Quantification of climate policy scenarios for long-term trends in sustainability in ASTRA

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Abstract: (129 words)

One aim of this paper is to show the mode of action of the integrated transport-economic-environment model ASTRA that is based on the System Dynamics Modelling method. Furthermore two policy scenarios - one in which a tax per ton of CO_2 emitted by transport will be introduced and another with a significant increase of crude oil price until 2020 - will be compared to a reference case. The reference scenario results will be analysed to identify long-term trends in transport, economy and environment. The scenarios results show the impact on a sustainable development by an introduction of transport emission pricing by policy makers on the one hand and of a stronger increase of crude oil prices based on the fact of growing scarcity of oil resources on the other hand.

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1 Introduction

The fact of transport playing an essential role for the functioning and growth of economy is confirmed by the White Paper "European transport policy 2010: Time to decide" (CEC 2001) of the European Commission. Globalisation in economy is proceeding and networks are opening which implicates growing transport activities. Besides the economic benefits of increased transport flows within Europe the burden caused by growing transport activities has to be kept in mind. Therefore one major challenge for policy makers in the transport sector is to achieve economic growth in an environment-friendly way.

While in the EU15 countries, projected trend of CO_2 emissions is stagnating or growing slower than the world level the situation in the new member states of the EU and the other Eastern European countries is different. Until the middle of the 1990s the already existing central environmental authorities in most of the Central and Eastern European countries had only low institutional capacities, small budgets and therefore a rather limited influence. This implied that the technical standards are not as sophisticated as in EU15 countries as well as that environment-friendly transport equipment has been before standard were enforced, nearly unaffordable. With the opening of markets for the Central and Eastern European countries and the simplification of access in consequence of the joining of the European Union, transport activities coming from these countries are increasing especially on the road mode. This implicates an enormous challenge for policy makers.

As in most transport policies the extension of transport infrastructure emerges one of the major topics and investments in infrastructure have long lead-times because realisation of infrastructure projects takes in some cases an entire decade policy makers rely on tools enabling projections of the impacts by their policies. With the aim to generate such a tool enabling the assessment of long-term impacts of the European transport policy with respect to economic, environmental and social effects the first version of the ASTRA model has been developed in the 4th FP of the European Commission by the Institute for Economic Policy Research (IWW), Karlsruhe, Trasporti e Territorio (TRT), Milan, Marcial Echenique & Partners (ME&P), Cambridge, and Centre for Economics and Business Research (CEBR), London, within the ASTRA project. ASTRA, which is the abbreviation for Assessment of Transport Strategies, is based on the System Dynamics Modelling method. The ASTRA model was enhanced within the EU project LOTSE to extend the coverage on all current 25 EU member states plus the candidate countries Bulgaria and Romania and EU15 neighbour countries Norway and Switzerland.

The purpose of this paper is on the one hand to give an overview on the mode of action in the System Dynamics model ASTRA. On the other hand the comparison of results of two chosen policy scenarios - implemented in ASTRA for the LOTSE project - with a reference case should help identifying long-term trends in transport, economy and environment. Therefore the ASTRA model is run from the time period beginning in 1990 until the year 2020. The first scenario is characterised by an introduction of a tax of 12 Euro per ton of CO_2 emitted by transport. As discussed by European policy makers, a CO_2 tax is one of the policy instruments that could lead to a sustainable development in Europe. In the second scenario the trend of significantly increasing crude oil prices, which occurred especially in the year 2004, is continued according to opinions of experts until the year 2020.

2 System Dynamics

To develop ASTRA the System Dynamics methodology and the System Dynamics standard software package Vensim 5.0 is applied. System Dynamics was developed during the 1960ies by FORRESTER (1962, 1977) at the Massachusetts Institute of Technology (MIT) to analyse the long-term behaviour of social systems like huge industries (General Electric) or cities (Boston). Forrester, who was an Electrical Engineer by education, applied the mathematical methods developed to analyse electric feedback control systems to social systems. He developed a graphical code, the mathematical foundations based on engineering approaches and the necessary software. In the end a theory and corresponding methodology was born that is based on:

- The theory of information feedback systems applied to social systems;
- The mathematics of differential analysis respectively difference equation analysis;
- Decision theory;
- An experimental model approach to the design of complex social systems;
- Digital computing for the vast amount of computation;
- A graphical scheme to represent systems of feedback loops.

Modern information feedback systems emerged at the beginning of the 20th century and by this time have been closely related to electrical systems like the first transcontinental phone lines in the United States and anti aircraft radar systems. Nevertheless, in the literature it is shown that they date back until three centuries before Christ when the first water clock flow regulators have been developed. All those systems have in common that they consist of at least one closed feedback loop in which a signal dependent upon the output of the system is fed back to the input of the system in such a way that it affects its own value. The mathematician Norbert Wiener in his book Cybernetics in 1948 has been the first to conclude that the feedback loop concept is a universal concept applying not only to mechanic and electric systems but also to humans and human systems. Forrester extended this conclusion by demonstrating that human systems including economy, society, technology and environment consist of a set of interacting feedback loops. Hence, he had to develop a theory and methodology that is able to model those interactions. One of the first steps was to develop a scheme to graphically present the interactions within a system of feedback loops: the so-called effect diagrams. Based on these diagrams interdisciplinary teams could discuss and develop the structure of feedback loops in their analysed social systems. A subsequent step was to make use of the experiences gained by Electrical Engineers from analogue computers the so-called differential analysers. With these differential analysers a mathematical formulation was provided that enabled to describe a systems development over time. Forrester and his associates made use of this in developing software tools in the end using difference equations for calculating the dynamic equations of the feedback system and its development over time. To change from one state of the system to the next stage they applied decision rules. Finally, the developed software, called SIMPLE and DYNAMO in the beginning of System Dynamics, together with the ever increasing capabilities of digital computers provided the capabilities to follow an experimental modelling approach incorporating expert judgements and mental creativity, if no analytical or data-based solutions are available.

At IWW the System Dynamics methodology has been extended by System Dynamics Calibration Analysis, which is an approach that uses the optimisation capabilities of the applied Vensim software. With this analysis the whole model or parts of the model can be simulated and iteratively the relevant model parameters are altered until a certain statistical fit to real data is achieved or e.g. in case the model specifications would be misleading until a certain number of tests is performed without achieving the minimum statistical fit.

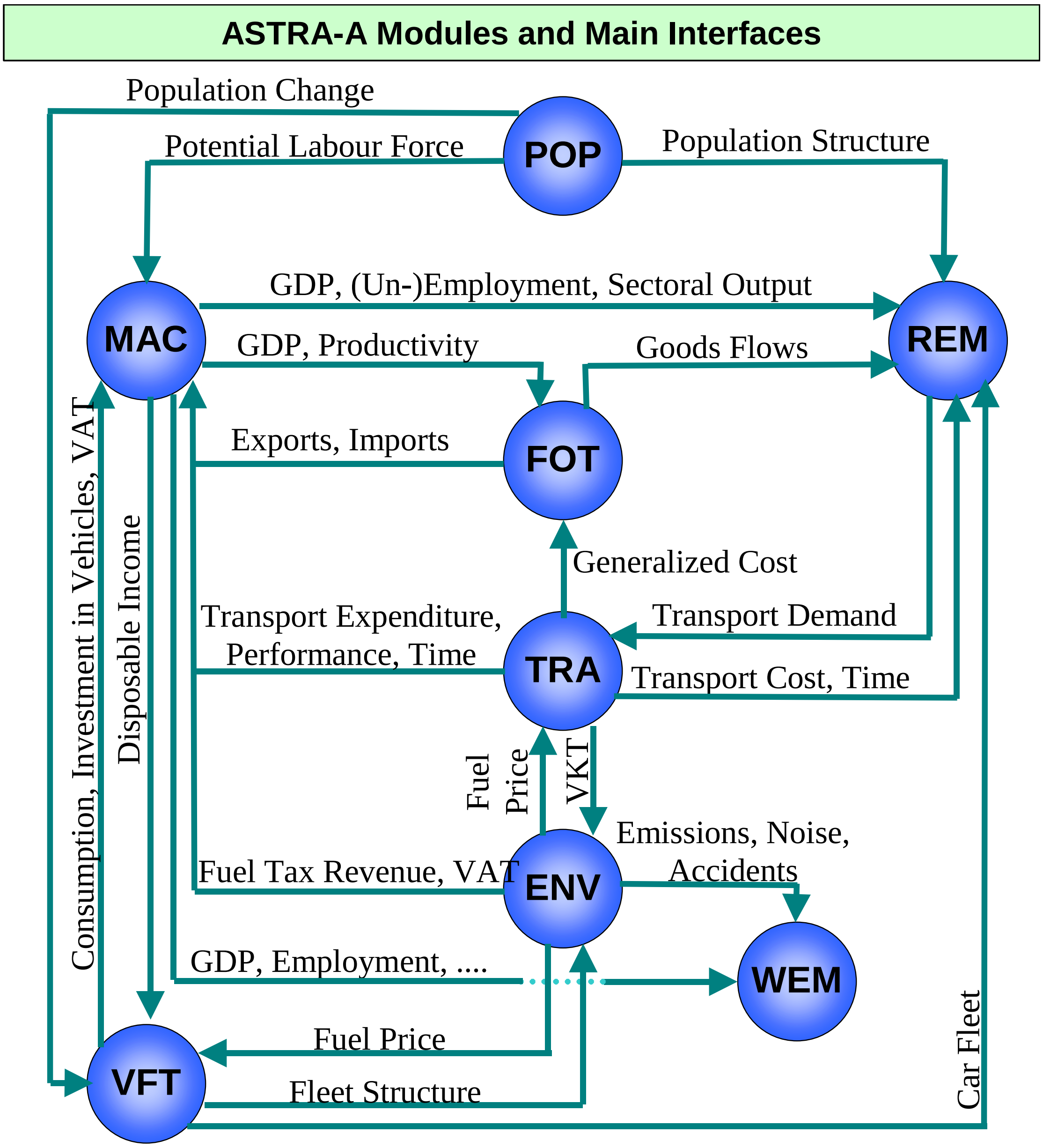
Additionally to the theory of System Dynamics, each module is based on specific theories related to the purpose of the module. For instance the macroeconomics module integrates neo-classical production functions with Keynesian consumption and investment behaviour and with elements of endogenous growth theory to incorporate technological progress.

