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Non-technical measures for influencing a shift in freight modal share in Germany in 2030

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Abstract

Modal share in freight transport in Germany is dominated by truck transport. Enhancing train transportation is supposed to diminish CO_2 emissions, which becomes more important as freight transportation demand is supposed to grow further in the long run. However, non-technical measures to achieve a shift in freight modal share and especially their overall impact on macroeconomic indicators are not well assessed.

The assessment of three instruments (transport pricing, railway acceleration and altering legal train capacity limits) and their combination was done with ASTRA-D, a System Dynamics model which allows evaluating wider economic impacts of measures in the transportation sector.

By combining all three instruments a rise in railway freight transportation service of 10 percentage points compared to base scenario in 2030 is possible. However, overall tonne-kilometres are rising and environmental benefits are smaller than expected. While transportation costs are higher, overall economic performance does not suffer. A shift in between different economic sectors is nevertheless indicated by the modelling results, leading to differences in the number of employees.

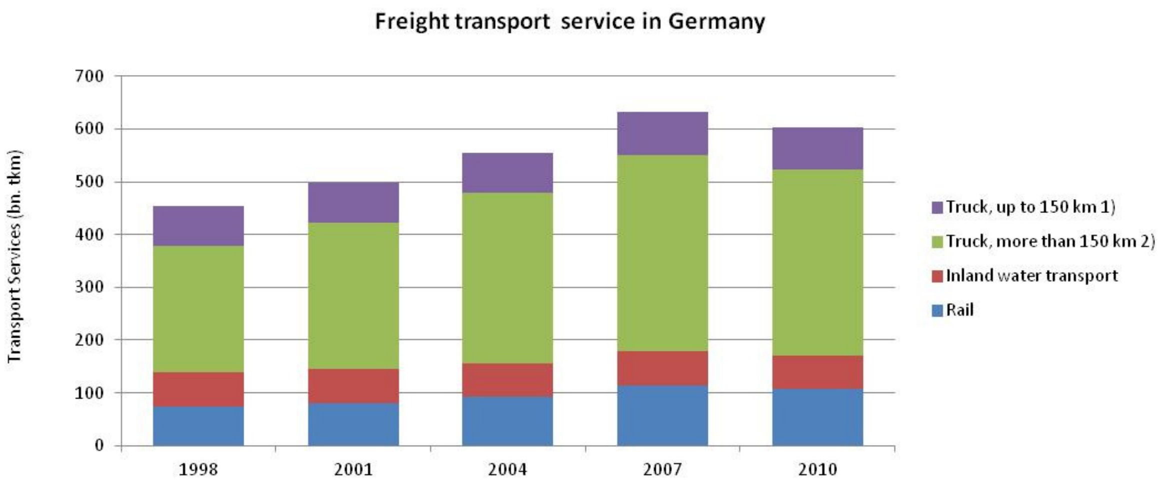
Technical improvements of rail freight performance are not sufficient for fulfilling the objective; a sharp increase in truck transport pricing is indicated. The necessary investments can have positive impacts for the German economy, though some sectors may suffer from this development.

1 Introduction

This study is based upon a project funded by the German Federal Environment Agency with the objective of evaluating the reduction potential of non-technical measures for emission reduction in transport. The focus of this paper is on shifting freight modal split ten percentage points from road to rail transport in 2030 in Germany. The shift refers to transportation service in tons kilometer.

Freight transport is of special importance as it forms a substantial part of emissions in transport. With rising global GDP growth freight transport is expected to rise in a similar way due to the strong coupling of GDP with freight transport volume.

Figure 1: Market shares freight transport 1998 - 2010



Source: own figure with data from BMVBS (2012); 1) only German trucks, 2) incl. foreign trucks

Market shares of train freight modal share for Germany has stabilized within the last 15 years at around 17%. The highest market shares are traditionally achieved in the following product groups: iron, steel and nonferrous metals, machinery and equipment (including containers) and chemical products. During the same period, road transport increased from 65% to 70%, while inland waterway transportation has shrunk accordingly from 15% to 10% market share (figure Figure 1). According to Essen et al. (2011) rail and inland waterway cause only about a third of the environmental and safety-related external costs of road transportation with heavy trucks, which has been the reason that a shift in transport modes had a negative impact on the sustainability of freight transport.

Against this background this study examines the economic and ecological impacts of a rise of rail modal share of 10 percentage points. This is equivalent to a growth of almost 60% measured in tkm, compared to the base run.

