Assessing direct or indirect benefits of transport ?

Comparing benefits of transport policies within the transport market versus within other markets with the ASTRA model

Submitted to 10th World Conference on Transport Research 2004 (WCTR 2004)

Istanbul, Turkey, July 4-8th, 2004

Authors:

Wolfgang Schade

E-mail: wolfgang.schade@iww.uni-karlsruhe.de

Institute:

Institute for Economic Policy Research (IWW)

University of Karlsruhe (TH)

Kollegium am Schloss, Bau IV

76128 Karlsruhe, Germany

Keywords:

Direct effects, indirect effects, assessment, CBA, transport policy

Abstract: (188 words)

Policy makers often assume that additional benefits exist beyond those benefits measured by the state-of-the-art CBA approach applied to transport policies that is based on measuring dis-/benefits on transport networks. Hence, the UK government commissioned a study to the SACTRA Committee to find out about the size of potentially additional effects respectively the total indirect effects, which occur outside the transport system due to transport policies. The study used a stylised spatial computable general equilibrium (CGE) model to identify indirect effects and concluded that indirect effects could be negative or positive and that they would be small. Since, the discussion is still ongoing this paper presents an alternative approach to measure indirect effects of transport policies and to shed light on the question of the size of those indirect effects. Applying the integrated economy – transport – environment assessment model ASTRA the indirect effects of selected European transport policies are analysed and compared to their direct effects. The conclusions drawn differ from SACTRA in that sense that much larger indirect effects of large-scale policies could be expected e.g. due to the consideration of dynamic mechanisms and fully-fledged transport policies.

Topic Area:

E1: Assessment and Appraisal Methods w.r.t. Transport Infrastructure Projects and Transport Activities

Date of Submission: 06.02.2004

1 Introduction

The ASCHAUER debate (1989) about a decade ago has highlighted that the question of macro-economic impacts of transport policy is still not answered. ASCHAUER concluded from a rather aggregate regression approach that public infrastructure investment including transport infrastructure investment would significantly foster economic growth. Critics convincingly argued that the analysis contained some flaws and would therefore exaggerate the impacts. Hence, common approach for transport policy assessment after the debate remained cost-benefit analysis following an engineering approach based on measuring direct transport impacts like transport time and cost changes on the transport networks. This leaves an open question on the indirect effects of transport policies occurring in the economy outside the transport market and on the additional effects that would be constituted by the difference between direct effects measured within the transport system and indirect effects measured outside the transport system.

An important contribution in the late 1990ies to the still ongoing debate on additional effects is contributed from the Standing Advisory Committee On Trunk Road Assessment in the UK (SACTRA 1999). Using results of a stylised spatial computable general equilibrium (CGE) model developed by VENABLES/GASIOREK (1999) SACTRA concluded that additional benefits of transport policy would exist, that they could become negative or positive and that they are meant to be small.

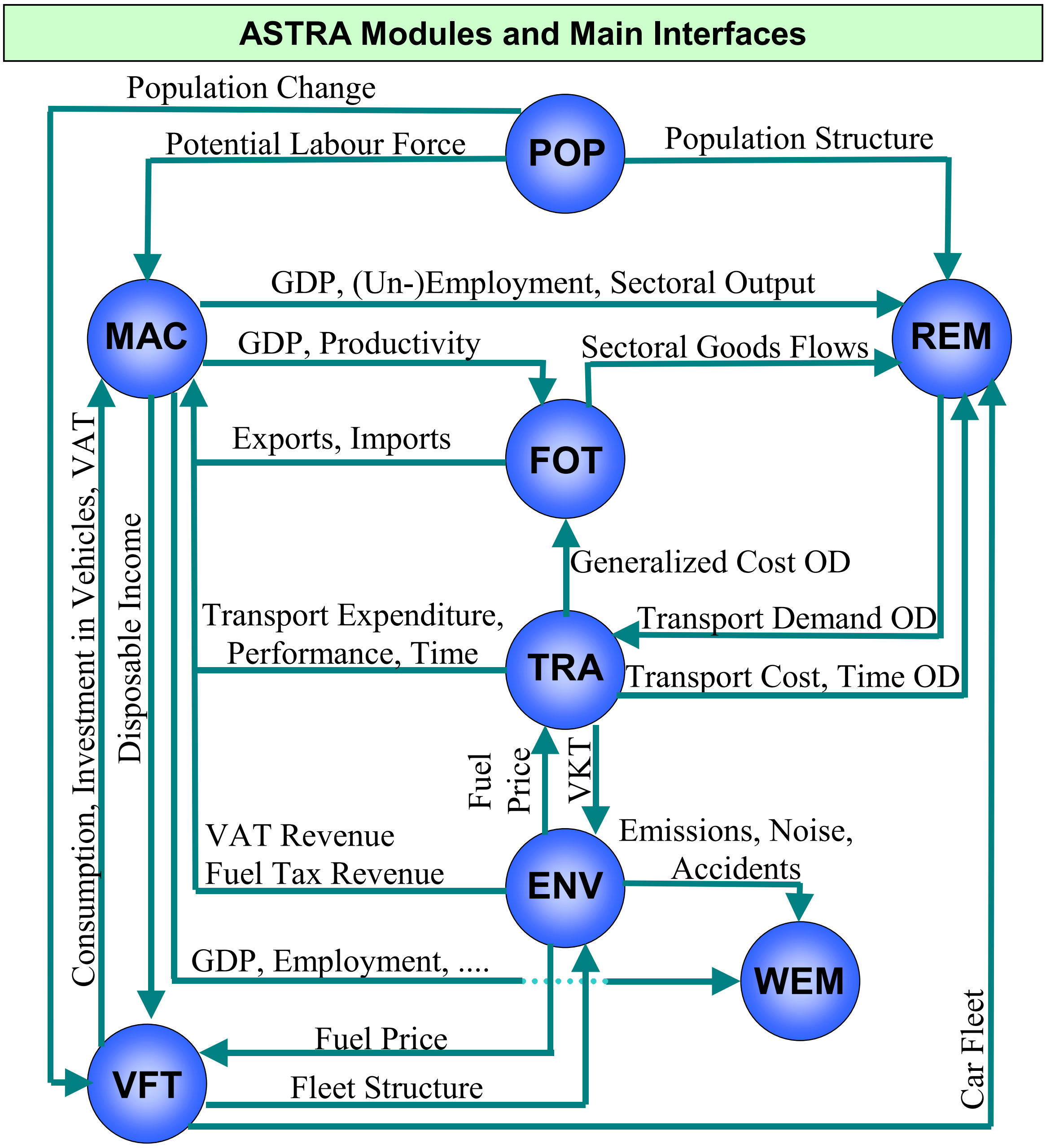
The usage of spatial CGE models to analyse additional effects of transport policies is followed by BRÖCKER (2001) and BRÖCKER et al. (2004), who arrive at similar conclusion as SACTRA with additional effects being small and either positive or negative. Their results are based on CGEurope a spatial CGE covering whole Europe with about 1300 zones and using a limited sectoral differentiation. OOSTERHAVEN/ELHORST (2003) developed a spatial CGE model for the Netherlands, which in contrast to CGEurope includes a finer sectoral differentiation and imperfect labour markets. Applying this model for case studies of new maglev links led to significantly higher results for additional effects.

Measurement of additional effects in this paper is performed by applying the system dynamics model ASTRA (=Assessment of Transport Strategies) (SCHADE 2004). ASTRA is originally developed in several European research projects to analyse the long-term impacts of transport and other policies for the fifteen current EU member states (e.g. SCHADE/FIORELLO/MARTINO 2002). ASTRA comprises eight modules: population (POP), macro-economy (MAC), regional economy (REM), foreign trade (FOT), vehicle fleet (VFT), transport (TRA), environment (ENV) and welfare measurement (WEM). Between these eight modules manifold interactions are implemented as depicted on an aggregate level in Figure 1.

The difference of ASTRA compared to the CGE approaches listed above accounts for the usage of a dis-equilibrium model instead of an equilibrium model and the formulation of a dynamic approach that reveals as results trajectories of reactions to transport policies. Furthermore the iceberg-type consideration of transport cost introduced into economic modelling by SAMUELSON (1954) and usually applied in CGE models is replaced by an OD-pair based and modal differentiated transport generalised cost approach. With respect to the dynamic formulation ASTRA fulfils a requirement that is suggested to improve new economic geography to which spatial CGEs belong (WALDORF 2004).

2 Brief description of the ASTRA model

The ASTRA model consists of eight modules that are all implemented within one Vensim system dynamics software file. One scenario simulation between 1990 and 2020 with yearly saving intervals of results generates 270 Mega-Byte of output data. About 12.000 time series are used to calibrate ASTRA for the period 1990 until 2000. Model variables are grouped into the following eight modules shown in Figure 1.



Abbreviations:

POP = Population Module
MAC = Macroeconomics Module
REM = Regional Economics Module
FOT = Foreign Trade Module
TRA = Transport Module
ENV = Environment Module
VFT = Vehicle Fleet Module
WEM = Welfare Measurement Module

Figure 1: Overview on the ASTRA model

A detailed description of the ASTRA model is provided by SCHADE (2004). The following paragraphs briefly describe the concepts of the eight ASTRA modules. The Population Module (POP) provides the population development for the 15 European countries[1] with one-year age cohorts. The model depends on fertility rates, death rates and immigration into the EU15 countries. Based on the age structure, given by the one-year-age cohorts, important information is provided for other modules like the number of persons in the working age or the number of persons in age classes that permit to acquire a driving licence. POP is calibrated to EUROSTAT population predictions (PONTI et al. 2002).

The Macroeconomics Module (MAC) provides the national economic framework, which imbeds the other modules. The MAC could not be categorised explicitly into one economic category of models for instance a neo-classical model. Instead it incorporates neo-classical elements like production functions. Keynesian elements are considered like the dependency of investments on national income extended by some further influences on investments like exports or government debt. Or elements of endogenous growth theory are incorporated like the implementation of endogenous technical progress as one important driver for the long-term economic development.

Six major elements constitute the functionality of the macroeconomics module. The first is the sectoral interchange model that reflects the economic interactions between 25 economic sectors of the national economies. Demand-supply interactions are considered by the second and third element. The second element, the demand side model depicts the four major components of final demand: consumption, investments, exports-imports and the government consumption. The supply side model reflects influences of three production factors: capital stock, labour and natural resources as well as the influence of technological progress that is modelled as total factor productivity. Endogenised total factor productivity depends on investments, freight transport times and labour productivity changes. Fourth element of MAC is constituted by the employment model that is based on value-added as output from input-output table calculations and labour productivity. Employment is differentiated into full-time equivalent employment and total employment to be able to reflect the growing importance of part-time employment. In combination with the population module unemployment could be estimated. Fifth element of MAC describes government behaviour. As far as possible government revenues and expenditures are differentiated into categories that can be modelled endogenously by ASTRA and one category covering other revenues respectively other expenditures. Categories that are endogenised comprise VAT and fuel tax revenues, direct taxes, import taxes, social contributions and revenues of transport charges on the revenue side as well as unemployment payments, transfers to retired and children, transport investments, interest payments for government debt and government consumption on the expenditure side.

