Assessing economic impacts of large scale transport infrastructure projects: the case of the Lyon-Turin corridor

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Abstract:
Assessment of large scale transport infrastructure projects by a classical 4-stage transport network model is meant to capture only the direct benefits of transport policies, while the additional indirect economic effects in non-transport markets would be partially neglected. The idea of this paper is to apply an integrated economy-transport-environment assessment model focussing usually on the assessment of economic impacts of national or supra-national transport policies to the question about the size of indirect economic impacts of one single large-scale project. Such a model enables to consider the interaction between transport and the economy as well as vice versa between the economy and transport closing the transport-economy feedback loop.

For this purpose the European ASTRA model (Assessment of Transport Strategies) is refined to model the implementation of the planned high-speed railway link on the Lyon-Turin corridor. This line forms part of the Trans European Transport Networks (TEN-T). The estimated cost of the 257 km new tracks amount to 13 Billion Euro over 10 years, which would be a sufficient size to make it a large scale project.

The results of the analysis indicate the feasibility to apply the ASTRA model for such kind of project assessment. Economic impacts on country level can be detected as well as impacts for the 15 Western European Union countries (EU15), though the latter are rather small if they are measured as percentage changes to a reference scenario. A crucial task remains the analysis of impact chains that have caused and explain the model results.

1 INTRODUCTION

In the framework of developing the European Union and of fostering the cohesion between the various European countries transport infrastructure that connects the member states with a high quality-of-service is of great importance. Such connecting infrastructure most often not only affects two neighbouring countries but a chain of countries stretching over six or more states. Therefore the EU heads of state have agreed to develop a Trans-European-Transport Network (TEN-T), which was first defined by the so-called Essen list of projects in 1994 and updated in later policy decisions. Projects contributing to these TEN-T constitute large scale infrastructure measures requiring usually significant investments.

The question addressed in this paper concerns if the ASTRA model so far applied for national and supra-national policy analyses of transport policies could also be applied for an assessment of such a single large scale project. For this analysis the Lyon-Turin corridor has been selected, which is foreseen to built a high-speed railway link through this corridor as part of the TEN-T.

The paper is structured into 5 sections after this introduction. First an overview on the Lyon-Turin project is given. Second the policy framework relevant for EU analysis is explained. Third, the applied ASTRA model is described to better understand the meaning of the results of the analysis. Fourth, the actual policy analysis is performed starting with the results for the business-as-usual scenario, followed by the policy scenarios, which then cover the three aspects: transport impacts, trade impacts and economic impacts. Finally, the paper presents some conclusions on the applicability of the ASTRA model for such a single project evaluation.

2 THE LYON-TURIN CORRIDOR

The Lyon-Turin corridor is located in the South-East of France and the North-West of Italy connecting those two countries by a conventional railway line and a major road link. On its way the corridor has to cross the Alps such that the railway line has to follow the significant slopes and the winding route defined by the mountains and valleys of the Alps. The Lyon-Turin railway link is part of several large Trans-European transport axis like a West-East axis commencing in Portugal and leading until the Ukraine or a North-South axis starting in the Benelux countries and ending in Southern Italy.

In 1994 the Lyon-Turin railway link was put on the list of the 14 priority projects defined by the European heads of states to become the core elements of a Trans-European Transport Network (TEN-T). Due to the main objectives of the 2001 European White Paper on Transport Policy [2] of shifting the balance of modal-split towards more environmental friendly modes and of eliminating bottlenecks especially the bottlenecks in the EU railway infrastructure increased in importance as railways belong to those more environmental modes.