2 Background

Thanks to technical improvements in vehicle technologies emissions from motorized has experienced a substantial drop within the last two decades. Due to European-wide implementation of catalyzers, engine control and emission filters (Euro norm) NOx in 2009 was only about 39% von the 1991 value. In the same time period SO2 and CO shrank to 1% and 20% respectively and thus do not play any further role in the discussion on air quality. On the other hand particle emissions remain at 90%, compared to the 1991 level and also the most important air pollutant CO_2 is with 93% also almost unchanged (BMVBS, 2012). As the Kyoto protocol goals are still valid for Germany, the reduction target for CO_2 is under given circumstances endangered.

There are a number of studies trying to forecast freight transport service in Germany up to 2030. It makes a huge difference whether or not the global crisis in 2008/09 finds consideration in the results. Table 1 gives an overview of recent projections and one can see that growth is substantially higher in the projections made before the crisis.

Table 1: Comparison of recent freight transport projections for Germany

	Bn. Tkm 2008	Bn. Tkm 2030	Growth	Crisis consideration
TREMOD	664	1.080	63 %	No
BMVBS VP 2025	604	1.074	78 %	No
Renewbility-II/Energiekonzept	654	876	34 %	Yes
ASTRA - IEKP-Makro *	604	817	35 %	Yes
ASTRA - iTREN-2030	609	702	15 %	Yes

* Values for 2010.
Source: Fraunhofer ISI

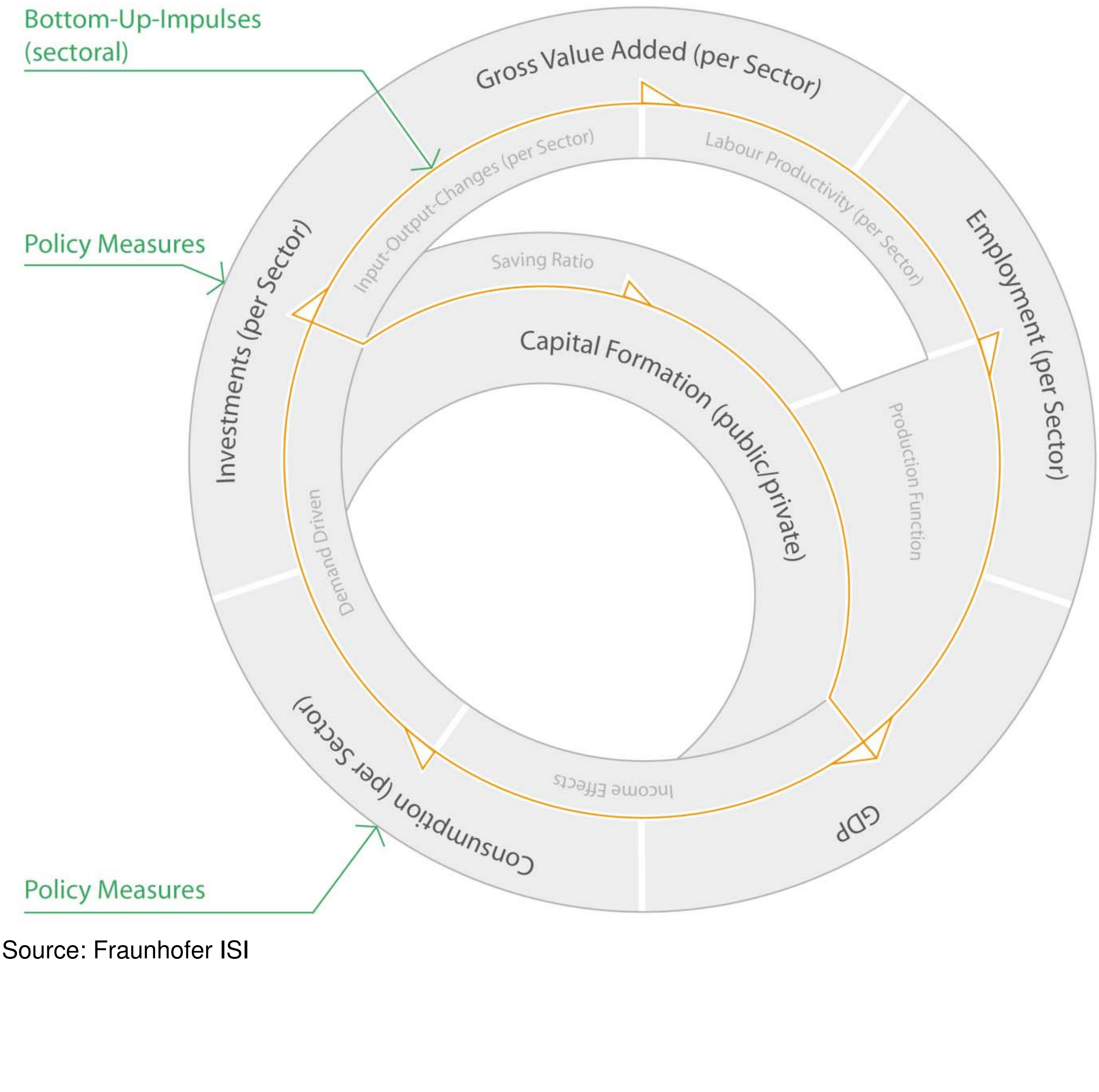
The economic evaluation of the actions carried out with the System Dynamics economic and transport Model ASTRA-D (ASsessment of TRAnsport Strategies) by Fraunhofer ISI. This allows the mapping of interactions between transport policies, transport demand, investment, overall economic size and sustainability indicators in a dynamic environment. In the context of the research project RENEWBILITY II newly created model version for Germany offers a regional breakdown for the Federal Territory and can be evaluated accordingly regionally.