Sixth and final of the elements constituting the MAC are the micro-macro bridges. These link micro- and meso-level models, for instance the transport module or the vehicle fleet module to components of the macroeconomics module. That means, that expenditures for bus transport or rail transport become part of final demand of the economic sector for inland transport within the sectoral interchange model. The macroeconomic module provides several important outputs to other modules. The most important one is, for sure, Gross Domestic Product (GDP). This is for instance required to calculate trade flows between the European countries. Employment and unemployment are two influencing factors for passenger transport generation. Sectoral production value drives national freight transport generation. Disposable

[1] For simplicity reasons I am speaking of 14 European countries, though this always means the 15 current member states of the EU, of which 13 are represented as single country and two, Belgium and Luxemburg are aggregated to form one region.

income exerts a major influence on car purchase affecting finally the vehicle fleet module and even passenger transport emissions.

The Regional Economics Module (REM) mainly calculates the generation and distribution of freight transport volume and passenger trips. The number of passenger trips is driven by employment situation, car-ownership development and number of people in different age classes. Trip generation is performed individually for each of the 53 zones of the ASTRA model. Distribution splits trips of each zone into three distance categories of trips within the zone and two distance categories crossing the zonal borders and generating OD-trip matrices with 53x53 elements for three trip purposes. Freight transport is driven by two mechanisms: Firstly, national transport depends on sectoral production value of the 15 goods producing sectors where the monetary output of the input-output table calculations are transferred into volume of tons by means of value-to-volume ratios. For freight distribution and the further calculations in the transport module the 15 goods sectors are aggregated into three goods categories. Secondly, international freight transport i.e. freight transport flows that are crossing national borders are generated from monetary Intra-European trade flows of the 15 goods producing sectors. Again transfer into volume of tons is performed by applying value-to-volume ratios that are different from the ones applied for national transport. In that sense the export model provides generation and distribution of international transport flows within one step on the base of monetary flows.

The Foreign Trade Module (FOT) is divided into two parts: trade between the EU15 member states of the year 2003 (INTRA-EU model) and trade between the EU15 countries and the rest-of-the world (RoW) that is divided into 12 regions (EU-RoW model). Both models are differentiated into 25 economic sectors and relationships between country pairs. The INTRA-EU trade model depends on three endogenous and one exogenous factor. World GDP growth exerts an exogenous influence on trade. Endogenous influences are provided by GDP growth of the importing country of each country pair relation, by relative change of sectoral labour productivity between the countries and by averaged generalised cost of passenger and freight transport between the countries. The latter is used as a kind of accessibility indicator between the countries. The EU-RoW trade model is mainly driven by relative productivity between the European countries and the rest-of-the-world countries. Productivity changes together with GDP growth of the importing RoW-country and world GDP growth drive the export-import relationships between the countries. Since, transport cost and time are not modelled for transport relations outside EU15 transport is not considered in the EU-RoW model. The resulting sectoral export-import flows of the two trade models are fed back into the macroeconomic module as part of final demand and national final use respectively. Secondly, the INTRA-EU model provides the input for international freight generation and distribution within the REM module.

Major input of the Transport Module (TRA) constitutes the demand for passenger and freight transport that is provided by the REM in form of OD-matrices. Using transport cost and transport time matrices the transport module is performing the modal-split for five passenger modes and three freight modes. Cost and time matrices depend on influencing factors like infrastructure investments, structure of vehicle fleets, transport charges, fuel price or fuel tax changes. For road transport network capacity and network loads are considered for four different road types such that congestion effects may affect the road transport time matrices in a simplified way. For other modes rough capacity models and capacity constraint functions are developed such that interactions between load and travel times can also be taken into account. Depending on the modal choices, transport expenditures are calculated and provided to the macro-economic module. Changes in freight transport times are also transferred to the macro-economic module such that they may influence total factor productivity. Considering load factors and occupancy rates respectively, vehicle-km are calculated. These represent an important input for the ENV module where emissions or accidents are calculated and for the VFT module, which estimates the new purchase of road vehicles besides cars.

Major output of the TRA provided to the Environment Module (ENV) are the vehicle-kilometres-travelled (VKT) per mode and per distance band and traffic situation respectively. Based on these traffic flows and the information from the vehicle fleet model on the different vehicle fleet compositions and hence on the emission factors, the environmental module is calculating the emissions from transport. Besides emissions, fuel consumption and, based on this, fuel tax revenues from transport are estimated by the ENV. Traffic flows and accident rates for each mode form the input to calculate the number of accidents in the European countries. Expenditures for fuel, revenues from fuel taxes and value-added-tax (VAT) on fuel consumption are transferred to the macroeconomics module and provide input to the economic sectors producing fuel products and to the government model.

The Vehicle Fleet Module (VFT) is describing the vehicle fleet composition for all road modes. Vehicle fleets are differentiated into different age classes based on one-year-age cohorts and into different emission standard categories. Additionally, car vehicle fleet is differentiated into gasoline and diesel powered cars with different cubic capacity categories. Car vehicle fleet is developing according to income changes, development of population and of fuel prices. Vehicle fleet composition of bus, light-duty vehicles and heavy-duty vehicles mainly depends on driven kilometres and the development of average annual mileages per vehicle of these modes. The purchase of vehicles is translated into value terms and forms an input of the economic sectors in the MAC that cover the vehicle production.

Finally, in the Welfare Measurement Module (WEM) major macroeconomic, environmental and social indicators can be compared and analysed. Also different assessment schemes that combine indicators into aggregated welfare indicators for instance an investment multiplier are provided in the WEM. In some cases e.g. to undertake a CBA the functionality is separated into further tools to avoid excessive growth of the core ASTRA model by including the assessment scheme directly within the model.

The integrated modular approach of ASTRA has the advantage that feedback loops, which commence on the micro- or meso-level in one of the modules (e.g. transport expenditures for one mode and one OD-pair in one distance band in the TRA) and then end up with an effect on the national level (e.g. changes in sectoral consumption and gross-value-added), can influence the originating module such that the feedback loop is closed e.g. in this case by the integration of the MAC module. Closing the feedback loop then implies to establish either macro-micro-bridges (e.g. from GDP and sectoral output to goods flows) or vice versa micro-macro-bridges (e.g. from transport investments into vehicle fleets to overall investments).

System Dynamics methodology used to develop ASTRA is first developed during the 1960ies by FORRESTER (1962, 1977). It rests on a few building blocks to construct a model, which are level and flow variables, auxiliary variables, parameters and, if using the graphical representation of a system dynamics model, connectors to describe the structure of the system. Mathematically a system dynamics model consists of non-linear differential equations that are computed by numerical integration since usually analytic solutions for the system of equations cannot be found (STERMAN 2000).

Construction of System Dynamics models assumes that the behaviour of a system is primary determined by its feedback mechanisms. "*The central concept that system dynamicists use to understand system structure is the idea of two-way causation or feedback*." (MEADOWS 1980 p.31). In that sense there exists similarity between new economic geography brought up by FUJITA and KRUGMAN and providing the baseline for spatial CGE modelling that could be identified looking at the terminology e.g. used by KRUGMAN (FUJITA/KRUGMAN 2004) who speaks of "*circular causation of forward linkages* [] *and backward linkages* []" as being important to consider the full effects of a policy. This would correspond to the systems approach and the feedback loop concept of system dynamics though the naming is different.

2.1 Important categories used in the ASTRA model

The two major categories of ASTRA needed for spatial modelling are the differentiation into EU15 countries (Table 1) with sub-categorisation into four functional zones per country (metropolises, high density, medium density, low density zones) and the categorisation into 25 economic sectors (Table 2) each dealt separately with e.g. in the trade model or the input-output model. For the EU-RoW trade model additionally a regional categorisation with 12 regions representing the rest-of-the-world countries is applied (Table 1).

Table 1: overview on EU15 countries and rest-of-the-world regions in the ASTRA trade models

Code	EU15 countries	Code	RoW regions
AUT	Austria	AUZ	Oceania
BLX	Belgium-Luxembourg	CEA_N	North Eastern European Associates
DNK	Denmark	CEA_S	South Eastern European Associates
ESP	Spain	CHI	China
FIN	Finland	EAS	East Asean Tigers
FRA	France	IND	India
GBR	United Kingdom	JAP	Japan
GER	Germany	LAM	Latin America
GRC	Greece	NAM	North America
IRL	Ireland	OEU	Other Europe
ITA	Italy	SEA	Southern European Associates
NLD	Netherlands	RotW	Rest-of-the-world
PRT	Portugal		
SWE	Sweden		

Table 2: overview on economic sectors following NACE-CLIO systematics[2]

Nr	Goods Sectors	Nr	Service Sectors
1	Agriculture, forestry and fishery products	**17**	Recovery, repair services, wholesale, retail
2	Fuel and power products	**18**	Lodging and catering services
3	Ferrous and non-ferrous ores and metals	**19**	Inland transport services
4	Non-metallic mineral products	**20**	Maritime and air transport services
5	Chemical products	**21**	Auxiliary transport services
6	Metal products except machinery	**22**	Communication services
7	Agricultural and industrial machinery	**23**	Services of credit and insurance institutions
8	Office and data processing machines	**24**	Other market services
9	Electrical goods	**25**	Non-market services
10	Transport equipment		
11	Food, beverages, tobacco		
12	Textiles and clothing, leather and footwear		
13	Paper and printing products		
14	Rubber and plastic products		
15	Other manufacturing products		
16	Building and construction		

Basic structure of both trade models is constituted by a three-dimensional trade matrix representing the sectoral flows between country pairs in value terms that are calculated on an annual base. An overview on the dimensions in the trade model is presented in Table 3.

Table 3: dimensional structure in both trade models

Model	Export-Index		Import Index		Sector Index		Matrix Elements
	Coverage	**#**	**Coverage**	**#**	**Coverage**	**#**	**#**
INTRA-EU trade	EU15 countries	14	EU15 countries	14	NACE-CLIO	25	4900
EU-RoW trade	EU15 countries	14	RoW regions	12	NACE-CLIO	25	4200

Further categories relevant for trade and transport modelling are the differentiation into transport modes, trip purposes, goods categories and transport distances as these are relevant for transport modelling (Table 4).

Table 4: overview on differentiation of the transport model

Type of transport	Mode in ASTRA	Included modes	Trip purposes / Goods categories in ASTRA	Includes
Passenger	slow	walking, cycling	Business	Business trips, commuting trips
	car	car, sports utility vehicles (SUV)	Private	Shopping, education, leisure, visit relatives
	bus	scheduled bus, coach	Tourism	Holiday trips (more than one day)
	rail	tram, metro, heavy rail		
	air	scheduled flights, charter		
Freight	truck	light duty vehicles (LDV), heavy duty vehicles (HDV)	Bulk	Ores and metals, basic chemicals, fuel, coal
	rail	heavy rail, inland waterway	General cargo	Metal products, machines, vehicles, agriculture products
	ship	ocean shipping	Unitised	Food, textiles, paper, plastics computer, electronics, other manufacturing

[2] NACE = General industrial classification of economic activities within the European communities, CLIO = Classification and nomenclature of input-output

The transport model in ASTRA is not based on a transport network modelling approach, but on OD-matrices connecting origin and destination zones considering different distance bands for passenger and freight transport. In both cases transport cost and travel time of the medium distance band, enabling to reach neighbouring countries, and the long distance band, enabling to reach all destinations in all countries, are relevant for trade decisions.