The Lyon-Turin link constitutes one of these bottlenecks as transport studies forecast that around 2015 both road and railway capacity on the link will reach their capacity limits [3]. Additionally the Alps crossed by the link constitute a sensitive area for environmental impacts caused by transport. For both reasons plans for implementing a new high-speed railway link for mixed passenger and freight transport gained momentum by the White Paper and the corresponding updated list of TEN-T priority projects [4], which has been refined by a decision process set-up by the European Commission: In this process the Van-Miert High-Level Group on the level of policy-makers pre-selected a number of priority corridors for the TEN-T [5] and the TEN-STAC project carried out a detailed model-based analysis for a great number of potential priority projects [6]. Both recommend the construction of the Lyon-Turin railway link as part of a larger framework, the Lyon-Budapest corridor, though the TEN-STAC analysis is estimating lower benefits and a smaller modal-shift then the studies of the involved companies [3]. In 2004 a memorandum between France and Italy agreed on an investment plan for a public-private-partnership amounting to 13 Billion EUROs of which the

European Commission (EC) should fund at least 20%. The whole link is planned to be implemented until 2015.

The high cost for the 257 km of new high-speed track are caused by the fact that several bridges and tunnels, including a 52 km long tunnel, have to be constructed. Transport forecast foresee a rise in freight volume over the Alps of 80% in the next 15 years. By 2030 on the link 40 million tons are expected to be transported by rail compared to 10 million tons today. Passenger transport time between Lyon and Turin will be decreased by 2 hours 15 minutes enabling also to connect Paris and Milan in the future by a 4 hours train trip compared with 7 hours today.

3 POLICY FRAMEWORK FOR ANALYSIS

The policy analysis presented in this paper has originally been part of the study on "Transport-related impacts and instruments for sensitive areas" (SAT) on behalf of the European Commission [7]. It has been modified for this paper to include:

- **Business-as-usual scenario** (BAU) with the implementation of EU transport policies according to the White Paper and described in the TIPMAC project [8] [9], but excluding the link Lyon-Turin. Transport policies from the White Paper like harmonisation of weekend bans on truck traffic, interoperability of cross-border railway traffic, deregulation of road haulage have been made operational for the scenario implementation in the ASTRA model by transforming them into cost and time changes for different modes, different transport distances and different transport purposes. The measures than have been implemented in the model according to the schedules foreseen in the White Paper.
- Lyon-Turin **railway infrastructure only scenario (RIO)** that is based on the BAU but additionally includes the construction of the Lyon-Turin high-speed rail link over a 10 years period until 2013 according to current construction and investment plans [1] [3].
- Lyon-Turing **railway infrastructure plus motorway toll scenario (RIPT)** that additionally imposes road pricing of 0.0105 EURO/tkm on trucks passing the corridor. This should encourage modal-shift towards rail and the better usage of the "Rail Motor-way" carrying trucks. The cost value is taken from the European UNITE study [10].

For the two policy scenarios the current plans have been translated into an investment time profile and a completion time profile of the new high-speed-link as shown in FIGURE 1. These profiles have then been implemented in ASTRA.