3 Integrated overview on ASTRA

This chapter offers an overview over the modules of ASTRA. SCHADE (2004b) contains a more detailed description of the ASTRA model. The ASTRA model consists of eight modules that are all implemented within one Vensim 5.0 System Dynamics software file that is running on the Windows XP platform. The eight modules are:

- Population module (POP),
- Macro-economic module (MAC),
- Regional economic module (REM),
- Foreign trade module (FOT),
- Transport module (TRA),
- Environment module (ENV),
- Vehicle fleet module (VFT) and
- Welfare measurement module (WEM).

Figure 1 shows the interrelationships between the eight ASTRA modules picturing the major output variables coming from and input variables going into the modules:



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 structure of the ASTRA modules

3.1 Population module (POP)

The population module (POP) provides the population development for all 29 European countries with one-year age cohorts. The model depends on exogenous factors like:

- fertility rates,
- death rates,

- infant mortality rates and
- migration into the 29 modelled European 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 working age or the number of persons in age classes that permit to acquire a driving licence. The population in ASTRA is calibrated to fit the EUROSTAT baseline population predictions until 2050 (PONTI et al 2002).

3.2 Macro-economic module (MAC)

The national economic framework in which the other modules are embedded is provided by the macro-economic module (MAC). The MAC cannot be categorised explicitly into only one economic category of models, for instance a neo-classic model. Instead it incorporates neo-classical elements, like production functions, but also Keynesian elements as the dependency of investments on consumption. These have been extended according to the requirements of the ASTRA objectives e.g. such that investments are also made dependent on exports. Four major elements constitute the functionality of the macroeconomics module.

1. Sectoral interchange model

The sectoral interchange model reflects the economic interactions between 25 economic sectors of the national economies by an Input-Output table structure. The structure of 25 economic sectors is based on the NACE-CLIO system established by EUROSTAT for input-output data. The input-output tables are driven by changes of final demand. The structure of the tables can either change due to shifts between sectors of final demand and due to changes in transport costs that are part of the intermediate inputs in the input-output table like for example in the Crude Oil Price scenario caused by growing mineral oil prices. The main output taken from the input-output model are the sectoral production value (total output) and the sectoral gross value added. The sectoral production value is the major driver for the generation of domestic freight.

2. Demand side model

The second element, the demand side model depicts the four major components of final demand:

- consumption,
- investments,
- exports-imports (which is modelled in detail in the foreign trade module) and
- the government consumption.

3. Supply side model

The basic element of the supply side is a production function of Cobb-Douglas type calculating potential output that incorporates the three major production factors labour supply, capital stock and natural resources as well as technical progress referred to as total factor productivity (TFP) Total factor productivity is endogenised depending on sectoral investments, freight transport time-savings and labour productivity changes.

4. Employment model

The fourth element of MAC consists in 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 in order to capture the growing importance of part-time employment. In combination with the population module, unemployment can be estimated via regulation of activity rate of labour force.

5. Government model

The fifth element of MAC describes government behaviour. Government revenues are differentiated into revenues from social contributions, direct, indirect and other taxes and additionally transport pricing revenues. Transfers to households, subsidies, government consumption and investments form 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 transport investments, interest payments for government debt, government consumption and for EU15 unemployment payments, transfers to retired and children, on the expenditure side.

6. Micro-macro bridges

The sixth element constituting the MAC is the micro-macro bridges. These link micro- and meso-level models for instance the transport module or the vehicle fleet module into parts of the macro-economic module (see Figure 2). That means, for instance, that private expenditures for bus transport or rail transport become part of the final demand of the economic sector for inland transport within the sectoral interchange model.

The macro-economic module provides several important outputs to other modules. The most important one is, obviously, gross domestic product acting as one of the major drivers for exports. Labour productivity is another element among factors that drive the foreign trade module. Finally, disposable income per adult affects car purchasing in the vehicle fleet module.

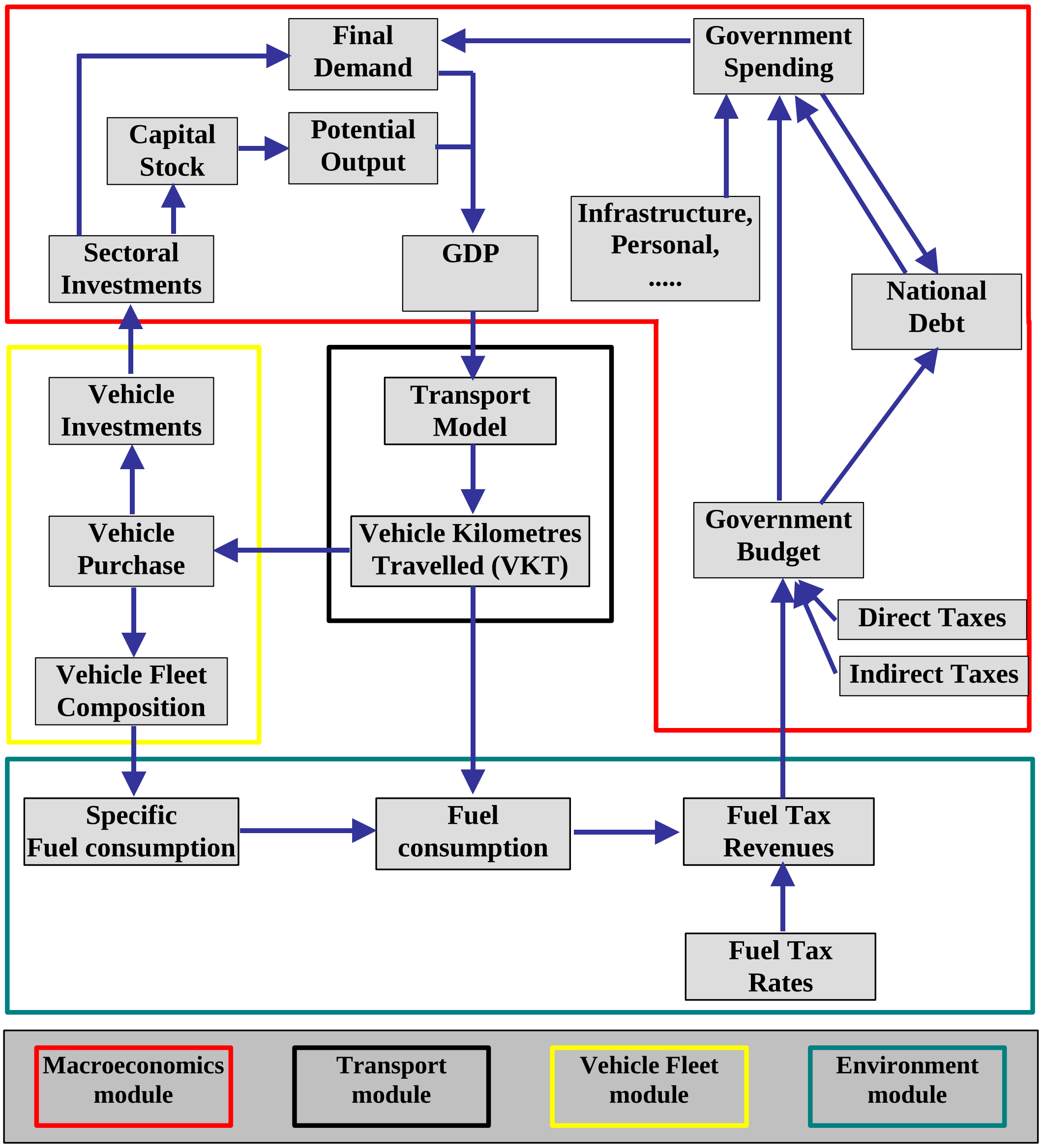


Figure 2: Examples for outputs of MAC and micro-macro-bridges to MAC

3.3 Regional economics module (REM)

The regional economics module (REM) mainly provides the generation of freight transport volume and passenger trips.