Table 5: overview on characteristics of transport distance bands that are relevant for exports

Type of transport	**Transport characteristics**			**Reach destinations in other countries**	
Distance band (DB)	Travel distances	Available purposes / goods categories	Available modes	Reach neighbouring countries only	Reach all countries all zones
Passenger transport					
Medium DB (MD)	40 – 160 km	Business, private and tourism trips	car, bus, train	X	
Long DB (LG)	> 160 km	Business and tourism trips	car, bus, train, air		X
Freight transport					
Medium DB (MED)	150 – 700 km	all goods categories	all freight modes	X	
Long DB (LGD)	> 700 km	all goods categories	all freight modes		X

2.2 Linking transport and the economy

Since it is impossible to explain the equations of ASTRA in such a brief paper the focus in this section is to explain selected equations that deal with a specific of the ASTRA model: the integrated micro-macro bridges between transport and the economy. These constitute one major advantage of ASTRA compared to most other models or model combinations between separate transport and economic models. Also this constitutes a brief way to show a bit of detail of ASTRA.

Micro-macro bridges provide the direct integration of micro level transport reactions with meso- and macroeconomic impacts. However, for some of the micro-macro-bridges no preceding examples have been found. Therefore it seems to be very important to understand reactions of the model in the scenarios, to explain and to demonstrate how these micro-macro bridges work and how significant transport impacts in the ASTRA model would be. Hence, the following sections present two out of the six most relevant micro-macro bridges which link:

- passenger transport and sectoral consumption,
- transport and sectoral investment,
- transport and sectoral employment,
- freight transport and total factor productivity (TFP),
- transport and intermediate inputs of input-output tables and
- transport and exports.

The analysis is based on a comparison with the results for the business-as-usual scenario (BAU) and follows two different approaches depending on the way the micro-macro-bridge is implemented. First, if the bridge is using absolute values one would loose a significant share of the value of the input variable e.g. consumption is composed out of transport and non-transport consumption; omitting non-transport consumption from total consumption would reduce consumption level by 5-12%, which alone would account for the changes in the model. Hence, the analysis in such a case has to find a reasonable substitute for the micro-level input from transport. In this case it seems appropriate to take the general trend of the variable affected by transport and to apply it on the initial values of the transport input to derive a trend for transport inputs that is harmonised with the total such that the absolute gap in the initial period is avoided. Differences between BAU and this analysis then would be due to the different development of general trend e.g. of consumption compared to the specific development of micro-level transport inputs e.g. private consumption expenditures for transport purposes.

Second, if the gap between transport and economy is bridged by a relative variable indicating percentage change of the micro-level transport input over a specified time period the approach would be simpler. Then it suffices to omit the changes from the macro variable and the results of the simulation exhibit the transport impacts in comparison with BAU.

2.2.1 Linking transport consumption to sectoral consumption

Transport consumption consists of three elements: firstly, private car purchase, secondly private transport service expenditures and thirdly private fuel consumption. The expenditures for private car purchase depend on the share of new cars that is purchased in each of the six car categories, which is calculated as part of the car fleet model in VFT. Car purchase depends either on the estimated change of the car fleet due to income changes, fuel price and other changes and on expected scrappage of cars in the current period. Suppressed in equation 1 remains the split of the car fleet into seven different emission categories since this depends on the time variable e.g. in 1994 all cars purchased belonged to the EURO-I emission standard. Each vehicle category is identified by its specific price that is then used to calculate the expenditures by multiplying number of new cars of each category with their specific price. Finally, the number of business cars has to be subtracted from the total car purchase to consider private expenditures, only. The resulting car expenditures become part of consumption for sector vehicles in the consumption model.

$$\mathbf{pCP(t)_{EC,v}} = \frac{(1-shBT)*shNewC(t)_{EC,v}*VP(t)_{EC,v}}{1000000}* \qquad \textbf{(eq. 1)}$$

$$\begin{cases} mRSC_{EC}*ScC(t)_{EC} \rightarrow \left[mRSC_{EC}*ScC(t)_{EC}\right] > \left[CF(t-dt)_{EC}*\Delta CF(t)_{EC}+ScC(t)_{EC}\right] \\ \qquad CF(t-dt)_{EC}*\Delta CF(t)_{EC}+ScC(t)_{EC} \rightarrow else \end{cases}$$

where:

	pCP =	private expenditures for car purchase [Mio*EURO]
	shBT =	share of business trips on car trips as fraction [dmnl]
	shNewC =	share of new cars for the different vehicle categories [dmnl]
	VP =	net vehicle price excluding VAT etc. [EURO/car]
	mRSC =	minimum replacement scrapped cars as fraction [dmnl]
	ScC =	scrapped cars in this period [car]
	CF =	total car fleet per country [car]
	ΔCF =	change of car fleet as fraction [dmnl]
	v =	index for car vehicle categories (3 gasoline categories, 2 diesel categories, 1 new technology category) plus emission standards (not shown)
	EC =	index for EU15 countries

Expenditures for transport services are aggregated by the origin concept to the modal-level per country, which means that expenditures are aggregated over at maximum 600 destinations for each of the three relevant modes (bus, train, air) and over each of the two private trip purposes (personal and tourism). This is shown in equation 2:

$$\mathbf{pTS(t)_{EC,m}} = \sum_{P,OC,ECD,DC} (TP(t)_{P,m,EC,OC,ECD,DC} * TCost(t)_{P,m,EC,OC,ECD,DC}) \qquad \textbf{(eq. 2)}$$[3]

where:
- pTS = expenditures for private transport services [Mio*EURO]
- TP = transport performance per OD-pair and mode [Mio*pkm]
- TCost = transport cost [EURO/pkm]
- m = index for modes (bus, train, air)
- P = index for trip purposes (personal, tourism)
- OC = index for origin functional zone in origin country (MPA, HDA, MDA, LDA)
- ECD = index for destination country of EU15 countries
- DC = index for destination functional zone in destination country (MPA, HDA, MDA, LDA)
- EC = index for origin country of EU15 countries

Private expenditures for fuel depend first also on transport performance. Since, this has to be translated into vehicle-km an occupancy rate is required to derive vehicle-km. These are split according to the composition of the vehicle fleet into different car categories each with specific fuel consumption for the different distance bands. Multiplying the driven km of each car category with its specific consumption of fuel leads to fuel consumption, which finally has to be multiplied by the fuel price taking into account that prices of different fuels differ. This is presented in equation 3

$$\mathbf{pFC(t)_{EC,v,f}} = FP(t)_{EC,f} * (1 - shBT(t)_{EC}) * shC(t)_{EC,v} * spFC_v * \sum_{P,OC,ECD,DC} \frac{TP(t)_{P,EC,OC,ECD,DC}}{OR(t)_P} \qquad \textbf{(eq. 3)}$$

where:
- pFC = expenditures for private fuel consumption [Mio*EURO]
- FP = net fuel price [EURO/l]
- shBT = share of business trips on total car trips [dmnl]
- shC = share of different car categories in the fleet [dmnl]
- spFC = specific fuel consumption for each vehicle category [l/km]
- TP = transport performance per OD-pair by car [Mio*pkm]
- OR = occupancy rate of cars for different trip purposes [persons/car]
- v = index for car vehicle categories that are divided into different fuels
- f = index for car fuel categories (gasoline, diesel, unknown new technology)
- P = index for trip purposes (personal, tourism)
- OC = index for origin functional zone in origin country (MPA, HDA, MDA, LDA)
- ECD = index for destination country of EU15 countries
- DC = index for destination functional zone in destination country (MPA, HDA, MDA, LDA)
- EC = index for origin country of EU15 countries

To analyse the impacts of these three linkages on consumption and the other variables of the macroeconomic module, it is obviously not possible to find a definitive analytical answer due to the manifold interactions that are induced by these inputs within the MAC but also feeding back to other modules. In this case a feasible way for analysis would consist of

[3] The equation is slightly simplified as it abstracts from the distance bands and presents the formulation for the longer distance bands, only. However, the number of potential destinations to reach depends on the long distance bands as the short trips remain within their zone and therefore could only reach one destination, which is the zone itself.

simulating the model with a kind of base transport influence of transport consumption that is following the growth trend of total consumption in BAU and compare this result with the base scenario in which transport is following its specific development as it results from the calculations of the transport model and for which the linkages are described in the previous three equations.

Figure 2 reveals that consumption from the beginning of the simulation in 1990 in three out of the four sectors affected directly by transport is significantly decreased. This implies that the micro level transport results suggest that transport grows superproportional compared to average consumption growth. Looking at Figure 3 one observes that besides investment the macroeconomic aggregates are not significantly influenced until 2005-2008. Until this period investment show reactions but rather undecided and not consistently into one direction. Around 2005-2008 it seems that some dynamics are induced that make investment grow steadily reaching +6% until 2020 compared to BAU. The reason should be connected with the link between sectoral consumption and investment such that shifts of consumption occur towards sectors that generate higher investment demand. The corresponding difference in Figure 2 would be the sudden divergence between change of car purchase and change of demand of services. Increasing investment with some delay positively affects TFP, since investment tend to increase technical progress, which, if no significant counterbalancing forces enfold, also increases GDP. Employment, in contrast, shows a noticeable loss of more than –1% in 2020. It seems that the sectoral shifts e.g. away from transport service sectors occur from sectors with lower productivity to sectors with higher productivity.

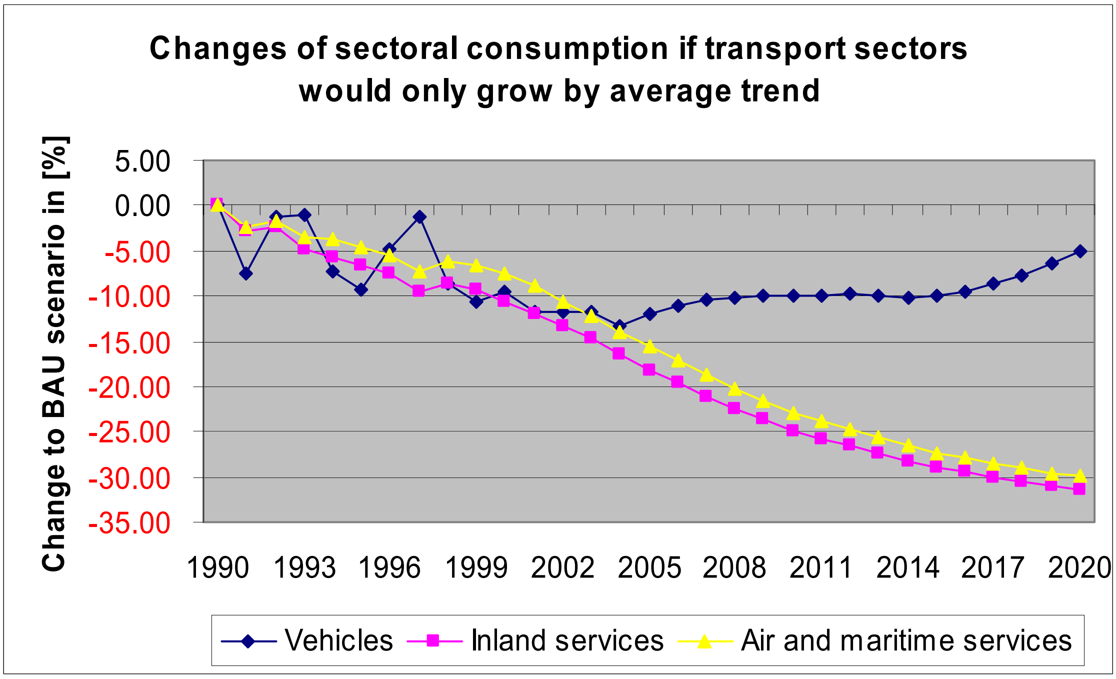


Figure 2: Impact of transport consumption growing only by trend growth of total consumption on the three transport consumption related sectors

