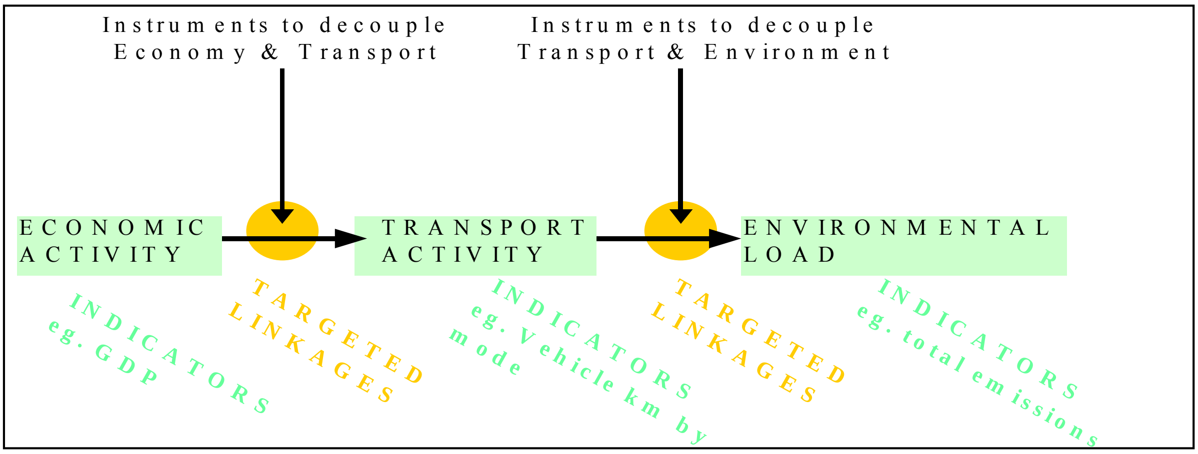

FIGURE 2: Approaches to decouple transport demand and environment (ITS, 2002).

Transport demand is induced by the demand for products from the manufacturing industry and retail market (Rommerskirchen, 1999). From an economic point of view it is therefore not recommended to implement measures to avoid freight transport. Such measures are economically inefficient and would counteract the Lisbon strategy of the EU. Measures that intervene politically in transport logistics to carry out transportation in an environmentally friendly way are usually inefficient, too. Assuming that the climate costs are already internalised in the current fuel price (this is already the case in terms of their amount but not in terms of earmarking of funds) and considering that the fuel price is a main cost driver for service provision in road freight transport, there should be an intrinsic motivation for the carriers to reduce fuel demand, become more competitive and simultaneously behave ecologically.

Different modes however bear different taxes and cover different shares of their external costs (Doll and van Essen, 2008). In many studies road freight transport is stated to be a rather inefficient mode with regard to external costs. Hence, one major objective of the European Commission is to shift freight transport from road to rail or ship. The European Commission comprises 60 measures to prepare the transport sector for the expected future demand (European Commission, 2001). The action programme is divided in four sections – whereof the first section is about shifting the balance between modes and the third is about placing users at the heart of transport policy. The aspect of fair and efficient pricing is inclosed in the third section (European Commission, 2001). Summarized, in the issue of this paper it states that transport demand should shift from road to other land based modes.

However, the strategy of shifting demand from road to other modes became to some extent independent from the economic argumentation of internalising external costs. Shifting demand to other modes is something like the magic bullet for a green transport sector. Most of the measures in the White Paper are therefore not based on the argumentation of fair and efficient pricing but on the general statement to shift demand away from the road because of environmental benefits.

A shift of transport demand to rail or ship is neither useful nor possible for all transport activities. The direct access of companies to the railway network or to waterways exists only in a limit number of cases. In particular the number of direct accesses to railways declined strongly in the last two decades (in the 90s about one third) (BMVBS, 2007). Hence, direct train or ship services are very rare. Pre- and post-haulage by truck is therefore needed to provide a door to door freight transport service. As a result, access to multimodal terminals is a major aspect in the discussion about modal shift. Because of the wide-meshed network of intermodal terminals in Europe, combined transport is competitive only on long distance transport services. There, the CO_2 reduction potential of combined transport is very high compared to unimodal road transport. Railways as the major provider of main haulage transport services in combined transport have a CO_2 emission advantage per kilometre of about 60 % compared to road transport (see below). However, this advantage might be thwarted by the longer distance of the rail track on the main-haulage and the need for a pre- and post-haulage by truck. On aggregate, the gross effect of the CO_2 reduction potential is unclear and needs to be quantified for each single transport process (IFEU and SGKV, 2002).