3 Model description

The Model used here is ASTRA-D. ASTRA-D is an enhancement of the European ASTRA model, focussing on Germany. ASTRA was developed in the framework of several European research projects for the assessment of transport strategies (Schade, 2005). For the German version, the degree of analysis is narrowed down significantly; the allocation of sectors now follows the classification of branches of economic activity of the German federal bureau of statistics (2003).

ASTRA-D is not restricted to one branch of the macroeconomic theory, it links elements like the neoclassical production function to Keynesian demand stimuli. Substantial is the possibility to allow imbalances between supply and demand, therefore ASTRA-D is no optimisation model.

Figure 2: Macroeconomic modelling with ASTRA-D



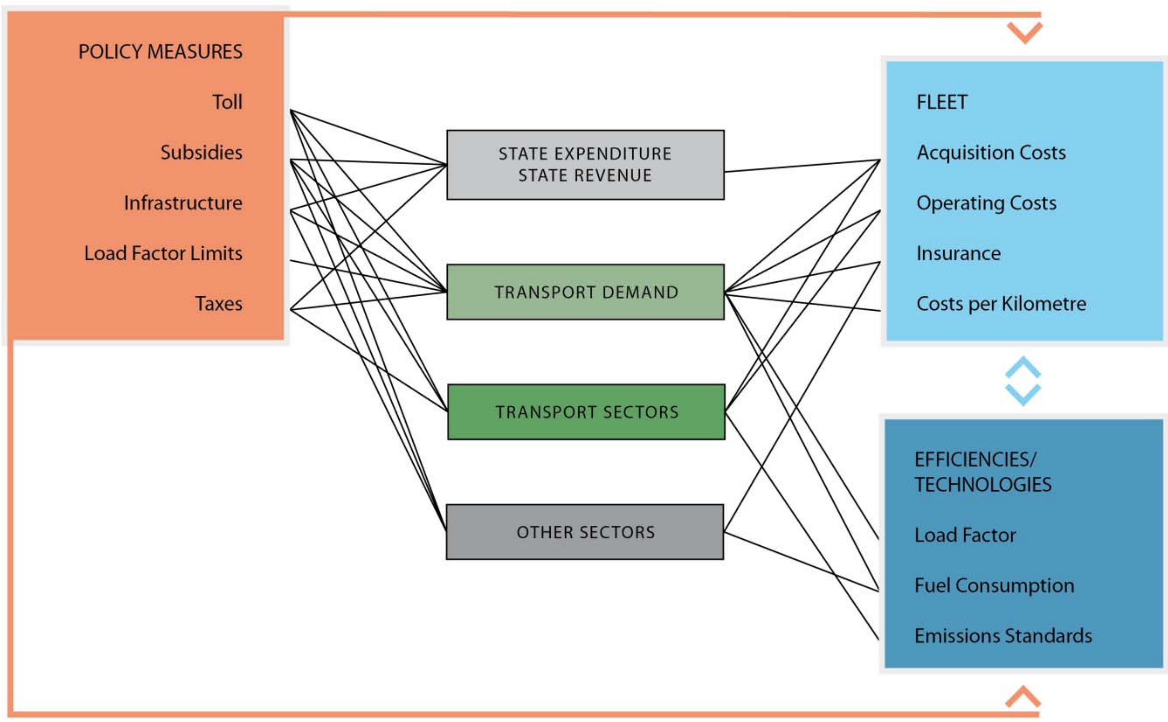
Source: Fraunhofer ISI

Figure 2 shows in a very simple manner, how the essential macroeconomic connections are modelled. It is not possible to list all equations of this model; however, all relationships in figure 2 are modelled quantitatively. For a more detailed discussion refer to Schade (2005) or Krail (2009).