The number of passenger trips is driven by

- the employment situation,
- the car-ownership situation and
- the number of people belonging to different age classes.

Trip generation is performed individually for each of the 75 functional zones implemented in the ASTRA model. Each of the EU15 countries is subdivided into four zones composed of groups of homogenous NUTS-II zones. The functional zones were identified by analysis of settlement patterns and GDP per capita. Due to the country size and the results of the settlement and GDP/capita analysis the new member states plus Bulgaria, Romania, Norway and Switzerland were subdivided into two respectively one functional zone for the small countries like Cyprus, the Baltic countries, Malta and Slovenia.

Domestic freight transport depends on sectoral output that is translated into flows for the fifteen sectors, which produce goods by means of value-to-volume ratios. Such ratios are derived from the SCENES model for EU15 and calculated for all other countries modelled in ASTRA by OECD, National Statistics export data and EUROSTAT transport performance data. International freight transport is generated by sectoral trade, output of the foreign trade module, and value-to-volume ratios are used again to compute the correspondent traffic volume. ASTRA uses a development trend of value-to-volume ratios as experts project higher growth of exported values than amount of goods, which implies an appreciation of exported goods. For freight distribution and the further calculations in the transport module the demand volumes of the fifteen sectors are aggregated into three goods categories: bulk goods, general cargo goods and unitised goods.

3.4 Foreign trade module (FOT)

The foreign trade module (FOT) is subdivided into an INTRA-Europe and an Europe to rest-of-the-world (RoW) countries model. The rest-of-the-world countries were aggregated into nine regions, consisting of: NAFTA, Latin and Middle America, Japan, China, India (India + Pakistan + some smaller countries), East Asian Tigers (e.g. South Korea, Thailand, Malaysia), Oceania (mainly Australia + New Zealand), Turkey, Rest-of-the-world. A detailed description of the Europe-RoW trade model can be found in SCHADE/SCHAFFER/KOWALSKI (2002) or SCHADE/KRAIL (2003).

Both, INTRA-Europe and Europe-RoW models are mainly driven by relative productivity between the 29 European countries or between the 29 European countries and rest-of-the-world countries, GDP growth of importing country and world GDP growth as external factors to trade. Additionally the INTRA-Europe trade flows depend on the development of averaged generalized cost of transport between each of the country pairs. The resulting export-import flows of these two trade models then are fed back into the macroeconomics module as part of the final demand. Secondly, the INTRA-Europe trade model provides monetary flows between countries that were transformed via value-to-volume ratios into international freight demand within the REM module.

3.5 Transport module (TRA)

The major input of the Transport Module (TRA) is the link based transport demand for passenger and freight transport. Using individual transport costs for each transport mode in Euro per km and individual transport time matrices per mode the transport module calculates the modal split based on a classical Logit functions depending on generalised costs (ORTUZAR/WILLUMSEN 1998). The development of passenger transport costs per mode is modelled similar for all modes and starts from exogenously calculated initial costs per km for each passenger mode, differentiated into countries and the three trip purposes business, personal and holiday. An exogenous trend for the cost development is constituted for each mode. Furthermore the development of costs per km for the usage of cars is influenced by the endogenous calculated fuel price development and by the introduction of road pricing in several countries. Similar to the calculation of costs per km for each passenger mode the transport times per mode and km are generated based on initial time matrices for each mode. For national transport the generation and distribution steps of a classical 4-stage transport model are ruled by the REM module (see 3.3 above), while for the international freight transport, generation and distribution, are replaced by input from the export model (see 3.4 above). In the final stage all flows are assigned to domestic networks to model capacity limitations and time reactions of the various modes.

Passenger and freight flows are subdivided into five, respective four, distance band covering local, regional, medium and long distances. Cost and time matrices depend on influencing factors like infrastructure investments, fuel price or fuel tax changes. For road transport also network loads are considered for several different road types such as congestion effects may affect the road transport time matrices. For the other modes capacity constraint functions have been developed as well to simulate – even though roughly – the effect of demand growing over than available capacity. Depending on the modal choice, transport expenditures are calculated and provided to the macro-economic module. Changes in transport times are also transferred to the macro-economic module such that they provide an input to *Total Factor Productivity*.

3.6 Environmental module (ENV)

The major input for the Environment module (ENV) are the vehicle-kilometres-travelled (VKT) generated by the TRA module per mode and per distance band respectively. Based on these traffic flows and the information from the vehicle fleet model on the drives, car categories and emission standards, the environmental module calculates the most important transport emissions - CO_2, NO_x, CO, VOC and soot particles - for each distance band. Emission generation is differentiated according its source in: emissions from vehicle and fuel production, emissions caused by cold starts and the hot emissions. Other than the emissions also fuel consumption and fuel tax revenues from transport are generated by the ENV. According to the calculation of emissions and fuel consumption for cars with conventional drive, emissions and fuel consumption of alternative fuel cars implemented in two of the technology scenarios were generated in the same way.

Traffic flows and accident rates for each mode form the input to calculate the number of accidents in the European countries. The expenditures for fuel, the revenues from fuel taxes and value-added-tax (VAT) on fuel consumption are transferred to the macro-economic module and provide input to the economic sectors covering fuel products and the government revenues (see Figure 3).

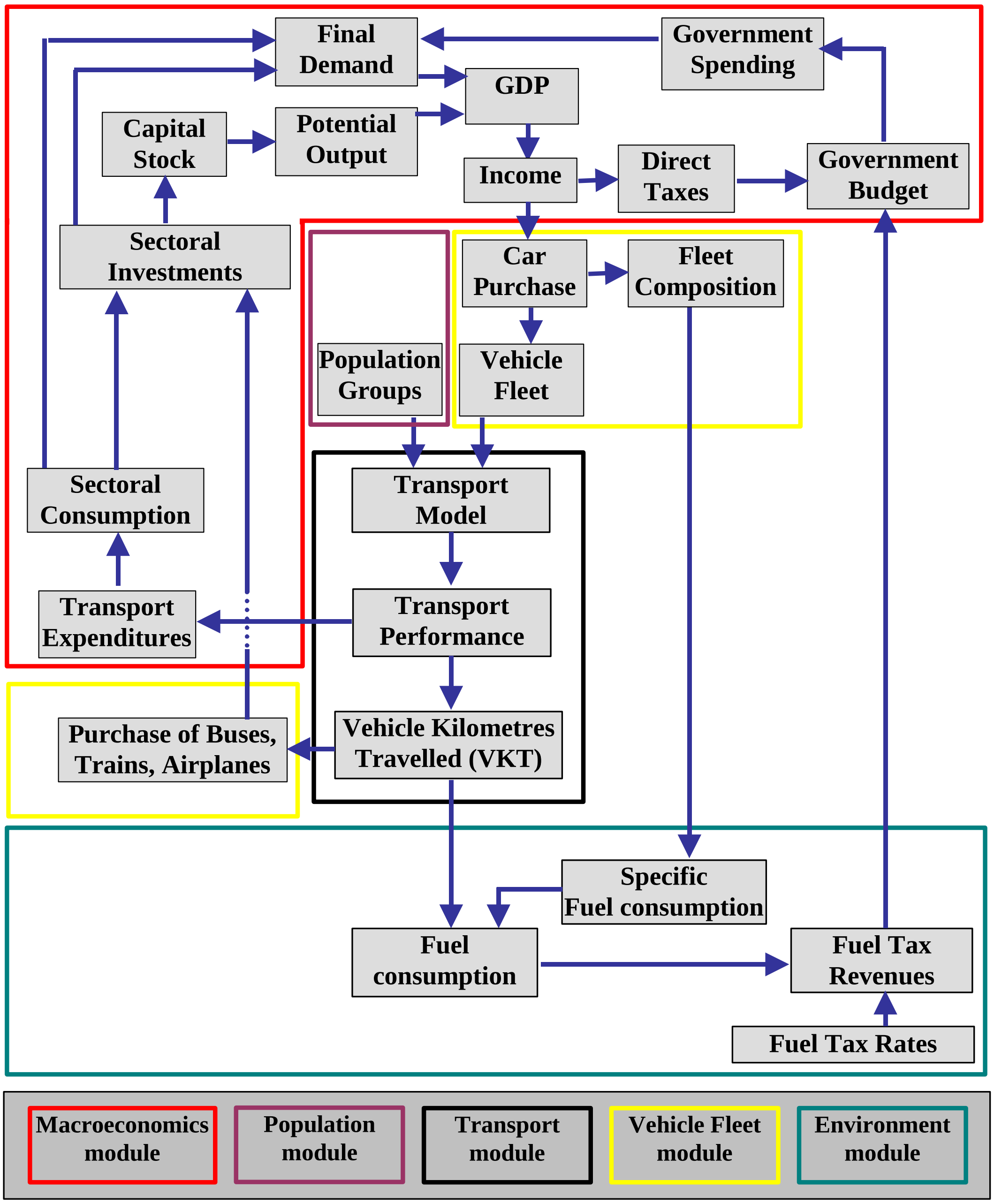


Figure 3: Macro-economic inputs, transport results, tax revenues and budget implications