In this paper we assess policy measures aiming at influencing mode choice decision and we quantify their effect on CO_2 emission reduction in freight transport. Based on a revealed preference survey of about 500 forwarders in Germany we identify the determinants of mode choice decision between trucks and combined transport by estimating a discrete choice model. Using the revealed preference survey, we further quantify the CO_2 emissions of each single transport process for unimodal truck and intermodal transport. Simulating the impact of a selected number of policy measures like e.g. the introduction and increase of the German road user charge means that we firstly assess the impact on the mode choice behaviour, secondly identify those transport processes where the forwarders would change the mode choice and finally quantify the CO_2 balance of the changing behaviour. In the second section of this paper we describe the survey design and the resulting database. The third section aims at describing the estimation results and the fourth section gives an overview about the policy measures and their impact on the mode choice decision and on the CO_2 emission balance.

2 Survey design and database

To encourage the shift to combined transport services it is necessary to know the stakeholder who is responsible for the mode choice decision and the decision factors which can be influenced through regulation measures. There is a vast literature on the question of mode choice responsibility (amongs others Browne and Allen, 2001). Depending on the kind of freight transport activity, the decision can be made by the shipper, the forwarder or by the carrier himself. According to Schulz et al. (1996) the organisation and therefore the mode choice decision in commercial freight transport is carried out by forwarders. They are the experts in transport logistics.

In the literature on mode choice decision, several determinants are identified. In general, these determinants can be classified into supply and demand side indicators (Bühler, 2006). Supply side indicators are determinants related to the service quality and price of the optional transport modes. Quality indicators are trip duration, reliability, flexibility or capacity. The category of demand side indicators varies remarkably from study to study, depending on its focus. In general, all requirements of shippers e.g. the departure/arrival date and time at the shippers'/receivers' company belong to this group of indicators (Miklius et al, 1976).

There is a broad literature on mode choice analysis in passenger transport. In freight transport however, there is only little. Most of this literature is based on a shipper's survey. Some analyse mode choice on a given transport corridor (Miklius et al, 1976, Jovivic, 1998), others don't (Bolis and Maggi, 2001, Schneider et al, 1996, Vellay and de Jong, 2003, Jiang et al, 1999). Only a few studies are available on mode choice of forwarders. They all have in common the focus on a given transport corridor (Golias and Yannis, 1998, Fosgerau, 1996 and BVU, 1999). To identify the potential for transport demand to be shifted from one mode to another it is necessary to consider all of different transport processes even those from country side to country side. This makes a country-wide analysis necessary.

The population of forwarders in Germany is about 8,500 companies whereof about 7,600 companies are located in West- and about 900 in East-Germany. Forwarders are usually small and medium sized companies. More than half of the companies have less than 10 employees, about 2,800 companies employ between 10 and 49 persons and only about 150 companies belong to the category of large firms (StaBu, 2004). For the purpose of this survey the classifycation according to the geographical location and size of the company is essential. Given the wide-meshed network of nodal points in East- and a relatively close-meshed network in West-Germany a different choice behaviour is to be expected. In addition, it is often stated that combined transport is only provided by larger companies. Therefore, a differentiation between small vs. medium and big companies is useful for this analysis. Furthermore, due to an allocation problem in the NACE classification of forwarders, the companies with less than three employees are excluded from the analysis. These companies are typically carriers and not forwarders (Bühler, 2006). The final population for the survey consists of 6,924 companies.

Table 1 illustrates the population of forwarders in Germany according to the two classification characteristics, the realised interviews and the number of interviews relevant for the given analysis. The survey was carried out as a computer assisted telephone interview (CATI). During these interviews the forwarders were asked to give detailed information about a typical transport process organised and/or carried out by the company. The aim of this survey is to get a representative sample for the revealed mode choice decision of German forwarders. It is up to the forwarder what he defines as a typical transport process for his company. Thereby he can refer to the frequency or regularity of the transport activity or to other attributes like the size and volume of the load, the transport corridor or other reasons.