In ASTRA-D, a gradual application of policy measures is possible because of the use of yearly calculation steps. Thus, political instruments can be designed in a very flexible way in terms of intensity and further on, any dif-ferences due to e.g. different investment trajectories, can be made visible.

There are several interdependencies between the different modules of ASTRA-D, so that different measures not only have impacts within a sector, but influence the whole economy. For example, a change in consumption will lead to a change in in-vestment behaviour of the actors in transport sector. From delivery variables from traffic consumption to the specific sectoral investment activities, one has a direct feedback to the economic part, in which the changes in the necessary advances for the transport sector are taken into account.

Figure 3: Interactions between differnt types of variables in ASTRA-D



Source: Fraunhofer ISI

Therefore, one has to differ between endogenous and exogenous investments. Endogenous investments are directly linked to the demand side and thus change according to necessary changes on the supply side. Exogenous investments are generally public investments and provide economic incentives to reach the goals of the measures.

Figure 3 shows a rough overview of the interplay between the participating actors within the transport module. Investments, that are relevant for traffic demand, directly overlap to other sectors, in case of for example investments in railway network improvement, to the construction sector. This reveals the strength of ASTRA-D: the measures are integrated straight into the economic modelling.

Also immediate are the interdependencies between development of the whole economy, development of the transport sector and development of the employment. Attention should be paid to the fact, that the employment in the transport sector is modelled in a more detailed way than in the other sectors.

The modelling of transport demand is separated into the modelling of passenger and freight transport demand. Both is done following the classical four-step-model, whereas the last step, assignment, is not done, this to the purpose of keeping the model still operable. The geographical resolution of the model complies with the European NUTS-2 classification. Within the specific zones, the amount of traffic is further divided into three distance bands.

We will now shortly summarize the three first steps of the four-step-model:

1. Trip Generation: based on the socio-economic and demographic develop-ment, the whole amount of trips is generated

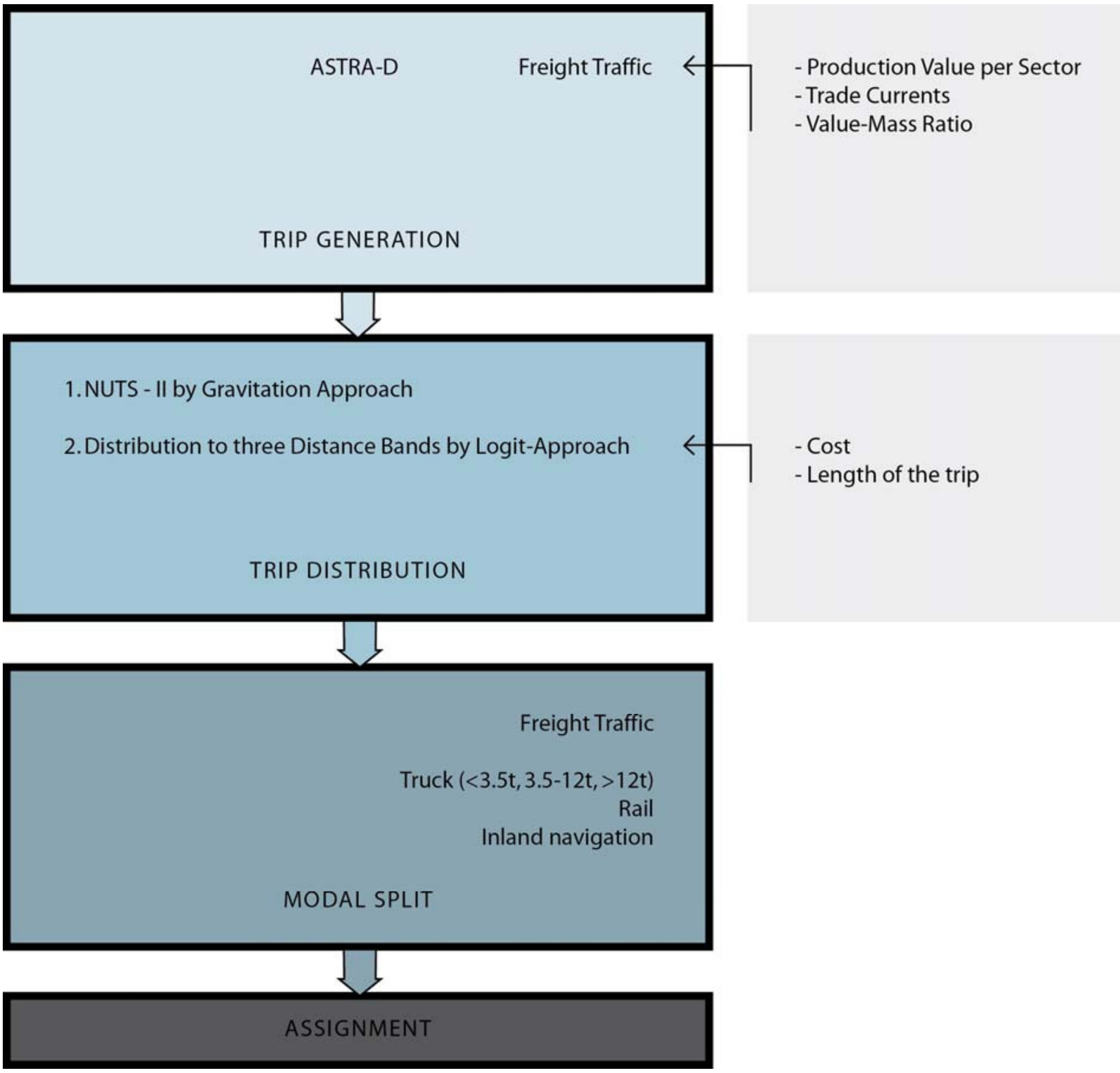
2. Trip Distribution: the number of trips is distributed in detail among the NUTS-2-zones and their functional sub-zones according to a gravitation-ansatz, where the different generalized times serve as weighting factors. In ASTRA-D, the intrazonal trips are then further distributed among different distance bands.