3.7 Vehicle fleet module (VFT)

The Vehicle Fleet Module (VFT) calculates the vehicle fleet composition for all road modes for the EU15 countries. Vehicle fleets are differentiated into different age classes based on one-year-age cohorts and into different emission standard categories. Additionally, the car vehicle fleet is differentiated into gasoline and diesel powered cars with different cubic capacity categories. The car vehicle fleet develops according to the income changes, the development of population and the development of the fuel prices. The vehicle fleet composition of bus, light-duty vehicles and heavy-duty vehicles mainly depends on the 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 covers the vehicle production. The EU15 vehicle fleet models consider also scrapping of a certain share of vehicles during the average lifetime.

3.8 Welfare measurement module (WEM)

Finally in the Welfare Measurement Module (WEM) major macro-economic, 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 framework directly within the model.

4 Base scenario (BAU)

Policy analysis for future decision-making always requires first to develop an idea of the most probable future including expected trends and consequences of already taken policies. This idea of the future then constitutes the base scenario or business-as-usual (BAU) scenario against which all other policy scenarios can be compared. The development of the BAU scenario in the LOTSE project considers the policy framework set by already taken decisions as well as European strategy documents. This includes:

- The accession of the ten new member states to the European Union in May 2004.
- The demographic development with a transition towards ageing societies
- The European White Paper on *European transport policy for 2010: time to decide* (CEC 2001), which defines about 60 measures to take actions to reach the four main goals which are shifting the balance between modes of transport, eliminating bottlenecks, placing users at the heart of transport policy and managing the globalisation of transport.

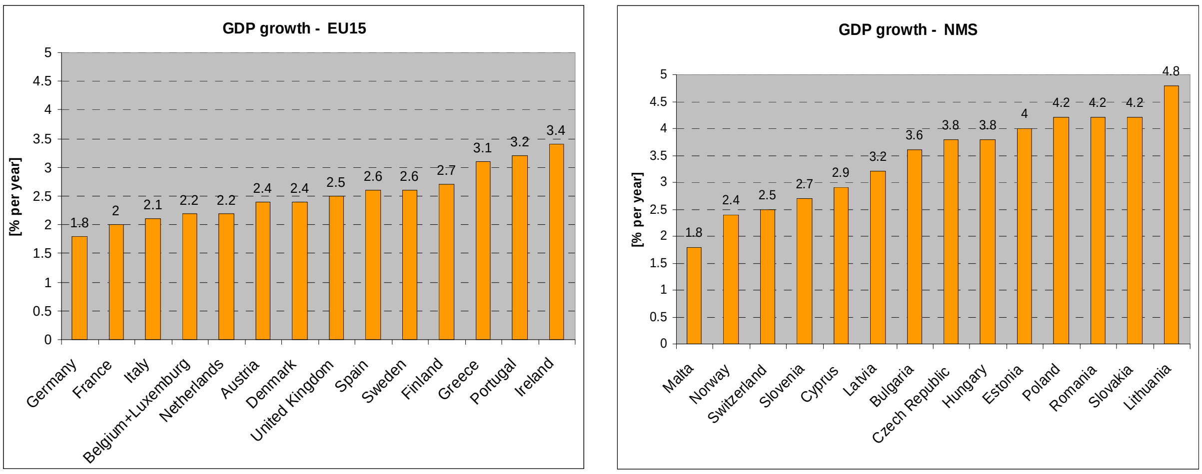


Figure 4: Comparison of annual average GDP growth rates from 2000 to 2020

The trends of GDP development are in the range of existing studies like PRIMES (CHRISTIDIS et al 2004) or TIPMAC[1] (SCHADE 2004a), though they are not exactly congruent. In general, GDP growth, illustrated in Figure 4, of the European member states before May 2004 (EU15) is significantly lower than for the new member states that acceded in May 2004 (NMS).[2] The expectation that the larger countries France, Germany and Italy reveal a slower growth pattern than the EU15 average, while United Kingdom and Spain would grow stronger than average is confirmed by the LOTSE BAU results. For NMS the Baltic countries are on the forefront of growth followed by Poland and Romania. Slowest growth is expected for Slovenia.

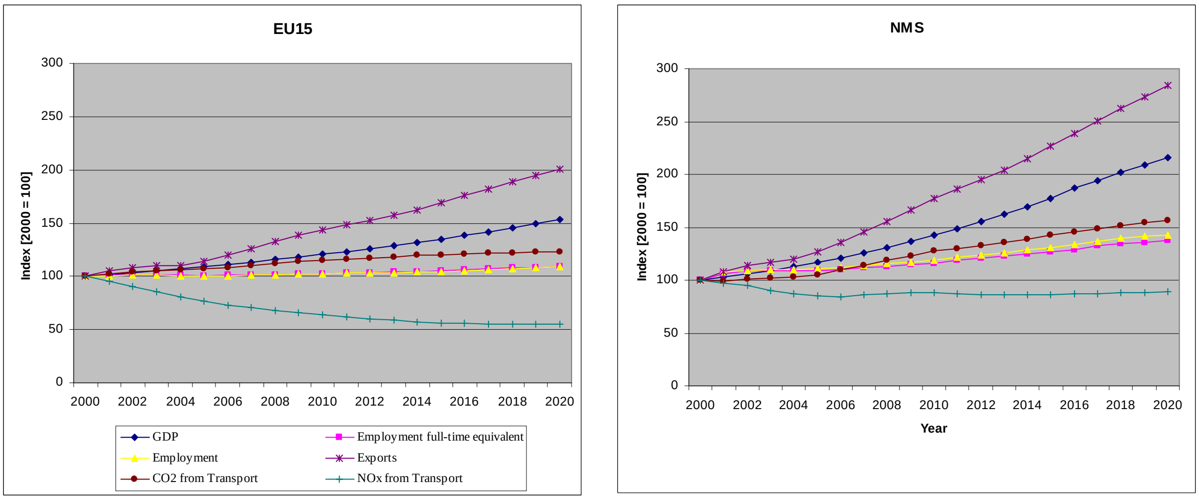


Figure 5: Development of main aggregate indicators for EU15 and NMS

Making reference to the major development indicators of ASTRA BAU scenario it can be noticed that: GDP growth over the two decades from 2000 until 2020 is more than double in NMS than in EU15 with +115% compared to +54% leading to average annual growth rates of +3.9% and +2.2% respectively. Exports even show a larger growth with +185% and +101% though putting export growth in relation to GDP growth exports contribute a larger share to economic development in the EU15 than in the NMS. The annual export growth rates would amount to +5.4% and +3.5% for NMS and EU15 respectively. In both case trade with the NMS is growing strongest i.e. for the NMS trade with other NMS shows the highest growth, while for EU15 exports to the NMS increase strongest. Employment growth differs also significantly between EU15 and NMS. Total employment in EU15 countries increases by +9% compared with +43% for the NMS. This fits to the rule of thumb that about +1.5 to +2% of GDP growth would be needed for Western European countries to increase employment. Since, the growth of EU15 is slightly higher a very moderate growth of employment could be expected. For NMS this threshold of +2% is outranged significantly with +3.9% such that also the employment growth of +43% seems to be plausible. Nevertheless, to reach this growth from the supply side of employment it will be necessary that the activity rate of the potential labour force increases such that the number of persons belonging to the actual labour force is growing.

[1] TIPMAC was a project in 5th RTD-FP of the European Commission. Reports are available at: http://www.camecon.com/services/projects/Tipmac/Tipmac_project.htm

[2] NMS, new member states, includes Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovenia and Slovakia. If Romania and Bulgaria are included in aggregated presentation of results we are speaking of NM10+CC2.