TABLE 1 Population, realised interviews and relevant interviews for the analysis

		population N = 6,924			realised interviews n_1 = 716			relevant interviews n_2 = 498		
Employees		3-49	≥ 50	Sum	3-49	≥ 50	Sum	3-49	≥ 50	Sum
Companies' location	West	77.0%	11.8%	88.8%	66.9%	22.1%	89.1%	66.9%	21.9%	88.8%
	East	9.8%	1.4%	11.2%	7.8%	3.1%	10.9%	7.8%	3.4%	11.2%
	Sum	86.8%	13.2%		74.8%	25.2%		74.7%	25.3%	

Sources: 27 and own survey.

To get a detailed insight of the transport process it is necessary to develop a comprehensive questionnaire. Besides the framework conditions of the transport process and corridor it is important to consider price and quality of the optional transport modes. An overview of the mode choice determinants can be seen in Schulz et al. (1996). They classify in demand and supply side factors. While supply factors of transport sevices are price and quality of the service provision, the demand factors are the requested condition of the transport process by the shippers. Consequently, the questionnaire for the survey consists of eight sections.

In the first section the companies' transport structure is specified. The second up to the seventh section of the questionnaire refers to one special transport process which should be typically for the forwarders. While section two and three is used to describe the transport characteristics like the location of the consignor and the receptor, the distance travelled, the time of departure and arrival etc., the third section aims at providing information about the product carried on this trip. Sections four to seven are used to describe the transport corridor, the used transport mode, the related costs and quality aspects of the modes. Finally, section eight is used to specify the forwarders' company.

For the analysis of the mode choice decision of German forwarders 716 interviews were obtained whereof 498 were relevant for the econometric analysis. 218 interviews needed to be extracted from the sample. Some interviews do not belong to the category of long distance transport services which is in the focus of this analysis, others are excluded because either the transport corridor or the framework conditions of the service are not sufficiently specified. Finally some implausible interviews needed to be extracted from the sample.

Comparing the distribution of the population and the relevant interviews in Table 1 a small and statistically significant difference in the companies' size can be identified. This is done on purpose to allow estimating the mode choice behaviour for small and large companies separately and to allow identifying different behaviour of the two sub-groups. The population and the sample are equally distributed in respect to the companies' location. The share of forwarders from East-Germany is about 11%.

The existing dataset clearly shows the dominant position of road transport. 85.5 percent of the forwarders stated to use a truck for the respective transport process. 70 percent of them provide the transport service with their own trucks. Only 30% of them commission carriers. 14.5 percent use combined transport services whereof about 70% provide a combined road rail service. Multimodal services are relatively rare. 32% of the combined and 40% of the unimodal road transport services is carried out with the respective mode on request of the shippers. In the other cases, the forwarders were free in choosing the mode for the transport process.

Subject to the origin and destination of the transport process the shares of combined transport services vary substantially. While the share of combined transport on national corridors is about 6% in the survey, it is 26% on the main axes of combined transport via the Alps in the transport services with southern parts of Europe. Furthermore, the results of the study indicate a correlation between the trip distance and the share of combined transport services. The longer the trip distance the higher the share of combined transport service. In the category of 150 to 500 kilometres, the share of combined transport is about 6% while it is more than three times higher when the trip distance is longer than 500 km.

For a comparison of the two modes with respect to their CO_2 efficiency the generated CO_2 emissions by train and truck is estimated. Surprisingly, the difference for Germany is not as big as assumed. This is mainly based on the "CO_2 inefficient" energy source mix of the German rail operators. Which is about 33.6 % black coal, 13.2 % lignite, 8.6 % natural gas, 29.9 % nuclear power, 13.3 % regenerative energy sources and 1.4 % other energy sources (IFEU, 2008). This energy mix leads to an average CO_2 emission factor of electrified freight trains of about 10 kg CO_2 per train km. This value is similar for diesel driven freight trains. Assuming 28 loaded wagons (with two twenty-foot equivalent units – TEU) per train (BGL and IRU, 2002) an average emission of about 180 grams CO_2 per TEU can be indicated.