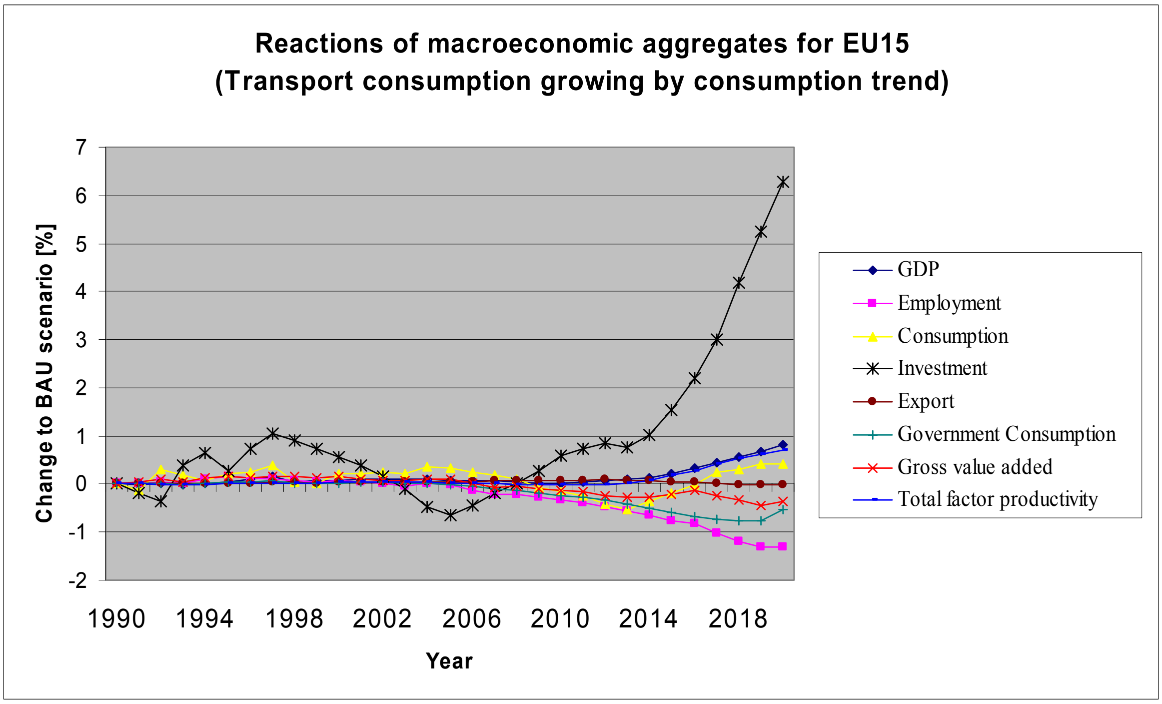


Figure 3: Economic impact of transport consumption growing only by trend growth of total consumption

2.2.2 Impact of transport on Total Factor Productivity (TFP)

It has been shown that technical progress in ASTRA perceived as total factor productivity (TFP) accounts for one of the most important drivers of long-term development. Hence, transport influences on this driver are of key importance for analysis of model reactions. Equation 4 presents the overall composition of TFP out of influences from labour productivity, investment and freight time-savings. This section deals with the analysis of the freight time component in TFP.

Freight time calculation in TFP is based on the origin concept calculating for each origin zone the average transport time per ton differentiated into goods category to reach any destination. The differentiation enables to take into account the different importance of the goods categories for the production process. Unitised goods are seen as more related to products for consumption e.g. food. Bulk goods seems to be less important for just-in-time production processes than general cargo goods that include machinery, metal products etc. Hence, transport times for general cargo goods are weighted twice. Despite globalisation domestic transport is assumed to play a more important role for distributed production processes such that is also assigned a doubled weight than international transport. Equation 5 presents the resulting formula to derive weighted freight transport times that go into the TFP equation 4.

$$\Delta \mathbf{TFP(t)_{EC}} = wP * \sum_{s} \left[\Delta LP(t)_{EC,s} * sGVA(t)_{EC,s} \right] + wI * \sum_{s} \left[\frac{IN(t)_{EC,s} * IE_s}{GDP(t)_{EC}} * DG(t) \right] + wT * \Delta FT(t)_{EC}$$

(eq. 4)

where:
ΔTFP = change of total factor productivity [dmnl]
wP = weight labour productivity on TFP [dmnl]
ΔLP = change of sectoral labour productivity [dmnl]
sGVA = sectoral share of total GVA as fraction [dmnl]
wI = weight investments on TFP [dmnl]
IN = investments [Mio*EURO]
IE = innovative effect of specific sector [dmnl]
GDP = gross domestic product [Mio*EURO]
DG = degression of effect of one unit of investment over time [dmnl]
wT = weight transport on TFP [t/h]
ΔFT = change of weighted freight transport times [h/t]
s = index for the 25 economic sectors
DB = index for the four freight distance bands
GC = index for the three goods categories
m = index for the three freight modes
EC = index for EU15 countries

$$\mathbf{FT(t)_{EC}} = \sum_{DB,GC} wGC_{GC} * wDB_{DB} * \frac{\sum_{m,OC,ECD,DC} TIME(t)_{DB,GC,m,EC,OC,ECD,DC}}{\sum_{m,OC,ECD,DC} TON(t)_{DB,GC,m,EC,OC,ECD,DC}} \qquad \textbf{(eq. 5)}$$

where:
FT = weighted freight transport times per origin country [h/t]
wGC = weight of goods categories [dmnl]
wDB= weight of distance bands to weight domestic transport [dmnl]
TIME = transport time per OD-pair [Mio*h]
TON = volume per OD-pair [Mio*t]
m = index for freight modes (road, rail+inland waterway, ship)
DB = index for freight distance bands (LOC, REG, MED, LGD)
GC = index for goods categories (BLK, GCG, UNT)
OC = index for origin functional zone in origin country (MPA, HDA, MDA, LDA)
ECD = index for destination country of EU15 countries
DC = index for destination functional zone in destination country (MPA, HDA, MDA, LDA)
EC = index for origin country of EU15 countries

To test the actual impact of freight transport on TFP provided by equations 4 and 5 it seems not sufficient to analyse the equation in a static context. The only possibility again would be to take ASTRA and to compare two runs: one with TFP calculated as described in the equations and another one excluding transport by switching it off in the equation. Only this approach would reveal the long-term impact of transport on TFP and the whole combination of downstream transport, meso- and macroeconomic impacts.

This test is documented in the following Figure 4 and Figure 5. The BAU scenario is used as baseline for the comparison and an alternative scenario is run excluding freight transport times from the TFP equation. Figure 4 reveals that over 10 years until 2000 the impact is rather little leading to a maximum change of investments of +0.6% and TFP itself of +0.7%. However, these minor changes amplify after 2000 such that until 2020 the initially small changes have accumulated to an increase of GDP of +6%. All other macroeconomic aggregates for the EU15 are increased significantly, also. Investments even reach a level that is +16% higher than in the BAU. This shows that in the dynamic integrated context transport can be an important factor for TFP and hence growth. Nevertheless, the distribution of weights on the three blocks with transport having the least weight shows that making the same experiment with investments or labour productivity would even lead to more dramatic results.

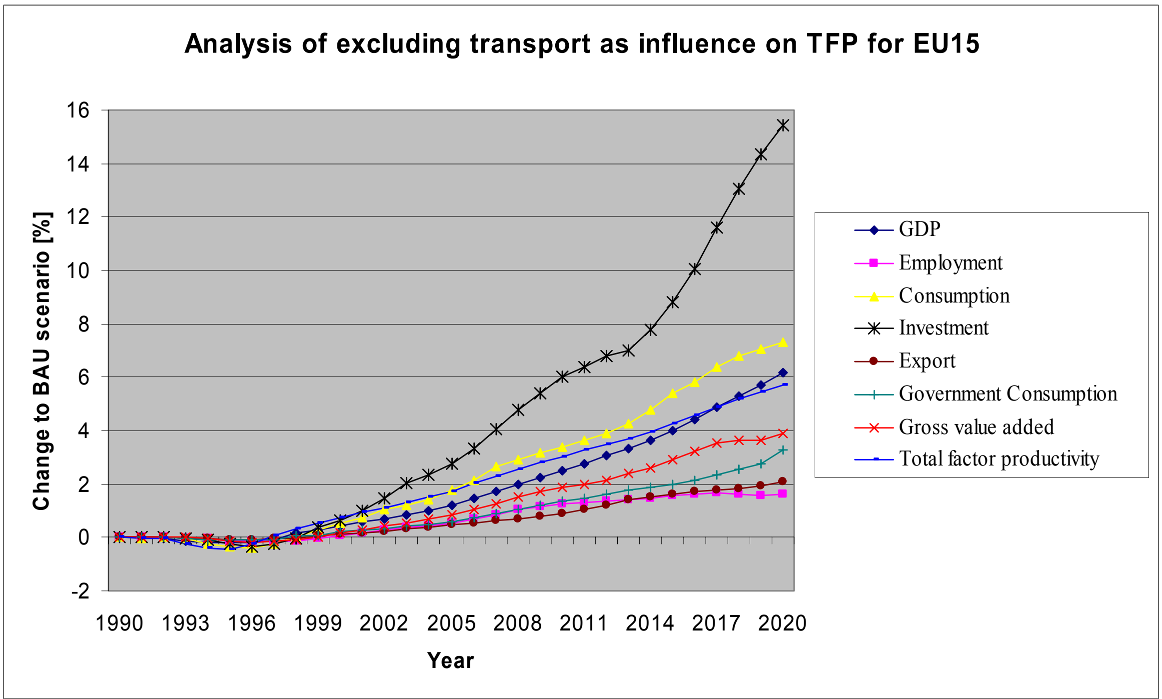


Figure 4: Impact of excluding transport from TFP on variables of national accounts for EU15

In the first instance the result might look counterintuitive as the expectation would have been that transport drives TFP and not considering transport in the TFP equation, being everything else unchanged, as leading to a decrease of TFP and consecutively also the other macroeconomic aggregates. However, one has to consider that this is an absolute transport time of a door-to-door trip for one ton (=hour per ton*trip) and not the specific transport time per one unit of distance (= hour per tkm). The absolute time seems to be more appropriate as for the productivity of the production process it does not matter how fast the truck was but how long it took to transport the good from one plant to the next plant. However, due to increased distances absolute freight transport times for all goods categories are increasing. This is presented in Figure 5 specified for the three goods categories with the strongest growth for bulk goods followed by unitised goods and the three freight modes with strongest growth for road, for which in addition to distance increases also congestion effects might increase absolute transport times. The only transport time decrease is observed for ship mode.