Finally the two environmental indicators in Figure 5 - CO_2 and NO_x - are also different for EU15 and NMS, even though their tendency is similar with CO_2 emissions from domestic transport growing significantly while NO_x emissions decrease. But domestic transport CO_2 emissions increase much stronger within NMS with +57% compared to +23% for EU15 countries. Taking an alternative point of view and measuring the CO_2 emissions by transport originating from a country these numbers would be higher for NMS with +74% and lower for EU15 with +20% only. This means NMS countries tend to increase the share of CO_2 emissions that is emitted by their transport activity outside their own country.

Looking at passenger transport again the comparison discloses large differences between EU15 and NMS (Figure 6): strongest growth in EU15 can be observed for the overall expenditures for business trips (+85%), while in NMS the largest growth concerns the car-ownership (+76%) and the car fleet (+67%). Expenditures for tourism trips grow at similar speeds though having in mind the differences in population development the growth per capita is higher in NMS. This difference of population development explains the difference of the growing number of trips in EU15 associated with the still growing number of population and people in working age, while the stagnation of population in NMS leads also to a stagnation of trips. Consequently this leads to a more than 10% higher growth of pkm in EU15 (+29%) compared to NMS (+16%) where the interurban pkm grow about 10% stronger.

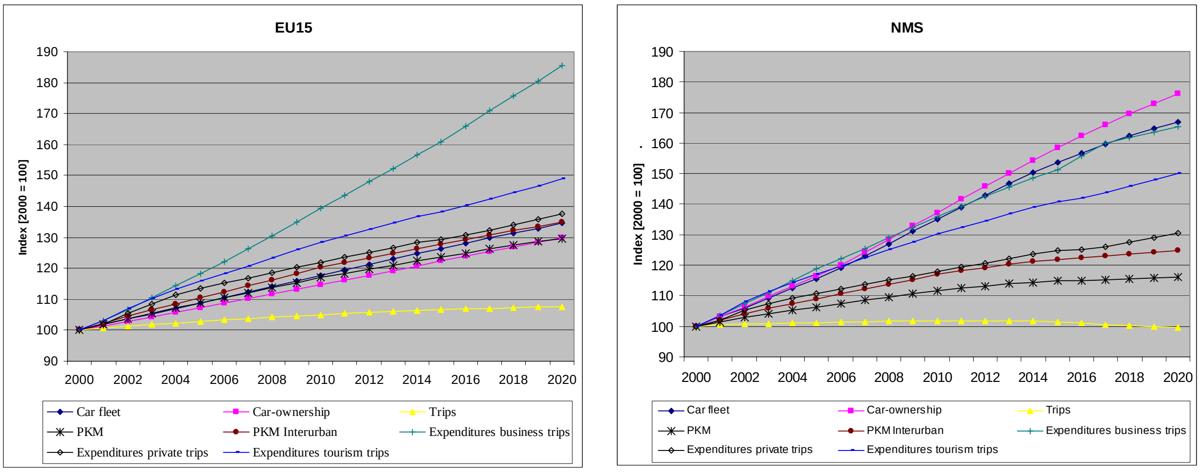


Figure 6: Development of passenger transport for EU15 and NMS

The difference of freight transport development between EU15 and NMS is significant, which could already be expected from the gap of GDP development presented at the beginning. Tkm originating from NMS increase by +188%, which is a combination of strongly increased exports (+185% in terms of monetary flows), increased distances due to changing spatial patterns and increased national transport. Volume of NMS grows by +98%, which is only half of the growth in tkm, while EU15 experiences only an increase of volume by +38%. In both cases, the increase of volume transported over long distances (inter-zonal) is growing much stronger than the overall volume. The cost structure for transport of EU15 over different distance bands supports the development towards longer transport distances, with the highest cost growth for local freight transport (+45%) and stagnation for the longest two distance bands. It should be mentioned that the cost per tkm figure is not representing a tariff but the overall averaged result of aggregated expenditures divided by all tons transported by all modes within a certain distance band. Hence, besides cost changes also shifts between modes and shifts between destinations and distances changes this averaged result.

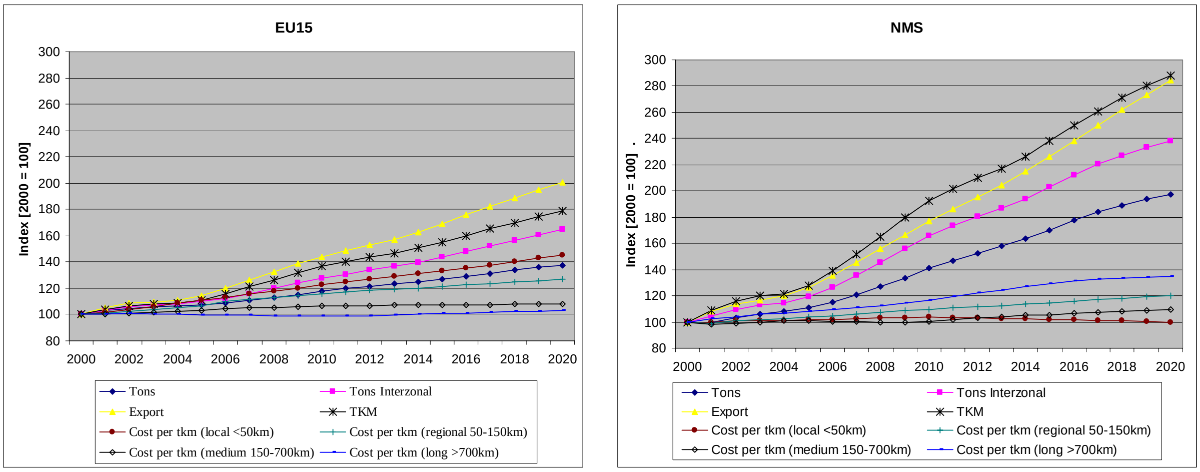


Figure 7: Development of freight transport for EU15 and NMS

5 Policy scenarios

The scenarios implemented in the ASTRA model make reference to three policy leverages: the first one is related to the introduction of a CO_2 tax on transport, the second one considers a constant and significant growth of crude oil price and the third one deals with technical development of cars and builds on the POLES[3] model projections for the development of electric, fuel cell and hybrid driven cars.

5.1 CO_2 tax scenario

In order to accelerate the reduction of CO_2 caused by transport a scenario testing the introduction of a CO_2 tax per emitted ton was implemented in the model. In the ASTRA "CO_2 Tax" scenario the influence on transport of an introduction of a CO_2 tax can be tested interactively: the user can determine the dimension of the CO_2 tax by himself in a predefined range of at minimum 1 and at maximum 25 Euro per ton of CO_2. The CO_2 Tax scenario, which will be compared to the BAU scenario, is predefined by a CO_2 tax charge of 12 Euro per ton of CO_2 emitted. In the CO_2 tax scenario a continuous taxation of emitted tons of CO_2 is simulated since year 2005 on for each transport mode, for both freight and passenger transport.

To enable the calculation of additional costs for each mode and distance band caused by the taxation, the total amount of CO_2 per freight and passenger mode differentiated according to distance band and, for freight transport, also according to goods category (bulk, generalized cargo and unitised goods) is converted into tons of CO_2 per passenger-km or ton-km. Multiplication by CO_2 tax rates allows to compute additional costs per passenger-km, respective ton-km, and add to the base costs to influence the modal split. According to user choice, additional government revenues from CO_2 taxation can be alternatively refunded via reduction of either direct or indirect taxes by 100%.

[3] POLES is an energy demand and supply model and the base model for "World energy, technology and climate policy outlook –2030"