On the other side in average a loaded 40 t truck consumes about 39.2 l/100 km and an empty 40 t truck about 29.3 l/100 km in average (BGL and IRU, 2002). For the CO_2 comparison we calculate with an average fuel consumption of about 35.1 l /100 km and a diesel specific CO_2 content of 26.5g/l. Thus a truck emits about 930 grams CO_2 per km. When assuming two TEU per truck, about 460 grams per TEU km can be defined for road transport. When neglecting restrictions to permissible maximum weight for truck, its CO_2 efficiency is (only) about 2.5 times inferior compared to freight trains.

3 Mode choice behaviour

The mode choice of forwarders is estimated by using a binary discrete choice model for the choice decision between the two alternatives – namely truck and combined transport. To estimate the relevant attributes' impact, it is necessary to specify the latent utility function of the discrete choice model. In the literature we found four model specifications. While the sociodemographic and transport corridor related attributes are specified in a linear manner in all four models, the specification of the quality and price attributes varies. Two models are based on a linear, one on a logarithmic utility function and one is specified as a ratio between the attributed of the two modes (Miklius, 1976, Schneider et al., 1996, Mandel et al., 1994 and Golias and Yannis, 1998). We found that the linear specification of the model derives the best estimation result for this study's purpose.

The estimation results for the aggregated sample and two sub-samples (small and large companies) indicate the relevance of the respective attributes for the choice decision of combined transport. It turned out that the *trip distance*, *transport volume*, the *used loading unit*, *tracking and tracing arrangements* and the *period for the trip's organisation* have a significant impact on the choice decision for combined transport. Against common hypothesis the *share of commercial employees* in the forwarding company, *product characteristics* (fragil, hazardous or perishable goods), a *cooperating carrier at the destinatio*n of the trip, a *return trip on the corridor* and the requirement "*just-in-time*" have no significant impact on mode choice.

For the impact assessment of regulations, the quality and price attributes are of utmost importance. These attributes can be influenced by political interventions. The logistic regression shows that (a) the *frequency of service provision of combined transport* on the corridor, (b) the *trip duration of combined transport service*, (c) the *existence of a direct combined transport service*, (d) the *costs per kilometre of truck and combined transport* as well as (e) the *reliability of truck transport*[1] have a significant impact on the mode choice decision for combined services. All other attributes do not seem to be relevant for the decision of the forwarder. Of no relevance for the choice decision of combined transport services are *the trip duration by truck* and the *reliability of the combined transport service*.

Finally the estimation results indicate differences between large and small sized companies. There are two major results of the two separate estimations. Firstly, the same attributes are statistically significant for the mode choice decision of combined transport services for small and large sized companies. Some differences can be seen in the impact of the product specification, in the pairing of the trips, in the number of assignments on the respective corridor and in the share of commercial employees. Secondly, the estimates of the attributes differ in the case of small or large sized companies.

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[1] Reliability is an instrumental variable. It is calculated by dividing of the difference of the available time for the trip minus the transport duration by the available time for the trip. Because of the positive correlation between the available time for the transport process and the dependent variable the sign of the variable is contrary to what can be expected for the variable reliability of truck service.

TABLE 2 Estimation results for large and small companies

Attributes		Total (N=498)	Large companies (N=150)	Small companies (N=348)
Constant		-2.401*	1.070	-2.922*
Location of the company in Eastern Germany		-0.092	--	--
Number of employees		0.000	0.000	0.000
Share of commercial employees		0.509	-1.773	0.719
Trip distance		0.003*	0.009*	0.004*
Used loading unit is a trailer		-1.412*	-2.282*	-1.569*
Transport volume		0.049*	-0.006	0.054**
Product characteristics:	hazardous	-0.133	-0.509	-0.425
	Perishable	-0.091	-3.016*	-0.142
	Fragile	-0.380	0.352	-0.566
Service arrangements:	Storage and logistics	0.371	-0.381	0.527
	Tracking & tracing	-0.831*	-2.819*	-0.821**
	Liability of forwarder	-0.193	-0.322	0.006
	Fixed transport price	0.400	-0.767	0.444
Return trip on the corridor		-0.240	-2.306*	0.009
Cooperating company at the destination		0.046	-1.105	0.357
Number of assignments on the corridor		0.001	0.004**	0.002
Period for the organisation of the trip		0.005**	0.001	0.005**
Just-in-time transport process		0.002	-0.406	0.291
Frequency of service provision in combined transport		0.083*	0.172*	0.080*
Direct connection of the combined service		0.0675**	0.210	0.683
Duration of the combined transport service		-0.021*	-0.121*	-0.018**
Duration of truck transport service		-0.027	-0.074	-0.041
Costs per kilometre of combined transport service		-2.081*	-3.188*	-2.100*
Costs per kilometre of truck transport service		1.473*	3.329*	1.278*
Reliability of combined transport service		0.009	0.022	0.003
Reliability of truck transport service		-0.038*	-0.084*	-0.036*