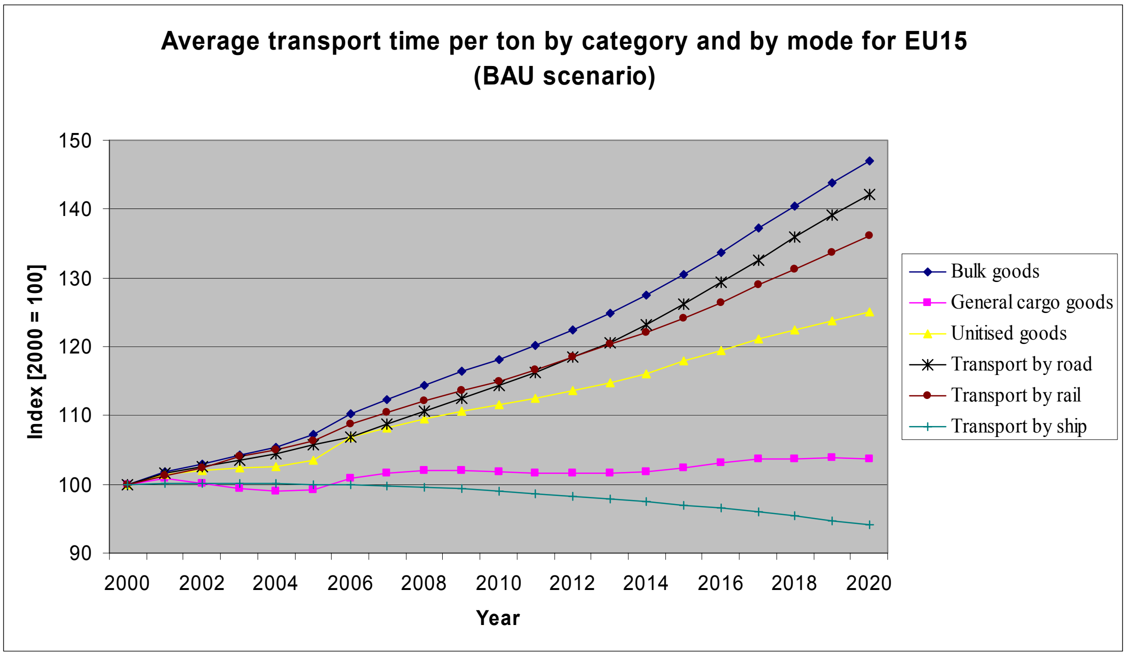


Figure 5: Average transport times per ton per trip are increasing besides for ship transport

3 Direct and indirect effects in ASTRA

Discussions about assessment of transport policies, focusing especially on infrastructure policies, emphasize that there might exist indirect effects of transport policies that are not measured by current CBA assessment practice that concentrates on measuring cost- and travel-time-changes of transport users on the transport network[4] as comprehensively as possible stating that these would describe the welfare benefits of the transport policy expressed by consumer and producer surplus. This way, sometimes called the engineering approach, of measuring costs and benefits of transport policies would be called direct measurement leading to a (dis-)benefit value for direct effects of transport policies. In theory, if markets would be perfect, this benefit would be equal to indirect effects of transport policies such that no additional effects would accrue and it would also not be necessary to speak about indirect effects. Nevertheless, as markets are not perfect the existence of indirect effects seems to be possible and probable. These indirect effects would appear outside the transport market elsewhere in the economy such that obviously a transport network model would be inadequate to measure them.

The previous discussion omits that besides economic effects also other kind of indirect effects of transport policies exist, namely environment and safety impacts. These constitute important elements for assessment of transport policies. However, in the context of discussions in this section it is assumed that all assessment approaches analysed would consider these effects and would treat them in the same way such that they would not make a difference to results.

SACTRA (1999) supported by VENABLES and GASIOREK (1999) using a stylised Spatial Computable General Equilibrium (SCGE) model conclude that additional effects of transport policies exist and that they could either become positive or negative. SACTRA estimates

[4] Though transport network in principle would be a physical object easily to define, it constitutes a crucial element of transport CBA to define, which part of the network is considered for the CBA. It is assumed here that this definition is made properly such that no additional effects would occur due to an imperfectly defined transport network.

additional effects, which would be the difference between direct effects and indirect effects, amount to 6-12% of direct effects measured by current CBA practice.

Concluding, there remain two important research questions associated with the discussion on direct and indirect welfare effects of transport policy: Firstly, what would be the relation between direct and indirect effects? Secondly, how could indirect effects be measured? ASTRA represents an appropriate tool to shed light on these questions as it allows for measuring direct effects as well as indirect effects, though it does not apply the theoretical concepts of welfare economics. Additionally, it enables to analyse in detail the impact mechanisms causing the indirect effects in the frame of ASTRA.

The following sections present measurement of direct and indirect effects with ASTRA using two scenarios to implement the Trans-European Transport Networks (TEN) in a faster way than planned so far. Faster implementations is either financed by an appropriate increase of fuel tax (**TEN+Fuel scenario**) or by the implementation of Social Marginal Cost Pricing (SMCP) for all transport modes such that part of the SMCP revenues is used to finance the TEN (**TEN+SMCP scenario**). The remaining SMCP revenues are refunded to the consumers via income tax reductions. Applied TEN investments in the scenario are shown in Figure 6 and SMCP charges in Table 6. In BAU scenario TEN are implemented according to plan and are financed by appropriate fuel tax increase, which is lower than in TEN+Fuel due to the longer construction period in BAU.

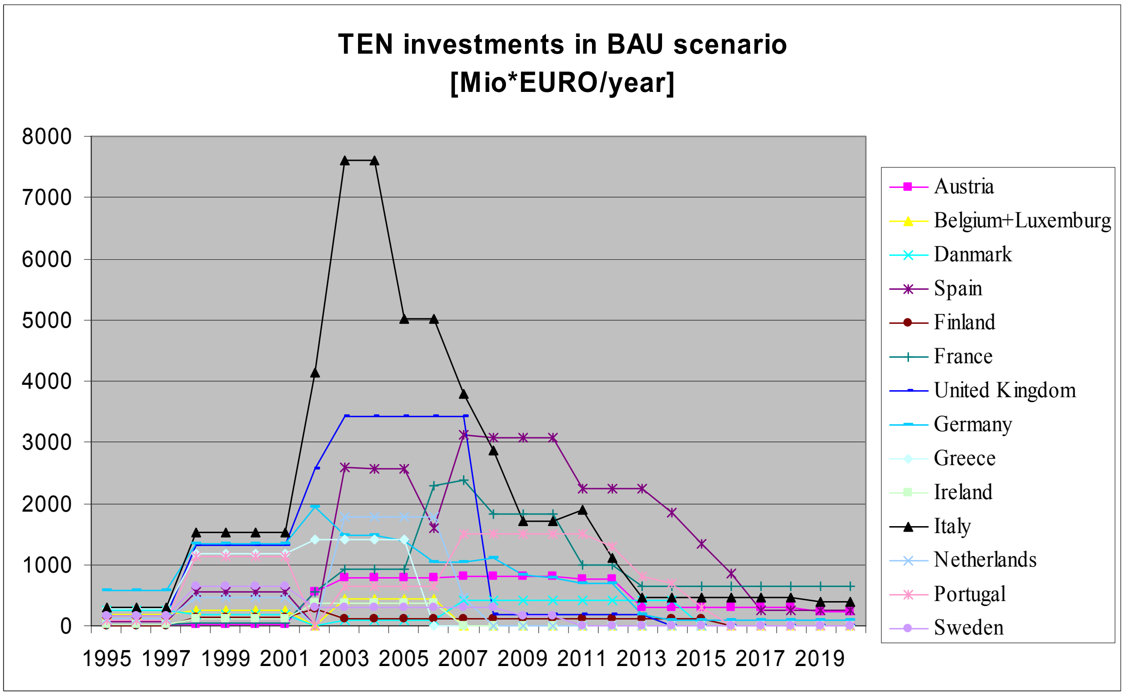


Figure 6: Development of yearly TEN investments in the European countries in BAU scenario

Table 6: SMCP in eurocents(2002)/pkm (passengers), eurocents(2002)/tkm (freight)

P/G	MODE	ALL	AT	BE	DE	DK	FI	FR	GR	IR	IT	LU	NL	PT	SP	SW	UK
Goods	HGV	2.40	2.73	2.52	2.03	1.90	1.85	2.60	1.99	1.97	3.98	3.19	2.66	2.05	2.57	2.52	1.32
Goods	Med.Truck	6.48	7.37	6.81	5.47	5.13	5.01	7.03	5.39	5.32	10.7	8.61	7.19	5.54	6.95	6.81	3.57
Goods	Rail	0.28	0.31	0.35	0.35	0.28	0.15	0.46	0.19	0.22	0.34	0.35	0.32	0.18	0.22	0.17	0.25
Goods	IWW	0.26	0.35	0.38	0.31		0.12	0.38			0.31	0.38	0.34			0.15	0.23
Goods	SSS	1.21		2.01	1.20	0.58	0.25	2.56	2.30	0.37	1.73		0.38	0.72	0.60	0.70	0.43
Passengers	Car	5.94	7.36	4.61	7.13	5.23	4.31	7.70	5.71	5.11	6.54	8.61	6.47	4.49	5.42	3.33	3.07
Passengers	Bus/Coach	2.49	3.13	3.21	2.79	2.06	1.39	3.39	2.15	1.64	2.86	3.56	2.76	1.67	2.08	1.57	2.42
Passengers	Train	1.56	2.07	1.83	1.72	1.77	0.76	1.68	1.00	1.36	1.62	1.83	1.69	1.01	1.18	1.90	1.48
Passengers	Ferry	1.90	-	2.14	2.07	2.18	1.80	2.02	1.23	1.74	1.99	2.14	2.01	1.26	1.44	1.89	1.80
Passengers	Air	3.73	3.93	4.07	4.03	3.88	3.39	3.93	2.40	3.18	4.27	3.84	6.44	2.49	2.76	3.32	3.64

Source: PONTI et al. (2002), IWW = inland waterway, SSS = short sea shipping

3.1 Measuring direct effects in ASTRA

Transport data provided by ASTRA for the calculation of direct effects differs from the link based approach of transport network models. ASTRA includes a four-stage transport model based on OD-matrices between the 53 zones of ASTRA. Matrices exist for five passenger modes and three trip purposes as well as three freight modes and three goods categories comprising for both passenger and freight matrices. The fourth stage, route choice, is simplified providing speed-flow functions in an aggregate manner for all modes. Transport demand is distributed onto five distance bands (i.e. distance categories) for passenger and four distance bands for freight. In both cases the two longest distance categories are differentiated into about 30.000 OD pairs each to cover all mode-purpose-zones combinations in EU15. Based on the briefly described transport model consumer surplus, as the appropriate welfare measure for direct effects of transport, can be calculated by using the rule-of-half (MACKIE et al. 2001) as follows:

$$CS = \sum_{EC,OC,m} CS_{EC,OC,m} = \frac{1}{2} * \quad \textbf{(eq. 6)}$$

$$\sum_{EC2,DC,p,db} \left[\left(GC_{EC,OC,EC2,DC,m,p,db,BAU} - GC_{EC,OC,EC2,DC,m,p,db,Sc} \right) * \left(V_{EC,OC,EC2,DC,m,p,db,BAU} + V_{EC,OC,EC2,DC,m,p,db,Sc} \right) \right]$$

with:

CS =	Consumer surplus [Mio*EURO]
GC =	Generalised cost [Mio*EURO]
V =	Volume [Mio*pkm, Mio*tkm]
m =	index mode (car, bus, train, air, slow OR truck, rail, ship)
p =	index purpose (business, private, tourism) or goods category (bulk, general cargo, unitised)
db =	distance band (<3,2km, 3,2-8km, 8-40km, 40-160km, >160km OR <50km, 50-150km, 150-700km, >700km)
Sc =	index policy scenario
BAU =	index Business-as-usual scenario
OC =	index for origin functional zone in origin country (MPA, HDA, MDA, LDA)
EC2 =	index for destination country of EU15 countries
DC =	index for destination functional zone in destination country (MPA, HDA, MDA, LDA)
EC =	index for origin country of EU15 countries

Producer surplus could not be calculated within the transport system as only full user cost functions are implemented while for producer cost only some elements are included in the model like the fuel cost or vehicle cost. As a proxy one might consider the change in gross-value added for the transport service sectors. But this would be an indirect indicator that is not based on welfare theory like consumer surplus.