3. Modal Share: according to a logit approach who takes into account the different generalized costs, the trips are finally distributed among the five traffic modes.

The logit approach was used as it is still the most common in modelling modal split (Abdelwahab and Sargious, 1992). Especially in freight transport there seems to be less “soft” factors influencing the decision for a transport mode than in passenger transport. So utility maximisation might still be a sufficient reasonable modelling assumption.

The instruments, we implemented to reach the specific goals of this study, were increasing the toll for duty vehicles, improving the average speed of cargo trains and raising the load factor of the latter.

Figure 4: Classic four step transport model implemented in ASTRA-D



Source: Fraunhofer ISI

The first instrument influences the absolute amount of general costs for duty vehicles and the investments in the transport sector. The generalised costs influence the logit-function, used to calculate modal share, as follows:

$$v_i = \frac{e^{-\beta c_i + \mu_i}}{\sum_{j=1}^{N} e^{-\beta c_j + \mu_j}}$$

where N is the number of freight modes (five). Generalised costs are formed on a vehicle kilometre basis differentiated by goods category, origin-destination-relation and freight mode. The logit parameters differ in goods category and freight mode and are given in table 2.

Table 2: Values of the logit parameters

		β	μ
Truck (<3.5t)	Bulk	0.0334	0.4464
	General Cargo	0.038	0.3978
	Unitised Goods	0.0316	0.525
Truck (>3.5t and <12t)	Bulk	0.102	0.5516
	General Cargo	0.1277	0.6287
	Unitised Goods	0.1019	0.1219
Truck (>12t)	Bulk	0.1047	0.4838
	General Cargo	0.2616	0.4314
	Unitised Goods	0.28	0.8707
Rail	Bulk	0.3645	0.527
	General Cargo	0.5462	0.4786
	Unitised Goods	0.5575	0.4256
Waterway	Bulk	0.6303	0.4958
	General Cargo	0.8542	0.3891
	Unitised Goods	0.7807	0.4039

Source: Fraunhofer ISI

The second instrument, improving the speed smoothly from 2015 to 2025, leads to a decrease in generalised time for rail for all goods categories. This decrease in generalised times yields changes in the generalised costs and thus is advantageous for rail.

The third and last instrument, allowing more liberal legal standards for the overall weight and length of cargo trains, attains an improvement in the load factor for trains differentiated by goods category.

4 Results

Two runs were generated whose results are compared in this section. Base run is a business-as-usual scenario; economic development is derived from Schlesinger et al. (2010), efficiency improvements from Akkermans et al. (2010), sector productivity from Schade et al. (2009), operating costs for freight transport services from BGL (2012) and BMVBS (2012) and emissions are calculated according to the emission factors from HBEFA (2011).

A combination of the above-mentioned three instruments was tested iteratively to obtain a sufficient good result. However, it has to be stated that ASTRA-D is not an optimizing model, so another combination of those instruments might have yielded better results. On the other hand ASTRA-D allows for second round effects as described above, so if investments change the GDP trajectory this will lead to higher transport volumes.