* Significance level of 1%

** Significance level of 5%

Sources: Bühler (2006).

By using the estimation results, elasticities of mode choice decision for combined transport services can be quantified. Table 3 illustrates these elasticities for the most important indicators whcih have a statistically significant impact on the choice decision. A first important result of this analysis is the relatively inelastic demand for combined transport. This means that the choice decision of combined transport services cannot be influenced by political measures substantially when the political measure itself is just marginal. Only those measures that cause a remarkable change in the attributes' value might affect the choice behaviour considerably.

Another interesting result is the more elastic demand for combined services of small companies compared to large companies. The reason for this fact might be the higher market power of large companies which might influence the planning and the realisation of the transport process.

TABLE 3 Elasticities of mode choice decision for combined transport services

Attributes		Total	Large companies	Small companies
Share of commercial employees		–	-0.12	0.14
Trip distance		0.84	1.06	1.23
Used loading unit is a trailer		-0.38	-0.29	-0.51
Transport volume		0.33	–	0.44
Product characteristics:	Perishable	–	-0.05	–
Service arrangements:	Tracking & tracing	-0.24	-0.35	-0.30
Number of assignments on the corridor		–	0.03	–
Pairing of the trips on the corridor		–	-0.26	–
Period for the organisation of the trip		0.09	–	0.10
Frequency of service provision in combined transport		0,23	0.25	0.28
Direct connection of the combined service		0.09	–	0.11
Duration of the combined transport service		-0.46	-1.06	-0.48
Costs per kilometre of the combined transport service		-1.20	-0.89	-1.49
Costs per kilometre of the road transport service		0.74	0.78	0.80

Sources: Bühler (2006).

Attributes that are influenceable by policy measures are quality and price aspects of the service provision. Looking at Table 3 the major results for the mode choice decision are:

- An increase of the number of combined transport services on the respective corridor increases the demand for combined transportation. The correlation is very weak.
- The existence of a direct connection between the terminal near the consignor and near the recipient does only have a positive impact for small companies because small forwarders do not like to spend so much time on organising combined transport services having multiple transport chains.
- The elasticity of the trip duration of combined transport services is negative. Does the trip duration rise the demand of combined services will decline. This effect is almost twice as high for large forwarders as for small ones.
- Transport duration of road transport services has no impact on the demand for combined transport services. If policy measures would change the trip duration of trucks e.g. by extending the recovery time no impact on mode choice would be realised.
- Transport costs from road and combined transport services have an impact on the demand for combined transport services. While the impact of higher costs in road transport would have positive effects on the demand for combined services, the impact is negative when costs increase for combined transportation. The results of the estimation indicate higher elasticities for cost changes of combined transport services than for cost changes of road transport.

4 Policy measures to reduce CO2 emissions in the transport market

The mode choice decision can be influenced by policy measures that affect the quality or the price of the provision of transport services. Fiscal measures like taxes and charges are very common in freight transportation because politicians often try to pursue two objectives with one single measure. When the road user charge on German motorways became effective, politicians initially thought of two effects. Firstly, road carriers should pay for the use of roads as other transport modes already do. Secondly – and even more important for the political argumentation – the road user charge aims at contributing to the political objective to shift demand from road to other modes and therefore contribute to CO_2-emission reduction (BMVBS, 2003). As the German Federal Ministry for Transport, Buildings and Urban Affairs (BMVBS) is planning to increase the user charge the same arguments come up again (BMVBS, 2008).