Results for consumer surplus are discounted by 3% and a period of 18 years is used for comparison as the most significant policy changes start in 2002. Usually for CBA´s of transport infrastructure longer periods are used as the usage period is above 30 years, but it should be emphasized that this analysis aspires no full CBA, which would include to look also at e.g. environmental effects, but a comparative dynamic analysis of potential direct and indirect economic effects of transport policies.

Table 7 presents the total consumer surplus for the two scenarios in comparison to the total TEN investment to enable the reader to classify the order of magnitude of results. Increase in consumer surplus in the TEN+Fuel scenario is smaller than investment needed. Nevertheless, one should consider that this provides not a complete CBA result as producer surplus, environmental improvements or accidents are not considered. TEN+SMCP scenario generates large disbenefits due to the high cost increase, also much larger than the investment. It can be concluded that the TEN+SMCP policy, and this is also valid for other policy scenarios including variants of implementing significant transport charges, provides large disbenefits if one would measure the direct effects only. Since consumer surplus on average accounts for about 70% of benefits it could not expected that considering further categories of benefits would change the picture fundamentally.

Table 7: Direct effect measured as discounted consumer surplus per country

[Mio*EURO95]	TEN Investment[5]	TEN+Fuel	TEN+SMCP
Austria	8,945	-1,015	-86,330
Belgium+Luxemburg	3,229	2,693	-130,767
Denmark	4,438	255	-61,056
Spain	29,785	4,220	-238,166
Finland	2,091	702	-53,847
France	16,844	9,259	-1,079,868
United Kingdom	24,902	19,309	-443,181
Germany	18,743	29,740	-1,431,385
Greece	11,001	972	-60,049
Ireland	2,289	790	-24,612
Irtaly	47,751	2,712	-783,708
Netherlands	9,210	3,728	-257,940
Portugal	15,598	-1	-38,972
Sweden	5,343	1,330	-87,992
EU15	**200,171**	**74,696**	**-4,777,872**

Source: ASTRA results

[5] After 2001 also discounted with discount rate of 3%.

Two points should be noted from these first results on direct effects:

- TEN+Fuel scenario generates a positive consumer surplus, while TEN+SMCP is negative.
- Results differ by at least one order of magnitude with TEN+SMCP having the by far larger impact.

Comparing cost and time changes the cost in both scenarios reveal larger impacts than time. Three reasons have been identified: first, the cost changes by SMCP are enormous; second, mode-shifts due to improved relative competitive advantage occurs towards slower modes, such that travel time in some cases increase; third, travel time improvements by the TEN could be underestimated in ASTRA.

Looking at the modal distribution of consumer surplus in Table 8 the results for TEN+Fuel show that most benefits accrue to car transport, which seems to be an effect of mode shift away from car leading to faster car transport. Despite significant rail improvements by the TEN rail benefits remain small due to increased load and a possibly underestimated improvement of rail travel time. The results for TEN+SMCP indicate the much higher increase of cost by SMCP for passenger transport compared to freight with more than 90% of disbenefits relating to passenger transport.

Table 8: Discounted consumer surplus per mode

[Mio*EURO95]	TEN+Fuel	TEN+SMCP
Car	62,684	-3,552,242
Bus	-1,172	-357,996
Rail Pass	1,144	-367,128
Air	22	-197,009
Slow	0	0
Truck	10,986	-137,771
Rail Freight	1,030	-161,529
Ship	0	-4,197
EU15	**74,696**	**-4,777,872**

Source: ASTRA results

To confirm that the results on direct effects of ASTRA are reasonable a comparison with results of the SCENES transport network model for that is running the same scenarios is undertaken. SCENES constitutes a sophisticated European transport network model on NUTS-II level (ME&P 2000).

Comparing the absolute values for consumer surplus between SCENES and ASTRA the basic structure of results can be verified (Table 9): scenarios including SMCP generate very high losses of consumer surplus, while scenarios excluding SMCP cause moderate changes, only. In TEN+Fuel SCENES generates a negative consumer surplus mainly because of reduced volumes, while ASTRA generates a positive consumer surplus as in some countries the specific difference of fuel taxation between BAU and TEN+Fuel leads to cost reductions in some countries combined with time savings amounting to an overall positive consumer surplus. TEN+SMCP documents for both models that the applied SMCP charging levels would lead to tremendous losses of consumer surplus with 6.800 Bio EURO for SCENES and nearly 4.800 Bio*EURO for ASTRA both accumulated and discounted over 18 years.

Table 9: Discounted consumer surplus per country for SCENES and ASTRA

	TEN+Fuel		TEN+SMCP	
[Mio*EURO95]	**SCENES**	**ASTRA**	**SCENES**	**ASTRA**
Austria	-4,534	-1,015	-110,053	-86,330
Belgium+Luxemburg	-2,857	2,693	-141,392	-130,767
Denmark	-1,433	255	-66,225	-61,056
Spain	-19,670	4,220	-273,888	-238,166
Finland	-637	702	-56,509	-53,847
France	-13,799	9,259	-807,596	-1,079,868
United Kingdom	-15,409	19,309	-448,090	-443,181
Germany	28,489	29,740	-3,796,179	-1,431,385
Greece	-4,630	972	-58,309	-60,049
Ireland	-949	790	-31,890	-24,612
Irtaly	-14,220	2,712	-593,921	-783,708
Netherlands	-481	3,728	-248,350	-257,940
Portugal	-3,021	-1	-54,979	-38,972
Sweden	-1,569	1,330	-112,302	-87,992
EU15	**-54,719**	**74,696**	**-6,799,684**	**-4,777,872**

Source: SCENES results, ASTRA results

3.2 Measuring indirect effects in ASTRA

So far, we focused on the direct effects measured in ASTRA. The following paragraphs concentrate on indirect effects. Indirect effects could either be measured by changes of GDP, Disposable Income or Consumption in ASTRA. Disposable Income would be most appropriate as it explicitly considers the taxation implications of policies that change direct or indirect taxation e.g. fuel taxation policies, refunding of SMCP. For easier comparisons of results with other models GDP has been selected as this is more commonly used for analysis.

Figure 7 presents as an example the time-path of discounted changes of GDP in TEN+SMCP policy for the EU15 countries compared to BAU. Aggregating these GDP changes over 18 years provides the indirect effects discussed later on in this section. Great variety of GDP effects for the different European countries can be observed. In some cases the sign of the GDP changes varies over time e.g. with France having a GDP increase in the short and medium term but a decrease in the long-term and Germany showing an increase in the short- and long-term, but a decrease in the medium term. These mixed patterns result for the total EU15 in a short-term increase of GDP, a medium-term decrease and nearly neutral long-term impact.

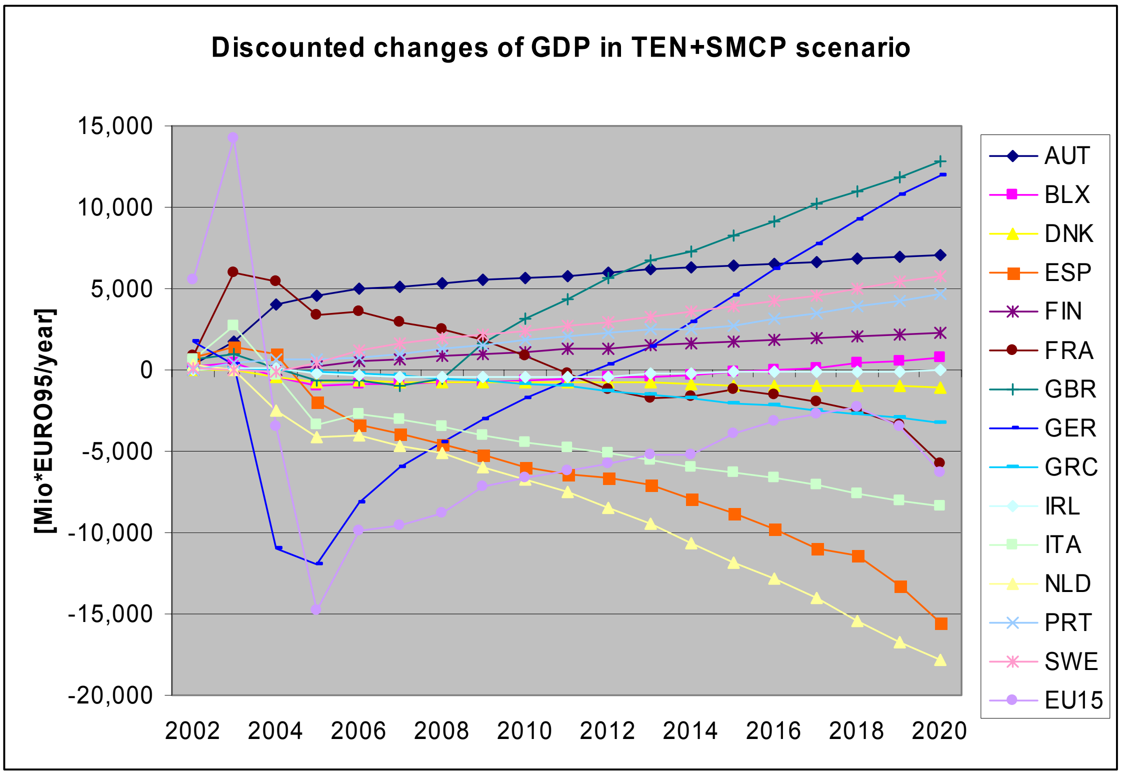


Figure 7: ASTRA indirect effects given as discounted change of yearly GDP

For the purpose of analysis variants of the scenarios could be calculated using fixed transport generation and for international freight transport also a fixed distribution that is taken from the results of BAU scenario. This adaptation of scenarios cuts off the feedback **from** the economy **to** transport such that no indirect network effects interfere with the direct effects. Hence, with adapted scenarios with fixed transport generation only direct effects due to reactions of the transport system are measured, while with the full scenario direct effects due to reactions only of the transport system plus indirect network effects due to reactions of the economic system could be measured within the transport system by consumer surplus.