In order to obtain the desired shift in modal share, measured in tkm, the following combination of instruments was used:

- Extension of truck tolls

  A rise from currently 15.5 €/100 vkm up to 30 €/100 vkm for high duty vehicles and a new introduction of a toll of 9 €/100 vkm for all other vehicles

- Improvement of average rail speed

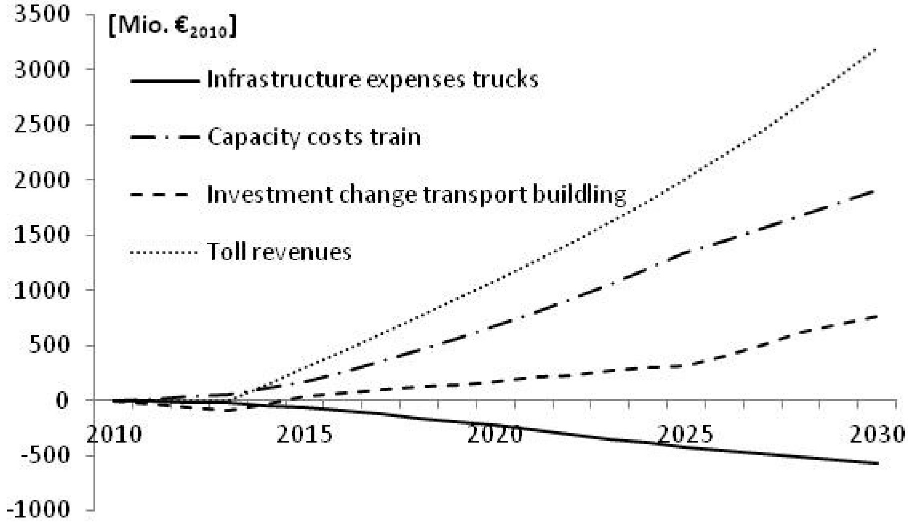
  Reduction of handling times with an improvement of 10% of average speed for railway freight transport

- Rise of legal standards

  Improvements of load factors for train from 8% up to 20%, depending on goods category

The instruments were financed by the government in the model; however, a lower usage of motorway led also to savings. Figure 5 pictures some of the main investment-related changes that were generated endogenously e.g. by the difference in vkm compared to base run. Furthermore, there were investment costs related to the introduction of the toll system for light duty vehicles and intermediate vehicles with 600 Mio. € annually, which is comparable to 10% of current annual expenses. In addition to that, 300 Mio. € were invested annually in order to rise infrastructure capacity for the train. For improving the handling and reducing the waiting time additional investments of 600 Mio. € annually were assumed to be needed. The investments for additional tracks in some highly-dense areas in stations of 500 Mio. € annually were assumed as well as they should be needed for not disturbing passenger transport, which is running on the same network. The calculation basis for infrastructure costs of roads for Germany were derived from Link et al. (2002a), Link et al. (2002b) and Lindberg et al. (2006) and for railways from Doll and Essen (2008), Lindberg et al. (2006), Link et al. (2009) and Kienzler (2011).

Figure 5: Differences of investment-related indicators compared to base run



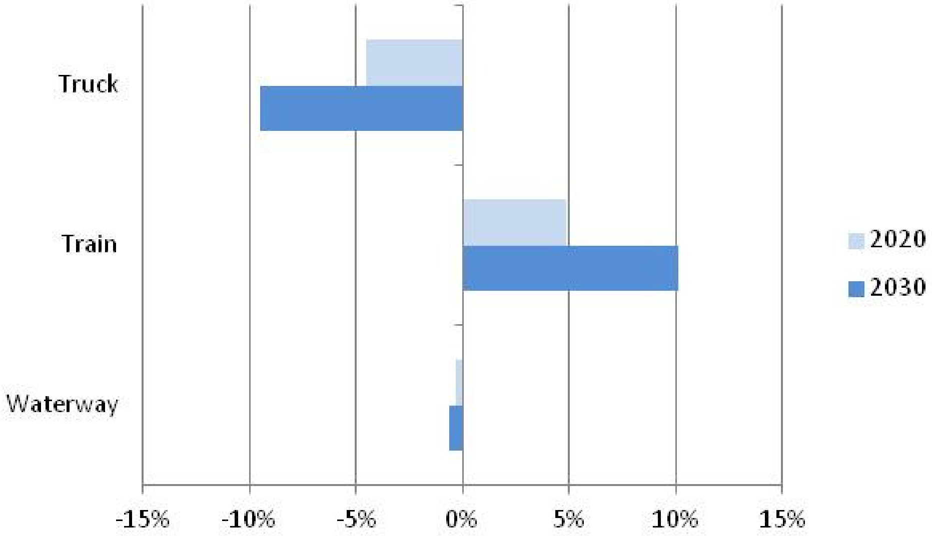
Source: Fraunhofer ISI

The implementation of these external investments were necessary as the difference investments mentioned before are an ex-post investment whereas also an ex-ante investment is needed. This, too, is due to the fact that ASTRA-D is not an optimizing model with perfect foresight.