In the past, the BMVBS already implemented several measures to improve the quality of the service provision (BMVBS, 2001). In its White Paper on transport policy (European Commission, 2001) the European Commission listed severalof measures which aim at promoting modal shifts to environmentally friendly transport modes in the future. To assess the environmental effect of both kinds of measures listed in the White Paper, we quantify the changes in mode choice decision resulting from the implementation of the road user charge in Germany and from a bundle of measures that together aim at increasing the average speed of rail services to 80 km/h (50 mph).

4.1 Road user Charge

The road user charge was implemented in Germany in 2005. The charge is levyed on motorways and on selected by-passes. Trucks with a gross vehicle weight of more than 12 tons have to pay the charge depending on the number of axes and on the emissions (BMBF, 2001). The charge is in a range of 9 to 14 Euro-Cent per kilometre. The European Commission proposed to raise the average rate of 12.4 to 15 Euro-Cents per kilometre in the coming years.

Table 4 illustrates the average cost increase per kilometre due to the introduction of the road user charge for the survey sample. The percentage changes are given for the unimodal road transport, the pre- and post-haulage by truck of the combined transport and for the entire combined transport service. The table shows increasing costs not only for the truck but also for the combined transport service. While the costs grew by about 7% on average of all truck transport processes in the sample, they raise only marginally in combined transport services because of the relatively short distance they cover on motorways on the pre- and post-haulage. Consequently, the cost increase in the pre- and post-haulage is 2.4% and on the the entire combined transport service about 0.8%.

TABLE 4 Elasticities of mode choice decision for combined transport services

Increasing costs due to road user charges on German motorways	Unimodal truck transport	Combined transport	
		Pre- and post haulage	total
N=498	7.34%	2.40%	0.75%

Sources: Bühler (2006).

The individual cost increases vary substantially between different transport processes depending on the kilometres coverd on German motorways. Consequently, the elasticities displayed in Table 3 would give unrealistic changes in mode choice and would lead to very rough estimates for the emission reduction. Therefore, we decided to use a four step approach to assess the impact of the road user charge on mode choice and on the emission reduction resulting from changing mode behaviour. At first we quantify the additional costs due to the road user charge for each transport process in the sample by taking into account the truck used and the number of kilometres driven on German motorways. Using the estimated parameters from the original model and multiplying them with the new transport costs we can quantify the new utility and hence an eventually changing demand for vehicles by quantifying the new individual probability of using combined transport services. Aggregating the individual probabilities we come to the new modal share resulting from a new cost structure due to the road user charge. Finally we quantify the emission reduction by subtracting the emissions of those forwarders that would change modes due to the road user charge.

The result of this procedure shows an increasing share of combined transport services in the sample by 2.1 percentage points. An interesting fact is that the choice probability of combined transport decreased in some cases without any impact on the mode used for service provision. In those cases, the overall distance was very short so that the increasing costs of the pre- and post-haulage due to the road user charge increased the costs for combined transport even more than the one of the unimodal truck service.

Quantifying the CO_2 balance of those transport services where the mode choice changed, a positive CO_2 effect can be identified. This means that the reduction of emission per kilometre during the main run overcompensate the additional emissions resulting from the additional kilometres needed to provide the combined transport service by truck. In this sample the CO_2 reduction of the road user charge on German motorways was about 39 t CO_2 which is equivalent to an emission reduction of about 1 %.

4.2 Increasing the speed of rail transport services by improving the railway network

The low average speed of the rail services especially on international corridors of about 20 km/h are often seen as reason for the low share of rail services in the modal split. The White Paper of the European Commission comprises of a bundle of measures that should improve the quality/speed of the railways until 2010. More or less, they all focus on the expansion of the network of railways to eliminate bottlenecks, on the increasing supply of direct train services on the main haulage of combined transport services, the abolition of the "give way regulation" of passenger tains or the introduction of international driving licences for train conductors to avoid stops at frontiers (European Commission, 2001).