Total discounted changes of GDP in the two scenarios and their variants with fixed transport generation are presented in Table 10 together with a comparison of the TEN investments. In both cases results of indirect effects measured as change of GDP for the scenario and the variant with fixed transport differ. In TEN+Fuel the feedback loop between economy and transport generate about 60 Bio*EURO additional GDP growth. In TEN+SMCP scenario the reaction differs with a negative result for the scenario including all feedbacks and a positive GDP change if indirect network effects are excluded.

Table 10: Indirect effects per country in ASTRA as total discounted change of GDP

[Mio*EURO95]	TEN Investment[6]	TEN+Fuel scenario Fixed Transport	TEN+Fuel scenario Closed Feedback from economy totransport	TEN+SMCP scenario Fixed Transport	TEN+SMCP scenario Closed Feedback from economy totransport
Austria	8,945	5,802	8,144	103,441	102,061
Belgium+Luxemburg	3,229	2,856	22,938	5,683	-4,492
Denmark	4,438	463	508	-12,848	-14,091
Spain	29,785	78,494	80,980	-112,950	-119,978
Finland	2,091	-2,190	-2,221	27,673	22,520
France	16,844	2,706	18,196	107,479	6,227
United Kingdom	24,902	30,613	30,454	125,311	91,137
Germany	18,743	8,772	7,917	85,879	10,354
Greece	11,001	-13,132	-11,682	-23,166	-23,938
Ireland	2,289	543	687	-4,005	-3,744
Irtaly	47,751	14,043	24,935	-31,408	-83,510
Netherlands	9,210	6,417	7,695	-116,705	-157,895
Portugal	15,598	5,745	11,245	42,565	39,614
Sweden	5,343	-1,291	-735	63,121	51,036
EU15	**200,171**	**139,840**	**199,060**	**260,069**	**-84,699**

Source: ASTRA results

3.3 Comparison of direct and indirect effects with ASTRA

Direct comparison between direct and indirect effects represented by consumer surplus respectively change of GDP both calculated on the time-path base is shown in Table 11. For both scenarios the signs are the same for the EU15. However, for the TEN+Fuel scenario the order of magnitude between consumer surplus and GDP is similar with GDP being three times consumer surplus. But for the TEN+SMCP scenario the direct effects differ by more than one order of magnitude from the indirect effects. Obviously this indicates that direct and indirect effects can differ significantly due to mechanisms in the economy that change, dampen or amplify the original direct effects. The result for consumer surplus would be disastrous with a loss of nearly 4,800 Bio EURO for EU15 by the policy though looking at the indirect effects a "mere" loss of 85 Bio EURO is observed.

[6] After 2001 also discounted with discount rate of 3%.

Table 11: Comparison of direct and indirect effects in ASTRA

	TEN+Fuel			TEN+SMCP		
[Mio*EURO95]	**Direct Effects**	**Indirect Effects**		**Direct Effects**	**Indirect Effects**	
	Consumer Surplus	GDP change	Employment [Pers*years]	Consumer Surplus	GDP change	Employment [Pers*years]
AUT	-1,015	8,144	54,353	-86,330	102,061	-2,381
BLX	2,693	22,938	298,648	-130,767	-4,492	80,682
DNK	255	508	8,282	-61,056	-14,091	-1,241,027
ESP	4,220	80,980	954,379	-238,166	-119,978	-5,053,918
FIN	702	-2,221	-22,956	-53,847	22,520	-303,728
FRA	9,259	18,196	194,186	-1,079,868	6,227	-2,920,140
GBR	19,309	30,454	982,534	-443,181	91,137	755,134
GER	29,740	7,917	265,210	-1,431,385	10,354	-4,380,214
GRC	972	-11,682	-105,096	-60,049	-23,938	-501,698
IRL	790	687	1,981	-24,612	-3,744	-73,262
ITA	2,712	24,935	204,338	-783,708	-83,510	-1,300,072
NLD	3,728	7,695	31,982	-257,940	-157,895	-999,537
PRT	-1	11,245	291,557	-38,972	39,614	54,556
SWE	1,330	-735	-4,405	-87,992	51,036	83,166
EU15	**74,696**	**199,060**	**3,154,993**	**-4,777,872**	**-84,699**	**-15,802,436**

Source: ASTRA results

Figure 8 presents this finding of large differences between consumer surplus (=direct effects) and change of GDP (=indirect effects) graphically for the TEN+SMCP scenario.

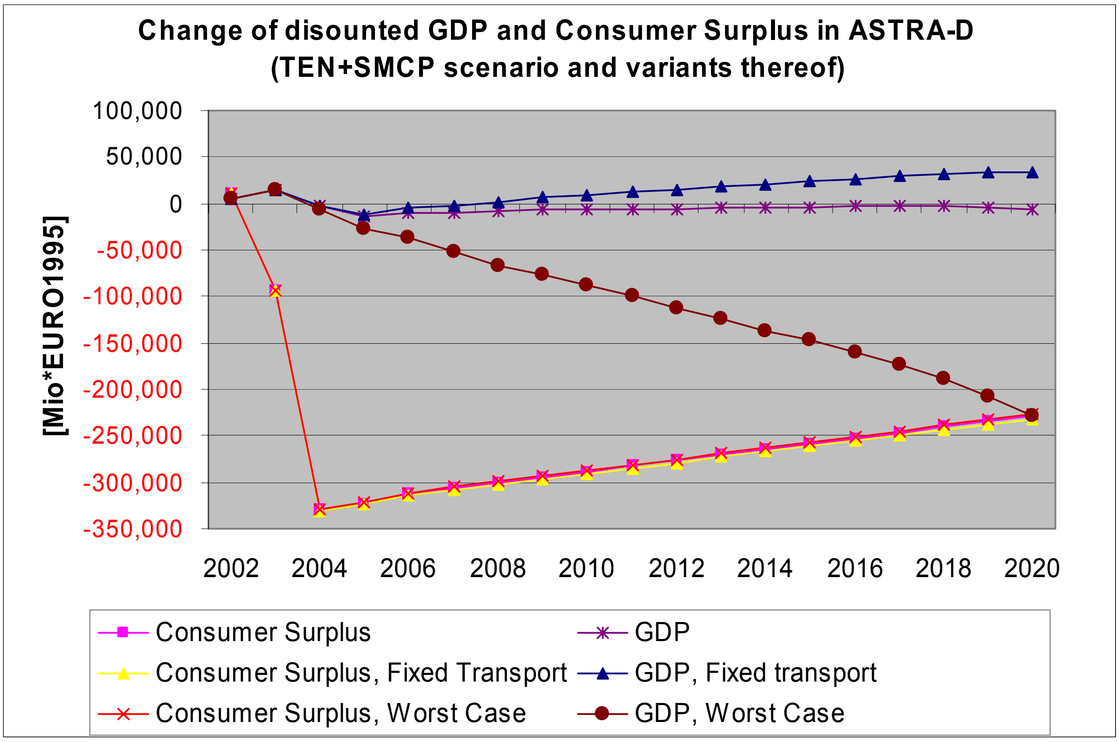


Figure 8: Comparison of direct and indirect effects in ASTRA for TEN+SMCP scenario

To emphasize that economic mechanisms outside the transport system cause the difference between direct and indirect effects one could think of a worst-case adaptation of the TEN+SMCP policy, which would be adapted by not refunding the revenues of the SMCP via a reduction in income tax. Instead the revenues would go into general government budget and are used to reduce the government debt. Introducing a thought experiment by assuming we would test this adapted TEN+SMCP scenario with fixed transport generation from BAU scenario then we would have no change of consumer surplus, because transport generation is fixed, but GDP would develop much worse than in the basic TEN+SMCP scenario due to missing economic mechanisms especially the refunding to consumers.

To confirm the thought experiment I tested the TEN+SMCP scenario with flexible generation but no refund such that SMCP revenues remain within government budget and reduce debt. In Figure 8 the result is presented by the curves on *Consumer Surplus Worst Case* and *GDP Worst Case*. It shows the expected development with a negligible change of consumer surplus, caused by changes of indirect effects feeding back to the transport system, and a deterioration of GDP with a total discounted loss over 18 years of 1900 Bio EURO compared with an 85 Bio EURO loss of the basic TEN+SMCP scenario. The reason is that now the negative impact of SMCP, which shows up in the change of consumer surplus, is not counterbalanced by increased consumption with further positive economic impacts e.g. on investments and exports. The alternative to feed revenues into government budget and reduce the debt does not provide similar positive impacts than increasing consumption. Obviously, the question if assessment based on direct effects is sufficient depends very much on the economic mechanisms that can be triggered either by accident or by design of the policy.

Table 12 presents the results from Table 11 in a different way to easily identify additional effects of the two scenarios. For TEN+Fuel it could be observed that additional effects could either be positive or negative due to different mechanisms that are triggered in the countries. In TEN+SMCP economic mechanisms in all countries improve the result compared with a mere measurement of consumer surplus.

Table 12: Additional effects in ASTRA from difference between change of GDP and consumer surplus

	TEN+Fuel scenario		**TEN+SMCP scenario**	
	Additional Effects [Mio*EURO]	%-additional to direct effects	Additional Effects [Mio*EURO]	%-additional to direct effects
AUT	9,159	902.36	188,391	218.22
BLX	20,245	751.76	126,275	96.56
DNK	253	99.22	46,965	76.92
ESP	76,760	1818.96	118,188	49.62
FIN	-2,923	-416.38	76,367	141.82
FRA	8,937	96.52	1,086,095	100.58
GBR	11,145	57.72	534,318	120.56
GER	-21,823	-73.38	1,441,739	100.72
GRC	-12,654	-1301.85	36,111	60.14
IRL	-103	-13.04	20,868	84.79
ITA	22,223	819.43	700,198	89.34
NLD	3,967	106.41	100,045	38.79
PRT	11,246	n.a	78,586	201.65
SWE	-2,065	-155.26	139,028	158.00
EU15	124,364	166.49	4,693,173	98.23

Source: ASTRA results presented in Table 11

Obviously the results differ significantly from expectations raised by the SACTRA conclusions as the additional effects could become much larger than 6-12% as concluded by SACTRA, though the statement that additional effects could become either positive or negative also holds for the ASTRA results. The analysis of reasons for the ASTRA model results revealed a set of transport-economic mechanisms that together generate the results. Figure 9 presents the mechanisms that are evoked by a SMCP policy and their associated time scale on which they enfold. Similar mechanisms are activated for other policies though e.g. infrastructure investment policies would show an additional direct impact on investment and final demand, which is not present in a mere SMCP policy.