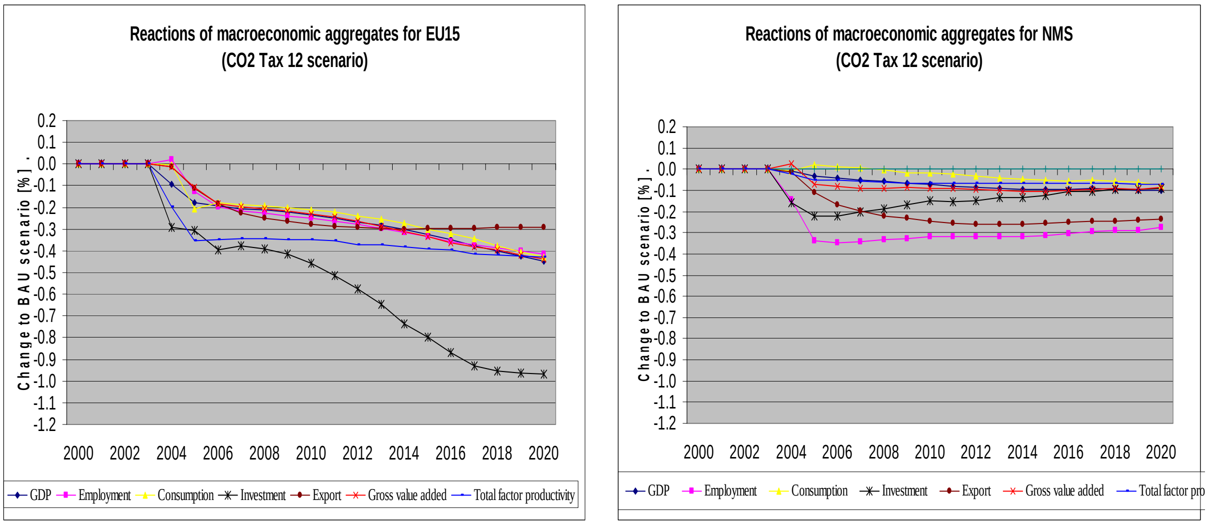


Figure 8: Reactions of macroeconomic aggregates in CO2 Tax 12 scenario

The macro-economic impacts of the introduction of a charge on CO_2 by transportation are illustrated in Figure 8: In comparison to the BAU scenario there is an overall negative development. GDP is decreasing in EU15 by –0.45%, investments even by –0.97%, consumption is negative by –0.43% and also employment shows a negative change of –0.42%. The development depicted for NMS is similar but smaller in the dimension of changes. GDP is decreasing only by -0.1%, investments, consumption and employment by –0.09%, -0.07% respective –0.28%. In the first period after the introduction of the CO_2 tax there is a small positive trend for EU15 and NMS. Nevertheless the positive impact is overcompensated by a significant reduction of exports (-0.29% for EU15 and –0.23% for NMS) and, more remarkable, by a decrease of investments: i.e. the investing industries are reacting with a reduction of their investment budget on the growing transportation costs induced by the CO_2 taxation.

Investments per country are constituting the origin of loses in GDP and employment compared to BAU. The most important reaction chain in this scenario starts with higher transportation costs for the consumer and therefore less disposable income to spend for products of all other sectors. Then the decrease of consumption reduces the investment budgets of all sectors besides the transport service sector. This negative impact on sectoral investments is at first slightly enforced by dampened growth of exports caused by increases of generalised times. The additional impact originated in increasing generalised times is put into a perspective by the impacts of changing modal split. The more CO_2 emitting modes, which are the road modes, are losing share and reduce on the other hand because of slightly ceasing congestion faster road trips. Therefore a balance between higher costs and faster trips equalises the impact. But as the impact of decreasing sectoral consumption is the major driver the impact chain is pursued by a declining final demand. This ends in decreasing GDP and is also decreasing gross value added which is the driver of total employment together with productivity. Therefore it is consequential that the trend that could be observed in GDP and employment is originally carried forward by the investment development.

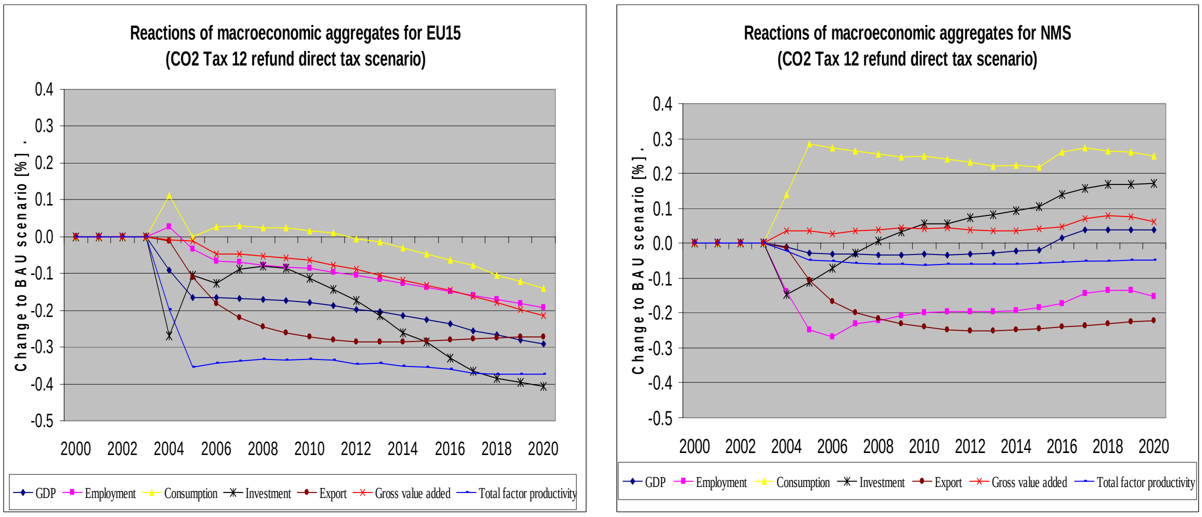


Figure 9: Reactions of macroeconomic aggregates in CO2 Tax 12 refund direct tax scenario

To compensate the higher transportation costs for the private user, it is assumed in a second alternative scenario that the amount of CO_2 tax revenue per country will be refunded to 100% via a reduction of direct taxes. The macroeconomic aggregates of the introduction of a charge on CO_2 by transportation are illustrated in Figure 9: Despite the refund mechanism there is still a negative development at least for EU15 with a decline of GDP by –0.29%. In EU15 increasing consumption in the first periods after the introduction of the tax cannot balance the decrease of investments and exports caused by higher transportation costs. Investments are decreasing by –0.4%, exports by –0.27%, employment by –0.19% and also consumption is negatively influenced until the year 2020 by –0.14%. In contrast to the still negative macroeconomic development in EU15 the picture in NMS is different. Caused by the refunding of CO_2 tax revenues GDP is slightly improving by +0.04% and thus at nearly at BAU level. It seems that in NMS the impact of consumption on development of investments is stronger than the influence of export development. In EU15 countries the negative export trend induced by higher generalised times overcompensates the growing consumption. Investments in NMS are growing by +0.17%, consumption by +0.25% while exports are similar to EU15 exports decreasing by –0.22%.

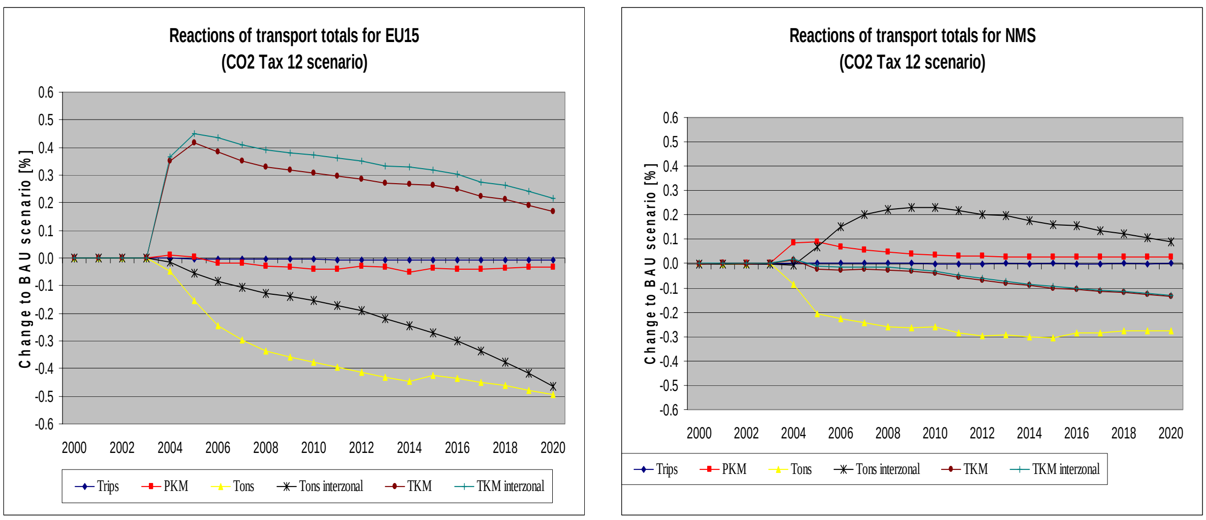


Figure 10: Reactions of transport totals in CO2 Tax 12 scenario

Compared to the scenario without refunding of CO_2 tax revenues this mechanism evokes small improvements, but at least for EU15 the overall macroeconomic result is still slightly negative. Besides the macroeconomic results there are nearly no changes of transport or environmental results visible due to the introduction of refunding. Therefore only transport and environmental results of the CO_2 Tax scenario without refunding are presented in the following.

The changes in transportation indicators visible in Figure 10 are twofold: on the one hand total tkm in EU15 have a positive development while EU15 total tons have a negative change compared to BAU and on the other hand the development of tkm and tons in NMS is going in the same but negative direction in comparison to BAU. In fact, the BAU trend in EU15 to growing distances and tkm will be enforced by the CO_2 tax introduction. Higher decrease in exports in the NMS is responsible for both curves showing a negative characteristic compared to BAU.