It is assumed that the listed measures will together lead to an increasing average speed of railway services. The Commission indicated in its Whipte Paper the target of 80 km/h (European Commission, 2001). To reduce complexity the following simulation is based on the assumption that all transport services by rail in the sample with an average speed of less than 80 km/h will reach the given target of 80 km/h. This increasing average speed will reduce the time span of the main haulage of combined transport by rail and finally of the overall transport chain.

Table 5 shows a reduction of the trip duration in the sample of about 52% on average. Considering the pre- and post-haulage and the waiting time in the terminals the transport duration of the overall combined transport of the sample is expected to increase by about 24%.

TABLE 5 Elasticities of mode choice decision for combined transport services

Increasing costs due to road user charges on German motorways	Unimodal truck transport	Combined transport	
		Pre- and post haulage	total
N=498	7.34%	2.40%	0.75%

Sources: Bühler (2006).

As in the previous case simulation changes vary tremendously between the observations in the sample. While combined transport services provided by truck and ship have no variation in the trip duration the others might have significant changes. It is therefore necessary to do the simulation on an individual basis and to follow the above mentioned approach of the impact assessment again.

On average of all observations the probability of choosing the combined transport service increased by 7.7 percentage points due to the higher average speed of rail services on the main haulage of rail services. This is a remarkable result especially when the share of combined transport services in the sample is about 14.5%. However, it is to consider that such a tremendous increase in the speed of railway services is not very realistic neither in short term nor in the medium-term but it shows that there is substantial potential to increase the share of combined transport services in the future.

Consequently, the CO_2 balance of the simulated policy measure is very high, too. In the sample 176 t CO_2 can be reduced applying these measures. The result is equivalent to a 4 % reduction of the overall emissions in the sample. However, in some cases such a policy would lead to unexpected results. Some transport processes which were originally provided by unimodal road transport and are now carried out in combined services would cause additional emissions. Although rail transport on the main haulage cause a drastical reduction of emissions per kilometre compared to the truck transportation, the longer distance to be covered will increase the emissions of those transport chains.

5 Conclusions

The transport sector is responsible for a substantial part of the CO_2 emissions in Germany and even more in the EU. Due to the growing demand for transport services, this share was even growing within the last years even though the efficiency of the vehicles has improved. If the political objective is a stronger participation of the transport sector in the emission reduction strategy of the EU, measures should focus on the optimal use of all transport modes.

Measures that influence the modal split of freight transport services have a potential to reduce CO_2 emissions. We quantified the potential of two policies in Germany: an increase of the German road user charge and an acceleration of the transport speed of rail services to 80 km per hour. The benefit is relatively weak. CO_2 emissions would decline by 1 to 4 % related to the overall road freight transport emissions. Two reasons can be identified that are responsible for the weak impact of a changing mode choice on CO_2 emission reduction. Firstly, the mode choice reacts very inelastic to changes in service quality or prices. Secondly, although the environmental effectiveness – expressed in CO_2 emissions per kilometre – of combined transport is higher than the one of unimodal road transport, it usually lose some of its benefit because of the longer trip distance necessary to provide the transport service.

Looking at the two policies analysed in this paper we see an advantage of price measures compared to structural and technical measures to improve service quality of combined services. However, both policies have only a weak impact on the emission reduction. While the road user charge increased the transport price of about 7 %, the impact on the mode choice and on the emission reduction is even smaller and amounts to about 2 % and 1 % respectively. In case of service quality the effect is even worse. From a tremendous change of about 24 % in the trip duration the result on the CO_2 emission reductions is about 4 %.

In addition, the survey shows that a modal shift is not per-se positive for transport emission reduction. Sometimes a change in the service quality or in the transport price will cause a modal shift of unimodal road transport services to combined services where the CO_2 efficiencies of road transport is better because the combined transport chain is by far longer than the unimodal road corridor.

The result of this survey is deflating. The potential to reduce CO_2 emissions by changing the modal split is very limited. Only large changes in service quality and price will lead to substantial changes in the behaviour of modal choice and, therefore, contribute substantially to CO_2 emission reductions. Technical measures to improve for example the energy mix of the train service provider or the fuel efficiency of trucks have higher reduction potential. Concluding, policy instruments which aim to improve efficiency of transport vehicles are more efficient than forcing a further mode shift.

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