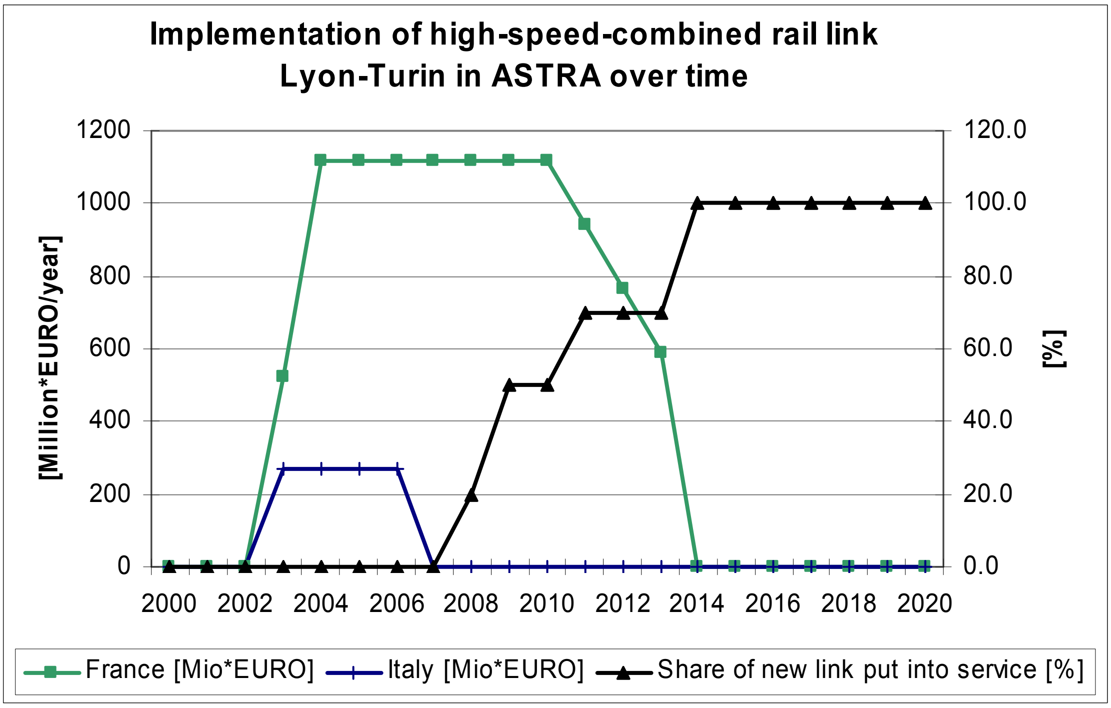


FIGURE 1 Investment and completion of rail link Lyon-Turin.

4 THE APPLIED ASTRA MODEL

ASTRA (=Assessment of Transport Strategies) is a System Dynamics model generating time profiles of variables and indicators needed for policy assessment. Originally it was developed on the base of existing models that have been converted into a dynamic formulation feasible to be implemented in System Dynamics. Among these models have been macroeconomic models (QUEST) and classical four stage transport models (SCENES [11]).

ASTRA runs scenarios for the period 1990 until 2020 using the first twelve years for calibration of the model. Data for calibration stems from various sources with the bulk of data coming from the EUROSTAT [12] and the OECD online databases [13].

4.1 Dynamic formulation of ASTRA

Structuring elements of System Dynamics models are feedback loops, which can be distinguished into positive feedback loops fostering reinforcing model behaviour and negative feedback loops providing dampening model behaviour. The feedback loops are built out of three basic variable types: level variables being integral variables, rate variables constituting functions within the integrals and auxiliary variables [14].

Mathematically System Dynamics models are systems of non-linear differential equations. However, due to the size of complex models of socio-economic systems analytical solutions will not be found, such that results have to be computed by numerical integration replacing the differential equations by difference equations. The simplest mechanism applied in all standard System Dynamics tools, as well as in ASTRA, is provided by Euler integration, which takes the current value of the rate variable and projects it into the future for the next integration interval as shown in equation 1:

$$L(t) = L(t-dt) + (I(t) - O(t))*dt \qquad \text{(eq. 1)}$$

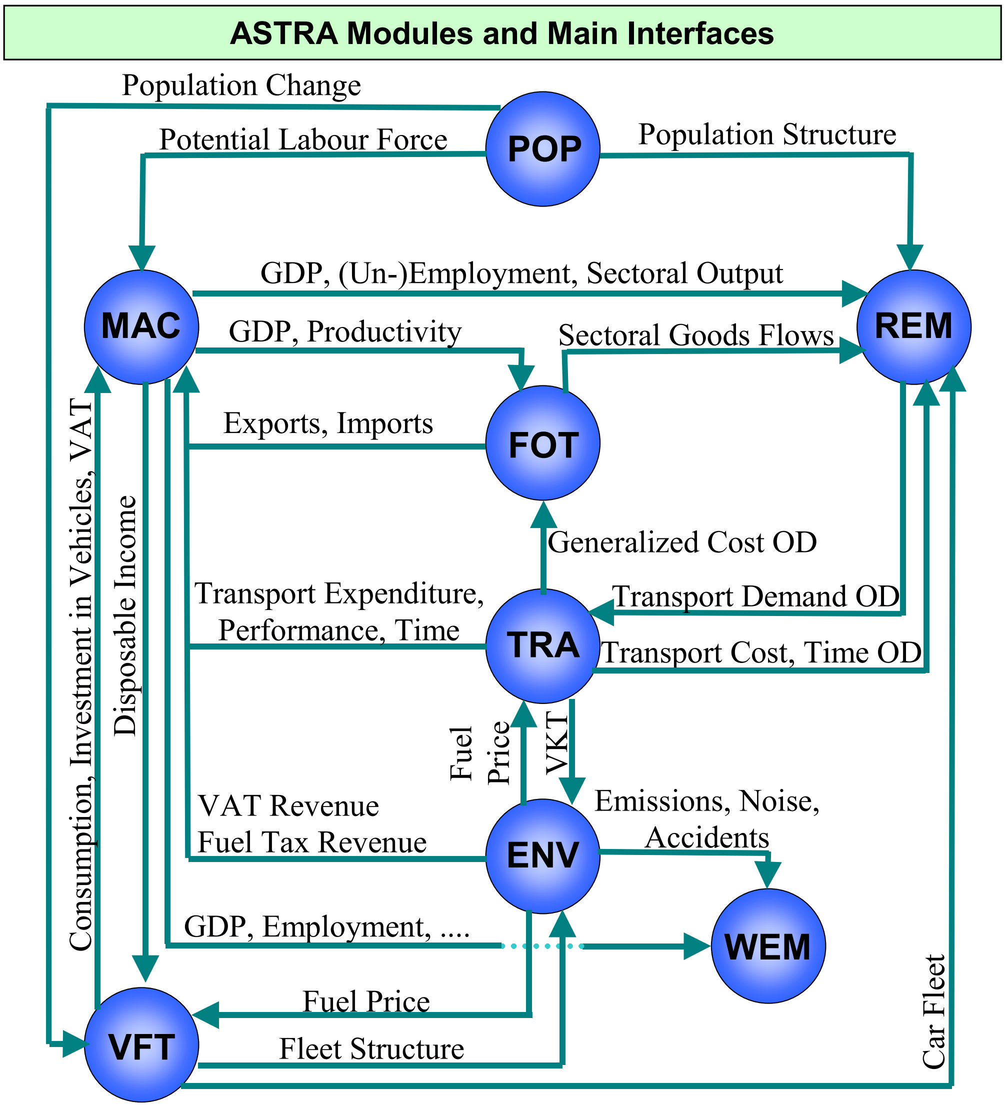
where:
- L = level variable [units]
- I = rate of inflow to level [units/time]
- O = rate of outflow to level [units/time]
- dt = integration interval [time]

Though there exist further methods like Runge-Kutta-4th order method, which can produce better results than Euler integration STERMAN concludes that "*Euler integration is almost always fine in models of social and human systems where there are large errors in parameters, initial conditions, historical data,"* p. 911 [15].

A further important element in System Dynamics models generating the dynamic behaviour of such models are the lag-variables, which take account of time lags between variables within one feedback loop.

4.2 Overview on modules of ASTRA

The ASTRA model consists of eight modules and the version presented in this paper covers the 15 Western European Union countries (EU15). A detailed description of the ASTRA model is provided by SCHADE [9]. The following paragraphs briefly describe the concepts of the eight modules for which the main interlinkages are shown in FIGURE 2.



Abbreviations:

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

FIGURE 2 Overview on the ASTRA model.

The Population Module (POP) calculates the population development for the EU15 countries with one-year age cohorts. The model depends on fertility rates, death rates and immigration. Based on the one-year-age cohorts for each country, important information is provided for other modules like the number of persons in working age. POP is calibrated to EUROSTAT population predictions [8] [12].

The Macroeconomics Module (MAC) provides the national economic framework. The MAC combines different theoretical concepts as it incorporates neo-classical elements like production functions; Keynesian elements like the dependency of investments on consumption extended by influences from exports or government debt; Or elements of endogenous growth theory 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, where the demand side model depicts the four major components of final demand: consumption, investments, exports-imports and the government consumption, and 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 (TFP). Endogenised TFP depends on investments, freight transport times and labour productivity changes. The fourth element 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 can be estimated. The 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.