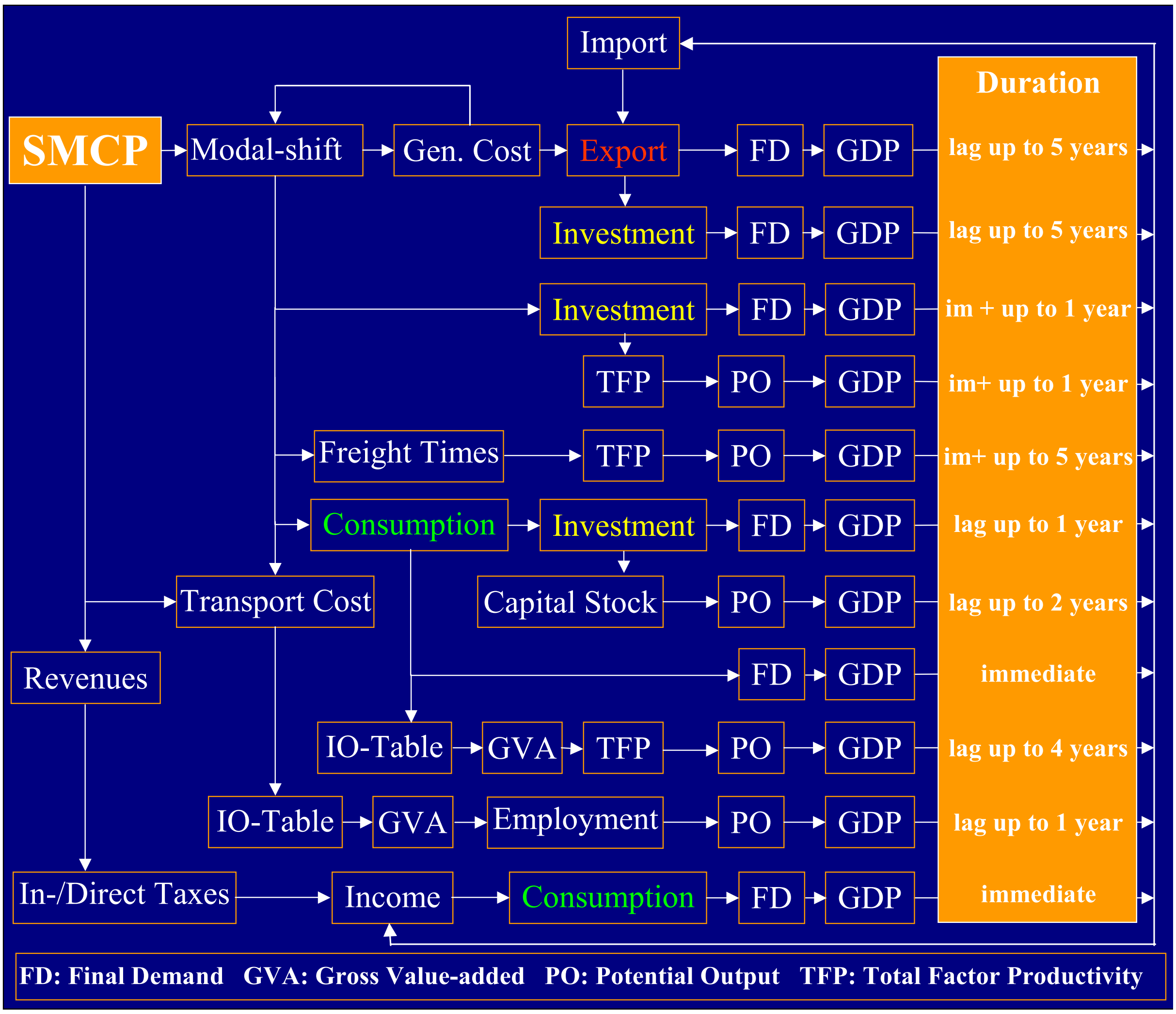


Figure 9: Impact chains and their time structure kicked off by SMCP policies (SCHADE 2004)

In principle each mechanism may have different strength in different countries. However, out of the many mechanisms three most relevant mechanisms shaping the results of the ASTRA model are identified with respect to the SMCP or other pricing policies:

- **Freight-time-TFP chain**: Freight modal-shift leads to in- or decreases of weighted freight times to reach all destinations from a region, which provides a kind of accessibility measure, that affects TFP and potential output of a country finally leading to changes of GDP. Starting from GDP a new cascade of impacts trickle down to other parts of the economy and enfold their impact over time.

- **Consumption-shift chain**: Changed car purchase behaviour and passenger modal-shift induces sectoral consumption shifts that affect sectoral final demand. Feeding through the IO-table sectoral gross-value added (GVA) affects employment as well as TFP such that in the end also potential output and GDP are affected and further impacts move on to other parts of the economy.
- **Export-Investment chain**: SMCP increases transport (generalised) cost that reduces sectoral exports affecting final demand both directly and via reduced investment. Final demand contributes a second driver for GDP besides the influence from potential output in the previously mentioned mechanisms.

In fact only the latter chain would have been intuitively expected as shaping the results. The other mechanisms have been identified by a thorough analysis of potential mechanisms.

4 Conclusions

The result of the analysis of direct and indirect effects does not reveal any pattern that would prove a structured relationship between direct and indirect effects of transport policies. In other words, it seems that direct effects and indirect effects may have very loose links, only, if significant long-term mechanisms enfold due to a policy, such that the objective of the discussion, mentioned at the beginning of this paper, to find a rule for adding a certain additional benefit to direct effects to consider indirect effects in transport policy assessment can not be fulfilled respectively has to be rejected.

In fact, economic mechanisms in ASTRA seem to dominate and transform direct effects measured in the transport system. This conclusion is valid for large infrastructure programmes or national policies. It could be different for single small-scale infrastructure projects e.g. like analysed in the SACTRA studies (1999) that came to different conclusions.

On the other hand, the simple thought experiment considering the same scenario from the transport side by cutting the feedback from the economy to transport, but changing the economic side using revenues generated in the scenarios in different ways either by refunding them to consumers or by putting them into government budget to reduce debt would also suggest that impacts of the two ways to use revenues will be different. The thought experiment substantiates the ASTRA results that show significant distinctions of indirect effects between the two scenarios though the transport effects (direct effects) are the same.

Obviously, for large infrastructure programmes or national transport policies current CBA practice based on direct effects only is not sufficient. The final results of transport policies in terms of social and economic impacts measured as (un-)employment and either as change of GDP, Income or Consumption are produced by economic mechanisms that seem to change the result for the direct effects based on Consumer Surplus or Generalised Cost significantly, in some cases even changing the algebraic sign between direct and indirect effects.

With ASTRA three important advancements can be contributed to the discussion on direct and indirect effects. Firstly, integrated models of transport and the economy are key to guarantee new insights as the feedbacks between transport and the economy are relevant. Secondly, the shift from static to dynamic models is important as economic mechanisms may enfold over time, and thirdly implementation of fully-fledged policies should be preferred to the application of partial policies.

Considering these points a model could enfold additional mechanisms that compensate or aggravate the changes in the transport system. Which mechanisms become important for a country, as the smallest regional level considered in this paper, depends on the endowment with mechanisms of each country. Potentially relevant mechanisms identified in ASTRA would be:

- sectoral reactions of trade relationships;
- modal-shifts of
  - freight transport affecting generalised cost of trade relationships and transport times with their impact on total factor productivity;
  - passenger transport affecting sectoral consumption and investment;
- thresholds of modal choice and redistribution decisions;
- shifts between imported consumption goods and domestic consumption goods;
- synergies between the various mechanisms.

The analysis presented in this paper will be enriched in the future as ASTRA is a continuously evolving model that could still be improved significantly e.g. by endogenizing the linkage with a finer spatial zoning system or by adding further mechanisms like increased segmentation of households that would allow to shift between households of different behaviour.

Anyhow, the analysis confirms that considering dynamics, which may enfold over years, and fully-fledged policies, instead of partial policies, both are of key importance to analyse and derive indirect effects on economic impacts of larger scale transport policies.

5 References

Aschauer D A (1989): "Is public expenditure productive?", in: *Journal of Monetary Economics*, vol. 23, pp. 177-200.

Bröcker J (2001): "Trans-European effects of Trans-European Networks: results from a spatial CGE analysis", in: Bolle, F., Carlberg, M. (eds.): *Advances in Behavioral Economics*. Heidelberg: Physica, 141-159.

Bröcker J, Meyer R Schneekloth N, Schürmann C., Spiekermann K, Wegener M (2004): "Modelling the Socio-economic and Spatial Impacts of EU Transport Policy", Deliverable D6 of IASON project funded by the European Commission 5th RTD framework, Kiel.

CEC - Commission of the European Communities (2001): "European transport policy for 2010: Time to decide", White Paper, Brussels.

Christidis P, Hernandez H, Lievonen J (2002): "Impact of technological and structural change on employment: Prospective analysis 2020 – background Report", EU publication-nr EUR 20258 EN, Report on behalf of the European Parliament, Seville.

Forrester JW (1962): "Industrial Dynamics", MIT Press, John Wiley & Sons, 2nd edition, New York.

Forrester JW (1977): "Principles of Systems", MIT Press, Cambridge MA.

Fujita M, Krugman P, Venables AJ (1999): "The spatial economy: Cities, regions and international trade", MIT Press, Cambridge MA.

Fujita M, Krugman P (2004): "The new economic geography: Past, present and the future", in: *Papers in Regional Science*, vol 83, pp 139-164.

Mackie PJ, Nellthorp J, Kiel J, Schade W, Nokkala M (2001): "IASON Project Assessment Baseline", Deliverable D1 of IASON project funded on behalf of the European Commission 5th RTD framework, TNO Inro, Delft.

ME&P (2000): "SCENES European Transport Forecasting Model and Appended Module: Technical Description", Deliverable D4 of SCENES project funded by the European Commission 4th RTD framework, Cambridge.

Meadows DH (1980): "The Unavoidable A Priori", in: Randers J (ed) *Elements of the System Dynamics Method*, Productivity Press, Cambridge.

Oosterhaven J, Elhorst JP (2003): "Indirect Economic Benefits of Transport Infrastructure Investments", in: W. Dullaert, B.A.M. Jourquin & J.B. Polak (eds) *Across the border. Building upon a quarter century of transport research in the Benelux*, De Boeck, Antwerpen, 2003, pp. 143-62.

Ponti M, Maffii S, Borgnolo C, Pastori E, Pasti G (2002): "Common assumptions and scenarios", Deliverable D1 of the TIPMAC project funded by the European Commission 5th RTD framework, Milan.

SACTRA - Standing Advisory Committee On Trunk Road Assessment (1999): "Transport and the Economy", The Stationery Office, London.

Samuelson PA (1954): "The Transfer Problem and Transport Costs; II: Analysis of Effects of Trade Impediments", in: *The Economic Journal*, no 64, pp 264-289.

Schade W (2004): "Strategic Sustainability Analysis: concept and application for the assessment of the European Transport Policy", Dissertation thesis, publication forthcoming in Nomos Verlag, Baden-Baden.

Schade W, Fiorello D, Martino A (2002): "ASTRA Model Update: Description of the ASTRA-T model", Deliverable D3 of the TIPMAC project funded on behalf of the European Commission 5th RTD framework, Karlsruhe.

Steininger K (2001): "International Trade and Transport – Spatial Structure and Environmental Quality in a Global Economy", Edward Elgar, Cheltenham.

Sterman JD (2000): "Systems Thinking and Modeling for a Complex World", Irwin McGraw-Hill, Boston.

Venables AJ, Gasiorek M (1999): "The Welfare Implications of Transport Improvements in the Presence of Market Failure", Report to the UK SACTRA Committee, London.

Waldorf BS (2004): "Path-breaking books in regional science", in: *Papers in Regional Science*, vol 83, pp 59-89.