The environmental impacts of a CO_2 taxation on transport can be observed in Figure 11. CO_2 and NO_x emissions are decreasing in EU15 and NMS as well, compared to BAU, but caused by growing transport performance for freight in EU15 and for passenger in NMS, such changes are moderate with –0.88% CO_2 and –0.47% NO_x for EU15 and -0.37% CO_2 and –0.06% NO_x for NMS. Compared to the new car technology scenarios the CO_2 tax one is providing a slightly better emission performance at least for NMS. The significant change of diesel consumption in EU15 and gasoline consumption in NMS is mainly caused by the fleet changes. It has to be kept in mind that the NMS vehicle fleet is modelled exogenously according to the IPTS POLES database while the EU15 car fleet could react on the CO_2 tax policy.

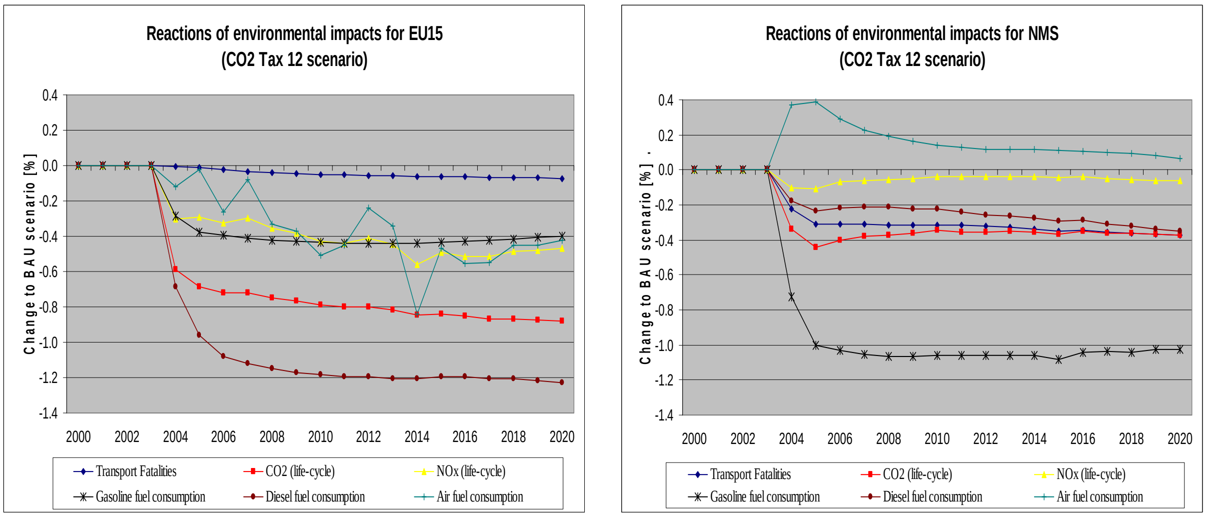


Figure 11: Reactions of emissions and fuel consumption in CO2 Tax 12 scenario

5.2 Crude oil price scenario

The trend of crude oil prices showed in the year 2004 an enormous increase. When at the beginning of 2004 the price per barrel was about 30 US Dollar the crude oil price crossed the 50 US Dollar border already in September (crude oil price at 10-10-2004: 53 US Dollar per barrel), which means an increase of 79 %, and experts now assume a further growth until 65 US Dollar within the next year. To show the impacts of a continuous (even if not as strong as in 2004) crude oil price growth on the transport performance and the macroeconomic situation, a crude oil price scenario is implemented in ASTRA. Based on an assumed price trend until 2020, which determines a price of 65 US Dollar per barrel in the year 2006, 85 US Dollar in the year 2010 and 115 US Dollar in the year 2020, the user can change the base trend from minus 20 to plus 20 percent. The price change will be introduced from the year 2005 on because the historical crude oil prices were implemented in the model according to statistics.

The crude oil price scenario supposes an increase of the price for crude oil compared to the base scenario. The continuous increase reaches a factor of 4 in the year 2020 and hence is rather significant. The price increase is split into an element that is beard by consumers reducing their disposable income and consumption and a second element that is carried by business, which is fed as increase of cost for intermediate inputs from the energy sector in the input-output-table. This split is currently seen as 50 to 50%. Furthermore a direct link between increasing crude oil price and growing fuel prices exists which has an impact on consumption of mineral oils for transport.

The overall macroeconomic development of the crude oil scenario is rather negative with –1.81% change of GDP, -4.86% change of investments, –2.22% less employed for EU15 and –1.71% change of GDP, -3.83% change of investments and –2.42% less employed for NMS. The only positive reaction is a medium term increase of investments due to mitigation strategies against the high price, e.g. investment in fuel and energy saving technologies. According to the different structure of economies, which means that high-technology sectors have a higher importance in EU15 economies, this medium term increase only occurs in EU15 countries. However, the strong negative impact on consumption that emerges affects with some delay also the other economic aggregates e.g. GVA (see Figure 12).

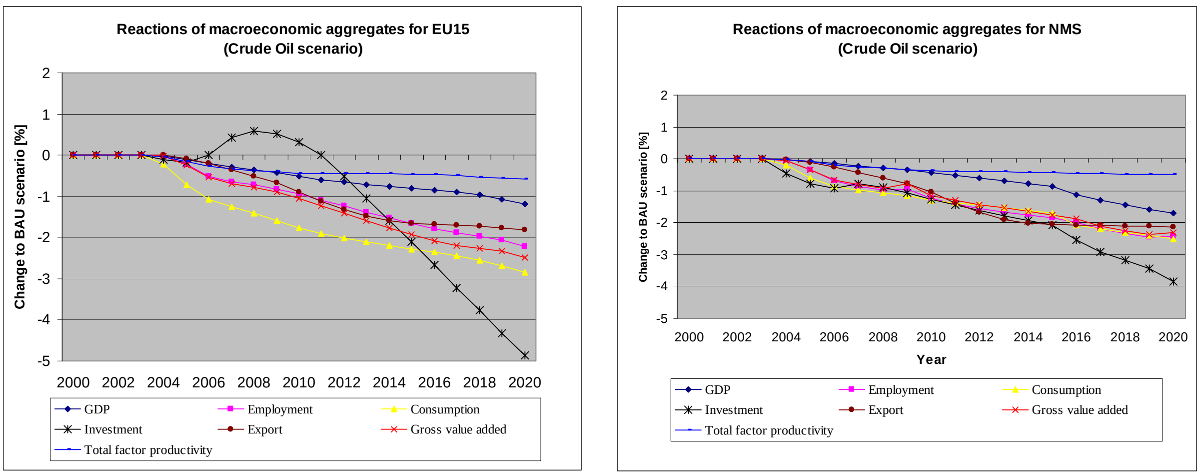


Figure 12: Reactions of macro-economic aggregates in Crude Oil scenario

Since, investments are rather stable in the first decade total factor productivity is less affected than the demand variables, such that the supply side of GDP stabilises the overall GDP development. EU15 and NMS react rather similar to the policy and results would improve if the fuel price increase would be less strong, as at some threshold of oil price increase the positive investment effects would outweigh the negative consumption effects.

Several impact chains interacting with each other are leading to the presented macroeconomic results. The most important one influencing GDP in the end in most countries negatively starts with the reduced consumption caused by higher consumer prices. The industry is forwarding at least a share of the additional costs raised to the consumer by increasing of goods and services prices. Besides the direct impact of higher fuel prices remaining less disposable income for consumption of other goods and services another factor influences the development of consumption. As average fuel prices are rising, increased variable costs of owning and using a car leads to less new registrations respective less purchase of new cars. This has a negative influence on the sectoral consumption for goods produced by the vehicle sector but on the other hand makes sure that there is again more money left to spend for consumption of other goods. In all countries besides Spain, Finland, Italy and Portugal this interaction of impacts leads to decreasing consumption. It has to be kept in mind that NMS car fleets are implemented exogenously which implies that the impact chain induced by less purchase of cars does not exist for NMS.

Another impact is introduced by shifts at the modal split caused by higher costs per km respective ton for all mainly fuel consuming modes. Higher transport costs and therefore higher generalised times have a negative impact on exports which is an additional but not as significant factor leading to decreases of total investment in most EU25 countries. Furthermore there is a last factor besides the decreasing final demand caused by less consumption and investment that is responsible for the negative development at the labour market in most EU25 countries. Total costs of intermediate products from the energy sector into all other 24 economic sectors based on the 1995 input-output tables are increasing due to the crude oil price growth which is an additional burden on the sectoral gross value added of all sectors besides the energy sector and reduces this indicator. The reduction of sectoral gross value added accounts for the negative development at the labour market compared to the reference scenario.