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 and enable to calculate the indirect economic effects of transport changes originating on the micro level. Hence, the micro-macro bridges and their counterparts the macro-micro bridges form important elements to close the feedback loops between transport and the economy.

The MAC provides several important outputs to other modules. The most important output is endogenous Gross Domestic Product (GDP) for each EU15 country e.g. influencing 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 income exerts a major influence on car purchase affecting finally the vehicle fleet module and 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 calculated by the Foreign Trade Module (FOT).

The 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 resulting sectoral export-import flows of the two trade models are fed back into the MAC as part of final demand.

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 applying a logit-function calculates 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 MAC as well as changes in freight transport times such that the latter can influence total factor productivity. Considering load factors and occupancy rates respectively, vehicle-km are calculated.

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 fuel tax revenues are estimated. Expenditures for fuel, revenues from fuel taxes and value-added-tax (VAT) on fuel consumption are transferred to the MAC.

The Vehicle Fleet Module (VFT) is describing the vehicle fleet composition for all road modes. Vehicle fleets are differentiated into age classes based on one-year-age cohorts and into emission standard categories. Additionally, car vehicle fleet is differentiated into gasoline and diesel powered cars of different cubic capacity. 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. 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.

4.3 Linking trade and transport in ASTRA

ASTRA includes two different trade models: one for INTRA European trade and one for trade between the EU and the rest-of-the-world. In the context of this paper only the INTRA European trade model is relevant and explained. In this model trade flows are calculated on a sectoral bi-national base i.e. for a matrix of 15x15x25 flows (countryXcountryXsector). Influencing factors on trade include:

- GDP of importing country.
- Relative sectoral productivity between the two trading partners, which is also considered as a proxy for exchange rates for those countries that have different currencies than the EURO and for the period before introduction of the EURO, since ASTRA is calibrated for the period 1990 until 2002, which includes a period before the introduction of the EURO.
- World GDP development.
- Transport cost for passenger and freight between the trading partners.
- Transport times for passenger and freight between the trading partners

This leads to the following set of equations describing the trade model and its influences either generated by the macroeconomics module (MAC) or the transport module (TRA). Several elements of the equations include lags like the influence of productivity changes that affect trade flows with a lag of up to 1.5 years (individually calibrated for each flow) or the changes in transport cost and times whose influence is spread over a period of up to 3 years.

Sectoral INTRA-EU exports:

$$\mathrm{Ex(t)}_{EC,EC2,s} = Ex(t-dt)_{EC,EC2,s} * \quad \text{(eq. 2)}$$

$$\left(1+\left(\Delta rPRO(t)_{EC,EC2,s} + \Delta GDP(t)_{EC,EC2,s} + \Delta exWGDP(t)_{EC,EC2,s} + \Delta fGC(t)_{EC,EC2,s} + \Delta pGC(t)_{EC,EC2,s}\right)\right)$$

Productivity influence:

$$\Delta \mathrm{rPRO(t)}_{EC,EC2,s} = cPROD_{EC,EC2,s} * \left[(\Delta PRO(t-LAG_{EC,EC2,s})_{EC,s} - \Delta PRO(t-LAG_{EC,EC2,s})_{EC2,s})\right] \quad \text{(eq. 3)}$$

GDP influence (endogenous):

$$\Delta \mathrm{GDP(t)}_{EC,EC2,s} = cGDP_{EC,EC2,s} * \Delta iGDP(t)_{EC2} \quad \text{(eq. 4)}$$