Figure 6 shows the results of the simulation endeavor. The impact of the instruments led almost to a single shift from truck to train transport. However, overall freight transport service rose also significantly from 786 bn. tkm in 2030 in the base run to 865 bn. tkm in the policy run. This is not only due to the second round effects and a subsequent change in transport volumes, as GDP does not rise accordingly, but to inherent inefficiencies in the non-individual freight transport modes as well. Average distances in the origin-destination-relations are higher for train transport than for road transport as the latter mode is able to deliver directly from source to destination. Also transport service with light-duty vehicles rise as distribution from freight railway stations to the destinations became necessary in higher amounts.

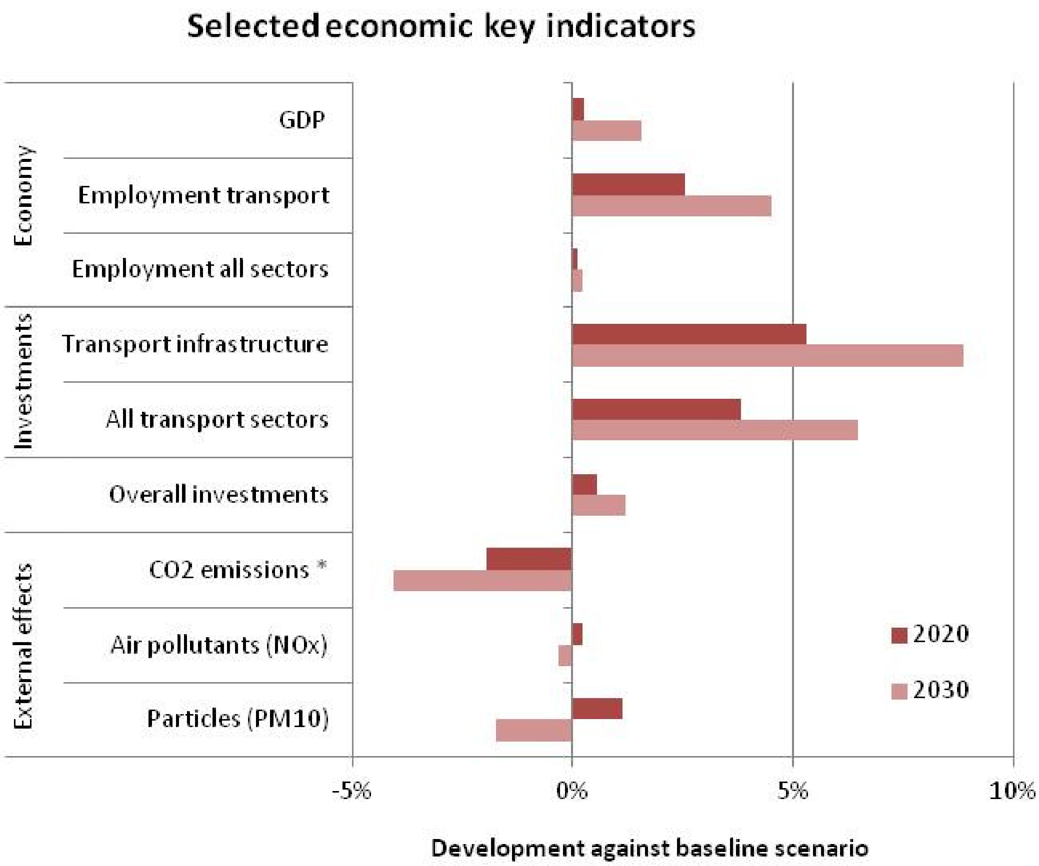
The main indicators are presented in figure Figure 7. One can see that while changes in the main economic indicators like GDP, investments and employment are better in the policy run this does not hold equivalently for emissions. This is due to the fact that an overall rise of transport service took place. However, in 2030 all forms of emissions were reduced.