National GDP, productivity and changes of generalised time are the drivers of INTRA-EU25 exports. Decreasing GDP and increasing generalised times caused by higher costs per km due to higher fuel prices are responsible for slow down of export growth. The consequence of export being the main driver of international freight transport is a significant reduction of tkm. National freight transport performance is affected by national production values that are the sum of the output of intermediates and final use. As described consumption and investments are negatively influenced by a stronger crude oil price growth, which decreases the final use. This leads in the end to a regression of national freight transport. Thereby the tkm react much stronger than the tons with –2.3% for tons against –6.7% for tkm. The major reason for this effect is that international transport volume is affected much stronger than national transport due to a more significant decline of exports, such that those tons reduced are mainly tons that would have been transported over a very long distance. This effect is much larger for the NMS than for EU15, with the peculiarity that in the beginning tons in NMS even increase. In general the impact on NMS is much larger showing that their trade and transport systems are more sensitive than the established EU15 systems. This effect observed for NMS could also be evoked by increased transport costs that have a stronger influence on exports than in EU15. This seems to be reasonable as the value of exported goods from NMS is on average lower than those goods exported from EU15.

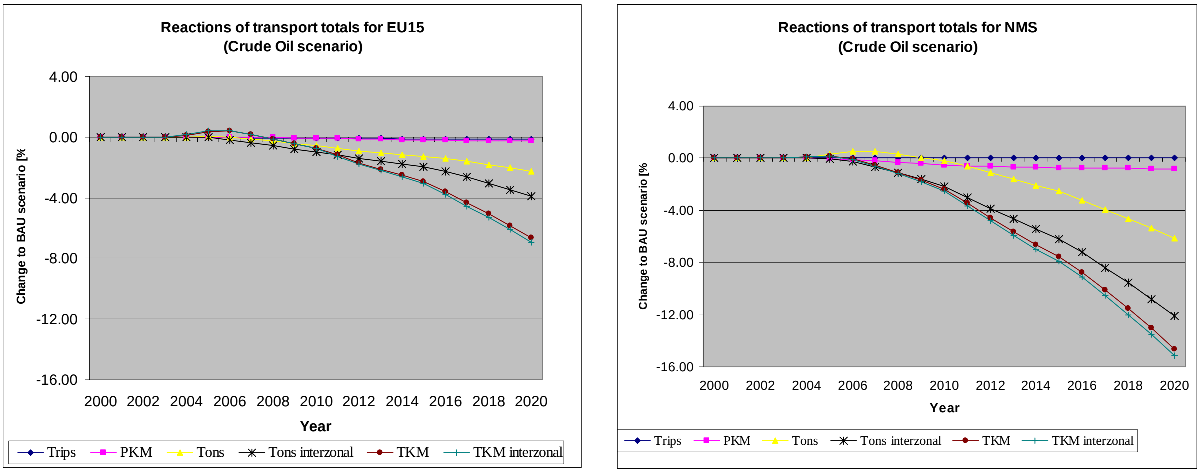


Figure 13: Reactions of transport in Crude-Oil scenario

Pkm are reduced to a small extent or even only stagnating. The small decrease of pkm is caused by higher fuel prices going hand in hand with increasing generalised times, which have an impact on the level of passenger demand. Additionally changes of population segments structure caused by changes in employment and car-ownership have an impact on passenger trips. In the Crude Oil scenario decreasing employment together with reduced car purchases due to stronger growth of variable costs for car owners change the population structure such that the group of people that are expected to make less trips per day is strengthened. In the case of pkm ASTRA seems to underestimate the impact of the oil price increase, as the decreases are rather moderate.

Given the strong reduction of freight tkm, it is plausible that environmental impacts from transport are decreased significantly with CO_2 emissions decreasing by –4% and –10% for EU15 and NMS respectively (see Figure 14) and air transport fuel consumption showing the strongest decrease.

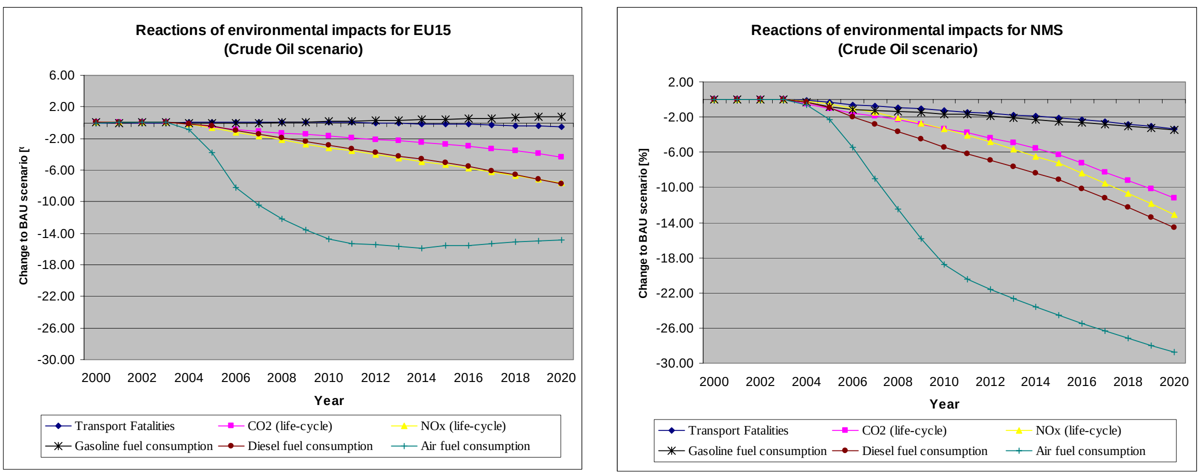


Figure 14: Reactions of environmental indicators in Crude Oil scenario

6 Conclusions

The picture drawn in the BAU Scenario is an optimistic one. GDP growth in NMS on average will be higher than in the EU15 member states reaching +115% in 2020 compared with +54% for EU15. The most important driver for such a development will be international trade: indeed trade relations will improve very significantly with a growth of trade of EU15 by +101% and NMS by +184%. A slight shift of trade relationships can be observed with a tendency that INTRA-NMS trade increases faster than other trade flows. Employment shows a very moderate but positive development, especially for NMS. NMS transport trends continue to develop into a less sustainable way with modal-shifts from rail to road for freight, from public transport to car for passenger transport and with increased distances for both, to mention just the most important trends. Overall tkm for EU15 increase by +78% and for NMS by +184%. The main driver for this strong increase is international transport resulting from the growth of trade. Concerning passenger transport, the growth will be much slower with +29% for EU15 and +16% for NMS. Concerning the modal balance expecting lower shifts than in other projections ASTRA seems to be more on the optimistic side. This could be because of relative cost developments that are too optimistic for rail transport compared to road transport and because of underestimating the influence of the strong NMS car-ownership growth on modal-choice decisions.

The CO_2 tax scenario, which implements a CO_2 tax of 12 Euro per emitted ton of CO_2, leads to a slightly negative macroeconomic development. This decrease caused by lower levels of investment and trade has its origin in a change of modal split due to higher transport costs. This induces lower export volumes, which have a negative impact on investments. In the end this leads to a decline of final demand, which introduces a negative economic development. Compared to BAU GDP changes by –0.45% for EU15 and –0.1% for NMS. Besides the marginally negative impacts of a CO_2 tax introduction on the economies the scenario provides only small environmental benefits with a slight decrease of CO_2 emissions caused by transport of –0.88% for EU15 and –0.37% for NMS respective –0.47% NO_x emission reduction for EU15 and –0.06% for NMS. The picture would be different with a higher CO_2 taxation than 12 Euro per ton showing an increased negative impact on passenger and freight transport performances leading to a more significant decline of emissions from transport. The refunding of CO_2 tax revenues by 100% leads to improved but at least for EU15 still negative macroeconomic results by –0.29% GDP.

The crude oil scenario shows an even worse economic outcome than the CO_2 Tax scenario though, it seems that the technology push, induced by higher energy prices, could outweigh the negative consumption effects in the long run, particularly if oil prices would increase in a modest way. Given the stronger price increase, GDP changes by –1.18% for EU15 and even –1.71% for NMS. The stronger economic reaction leads to more significant decline of freight transport performance with –6.63% less tkm for EU15 respective –14.63% reduction of tkm in NMS compared to BAU. Caused by this impact and by the influences of modal split tending to more share of rail, CO_2 and NO_x emissions were reduced most noticeable compared to all other tested scenarios with –4.32% respective –11.23% less CO_2 emissions for EU15 respective NMS and –7.66% respective –13.12% less NO_x emissions for EU15 respective NMS compared to BAU. In contrast to freight transport performance, ASTRA seems to undervalue the impacts of rising crude oil prices on passenger transport, as the changes are by –0.26% respective –0.81% less pkm related to BAU rather moderate.

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