World GDP influence (exogenous):

$$\Delta \mathrm{exWGDP(t)}_{EC,EC2,s} = cWGDP_{EC,EC2,s} * \left[\Delta WGDP(t) - thWGDP + \left[\Delta WGDP(t) - \Delta WGDP(t-0.5)\right]\right] \quad \text{(eq. 5)}$$

where:	Ex =	sectoral exports between two EU15 countries [Mio*EURO]
	cGDP =	calibrated coefficient for influence of GDP on export [dmnl]
	cPROD =	calibrated coefficient for influence of productivity on export [dmnl]
	cWGDP =	calibrated coefficient for influence of world GDP growth on export [dmnl]
	LAG =	time lag between change of productivity and impact on exports [year] on exports [dmnl]
	ΔfGC =	influence of changes in accessibility of freight transport [dmnl] (see equation 6)
	ΔGDP =	influence of GDP growth of importing country [dmnl]
	ΔiGDP =	change of GDP of importing country over a period of 1 year [dmnl]
	ΔpGC =	influence of changes in accessibility of passenger transport [dmnl]
	ΔPRO =	change of productivity over a period of 1 year [dmnl]
	ΔrPRO =	influence of relative sectoral productivity on exports [dmnl]
	ΔWGDP =	world GDP growth over a period of 1 year [dmnl]
	ΔexWGDP =	influence of world GDP growth on exports [dmnl]
	thWGDP =	threshold above which world GDP growth exerts a positive influence on exports
	s =	**index for 25 economic sectors**
	EC2 =	**index for importing EU15 country**
	EC =	**index for exporting EU15 country**

The following transport related equations 6 and 7 add new influences to the trade model. Transport flows are generated on a zonal origin-destination (OD) base consisting of 4 zones per country. Furthermore, modes, distance bands, trip purposes for passenger transport and goods categories for freight transport are differentiated. The rationale behind the equations is that changes of generalized cost of transport composed out of cost and time changes provided in the above differentiation are after a time lag affecting trade flows due to restructuring of trade relationships because of changes in transport accessibility, which is represented by the aggregated generalized cost. Furthermore, the model considers that trade of goods is stronger affected by changes in freight accessibility while trade of services depends more on passenger accessibility. The equations for freight are presented in the following:

Transport influence in trade model in equation 2:

$$\Delta fGC(t)_{EC,EC2,s} = cfGC_{EC,EC2,s} * \left[EXP\left[\frac{\sum_{DB} wDB_{DB} * \Delta sfGC(t)_{DB,GC,EC,EC2}}{\sum_{DB} wDB_{DB}} * wGS_s \right] - 1 \right] \quad \text{(eq. 6)}$$

$$sfGC(t)_{DB,GC,EC,EC2} = SMOOTH\left[\frac{\sum_{m,OC,DC} GCost(t)_{DB,GC,m,EC,OC,EC2,DC}}{\sum_{m,OC,DC} TON(t)_{DB,GC,m,EC,OC,EC2,DC}}, RT \right] \quad \text{(eq. 7)}$$

where:

where:	cfGC =	calibrated coefficient for influence of freight generalised cost on export [dmnl]
	EXP =	exponential function
	ΔfGC =	influence of smoothed freight generalised cost on sectoral export [dmnl]
	ΔsfGC =	change of smoothed freight generalised cost per country pair over a one year period [dmnl]
	GCost =	generalised cost per time period per OD-pair [Mio*EURO]
	sfGC =	smoothed and weighted averaged freight generalised cost per country pair [EURO/t]
	SMOOTH =	function providing smoothing and spreading of impacts over time [dmnl]
	RT =	smooth time used here as reaction time of exports to changes in generalised cost. A reasonable value used in the model is 3 years implying that some changes appear directly but other changes occur after 3 years or later. The peak of yearly changes is then in the 3rd year.
	TON =	volume transported per OD-pair [Mio*t]
	wDB =	weight of distance bands weighting long distance band double [dmnl]
	wGS =	weight of freight transport on sectors introduces higher weight of freight for goods sectors and vice versa lower weights for service sectors [dmnl]
	DB =	**index for distance bands**
	GC =	**index for goods categories**
	m =	**index for modes (road, rail, ship)**
	OC =	**index for origin functional zone**
	DC =	**index for destination functional zone**

The variable GCost in equation 7 actually transfers the transport policy influences to the trade model as it incorporates the time changes due to new infrastructure and the cost changes due to road pricing.