Figure 6: Changes in percentage points modal share, measured in tkm



Source: Fraunhofer ISI

Figure 7: Main modelling results



Source: Fraunhofer ISI

Transportation service costs rose in the policy run, compared to base run, due to the introduction or rise of tolls. However, there were also dampening effects as average transportation time plays also a role, which was influenced for railway transportation by the other two instruments. Table 3 provides an aggregate overview of costs per ton, which is calculated by multiplying freight volume with generalized costs per ton, mode, goods category and origin-destination-pair as well as transport volume and service per mode. One can see that though transportation volume and service is rising significantly for railway transport, the same is not true for generalized costs. So the competitive advantage that truck transport has of railway is only dampened somewhat but still remains high.

Table 3: Changes in aggregated generalised costs, transportation service and transportation volume per mode

Mode	2020			2030		
	Volume (in t)	Service (in tkm)	Costs (in €)	Volume (in t)	Service (in tkm)	Costs (in €)
Truck (<3.5t)	1.44%	4.68%	1.47%	3.32%	9.27%	3.45%
Truck (>3.5t and <12t)	0.61%	0.89%	1.23%	0.37%	0.70%	1.82%
Truck (>12t)	-1.65%	-2.31%	1.59%	-4.95%	-4.96%	2.75%
Rail	8.87%	32.42%	4.30%	26.64%	69.25%	11.28%
Waterway	1.62%	1.53%	1.57%	2.46%	2.71%	2.40%

Source: Fraunhofer ISI

From an environmental economic point of view the reduction of the greenhouse gases is the most important goal. In 2008 the emission of carbon dioxide was already about 60 per cent of the total air pollution (Essen et al., 2011). The percentage of emissions of NOx and of particles is considerably decreasing so that it is negligible for the freight traffic.

Based on this background it is possible to make a positive statement about the sustainability assessment. One of its key points is the reduction of the emission of greenhouse gases. This can be done by non-technical measures.

The average costs for trucks on motorways are 0.21 €/vkm and for cargo trains with electrical traction 1.76 €/train-km (Essen et al., 2011). With a loading of 10.7 t and 407 t there are external costs of 19.7 €/1000 tkm (truck) and 4.32 €/1000 tkm (cargo train).There are additional accident costs of 10.2 €/1000 tkm by road freight transport and 0.2 €/1000 vkm by train freight transport. Until 2030 there will be a reduction of these costs of 30 % by trucks and of 40 % by trains (Kienzler, 2011 and Akkermans et al., 2010).

Compared to the investments in transport infrastructure the balance would first decrease because of the higher investments. By the end of the investments in 2025 the benefit would raise the balance for a sustainable market structure.

Furthermore it can be assumed that a combination of technological support and non-technical measures will lead to even more reductions of carbon dioxide emissions. There are existent technical measures to reduce emissions in both road and railway freight transport:

improved aerodynamics, perfect tire pressure and advanced driver assistance systems can decrease the fuel consumption of trucks by nearly the half. As well as the air pollution by diesel engines of trains has got a high reduction possibility.

5 Summary

In the study we analysed the impacts of a policy measure whose goal was to increase the rail modal share by 10 percentage points in 2030 compared to a base scenario. We successfully implemented a mixture of three instruments by which we obtained this goal: increasing the tolls for trucks, raising the average speed of trains by construction measures in the rail network and changing the legal standards to improve the load factor for trains.

The costs were beard by the state, but were partly compensated by the toll revenues and the savings due to less duty vehicles on the highways. One can definitely state that the economic effects are positive, GDP grows more than in the base scenario, as well as the total investments, that are predominantly driven by the transport investments and partly by the investments mainly in the construction sector, that are necessary to make the rail network fit.

Driven by the employment of the transport sector and the positive development of the whole economy, the overall employment impact is also positive.

As one would expect, the most benefits are received from the ecological side: after a little worse performance in 2020, in 2030, particles and air pollutants are significantly less than in the base scenario and the most important activator for climate change, the CO_2-Emissions, are continuously and significantly lowered.

Even though ASTRA-D is no optimisation model, what means, there could be scenarios with a more positive impact on ecology and economy, our iterative model runs showed in a non-ambiguous way that it is definitely possible to reach the goals of reducing air pollutants and greenhouse gases by shifting the modal share in a substantial way towards rail traffic and at the same time obtain positive economic effects.

One always has to keep in mind that these predictions are based on a model with simplifying assumptions, calibrated by a huge amount of data from many different sources and thus can only offer a trend; but this trend is, as mentioned before, quite unambiguous and future model runs with ASTRA-D, which is in a state of continuous and enduring further development will probably give results, that are directed towards the same direction.

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