5 ASSESSING POLICIES FOR THE LYON-TURIN CORRIDOR IN ASTRA

Given the described structure the ASTRA model is not suitable to identify regional economic impacts of small scale transport projects that should have no measurable impact on national level. However, the Lyon-Turin link with a length of 257 km and the corresponding high-speed- and combined-rail project involving investments of 13 Bio EURO over 10 years as part of the TEN corridor Lyon-Turin-Trieste-Budapest reveals a size that should be substantial enough to provide national impacts such that the usage of ASTRA would be promising.

The ASTRA model does not include a transport network model that would enable addressing transport cost and time changes of specific network links. Instead, ASTRA incorporates modal Origin-Destination (OD) matrices indicating the point of origin of a trip and the point of destination for different distance bands that provide the cost, time, distance and demand information for each OD-pair linking the four zones considered for each European country. ASTRA calculates travel times and modal demand completely endogenously for each OD-pair. Cost is modelled partially endogenously and partially by exogenous trends. Distance development is provided exogenously though by shifting demand between different distance bands also an endogenous component of distance modelling is implemented.

Policy implementation for the Lyon-Turin corridor has to consider the OD-matrix structure of ASTRA. This is done by considering international country-pair OD-elements that are potentially passing through the Lyon-Turin link and taking into account for policy implementation in ASTRA aggregated results of a detailed transport network model, in this case VACLAV [16]. OD-country-pairs selected for being relevant for policy implementation are (forth- and backwards):

- France-Italy
- France-Austria
- Belgium-Italy
- Spain-Italy
- Portugal-Italy
- Spain-Austria
- Portugal-Austria.

For each of these international OD-pairs the share of total demand that is passing through the Lyon-Turin link and the share of the distance of the link on the total travel distance of the OD-pair is derived from VACLAV results. This information is needed to translate cost and time changes as well as demand results between the link-level Lyon-Turin and the level of OD-matrices. For the base scenario this results into the transport demand data shown in TABLE 1. Total demand refers to the total demand transported between two OD-countries, which includes both demand transported via the Lyon-Turin link and demand transported via alternative routes e.g. along the Mediterranean coast crossing the French-Italian border at Ventimiglia.

TABLE 1 Road Freight Demand on Lyon-Turin Corridor and Total Demand for Selected Country Pairs

Road Transport	unit	2000	2005	2010	2015	2020
Lyon-Turin						
Trucks per day	[vhc/d]	4,993	5,330	6,214	7,201	9,065
Tons per year	[1000 tons]	19,291	20,315	22,300	24,189	28,691
Total demand						
France-Italy	[1000 tons]	21,318	21,922	22,645	22,888	24,840
France-Austria	[1000 tons]	752	923	1,256	1,676	2,367
Belgium-Italy	[1000 tons]	1,740	1,846	2,030	2,163	2,467
Spain-Italy	[1000 tons]	1,750	2,016	2,844	3,725	5,416
Portugal-Italy	[1000 tons]	31	42	80	204	404
Spain-Austria	[1000 tons]	93	139	232	370	588
Portugal-Austria	[1000 tons]	2	3	8	29	61
All country-pairs	[1000 tons]	25,686	26,891	29,094	31,055	36,143

Source: ASTRA results in BAU

5.1 Transport impacts

Since impacts of the policies can first be measured in the transport system itself the analysis commences with the results for changes of transport demand between the most affected countries. The following tables present the changes of freight demand (tons) and passenger demand (trips) for road and rail mode. It should be taken into account that these are the aggregate results for all transport between the countries, since the question in this paper is not so much on the link Lyon-Turin itself but on the overall impacts of removing a bottleneck on such a major transport link. Looking at the most important road freight changes in TABLE 2 it shows that the strongest change is observed for transport from Italy to France with nearly a reduction of -10% in the year 2020 compared to BAU. Surprisingly, the opposite direction from France to Italy shows only a reduction of nearly -3%, while for both directions rail is gaining about +23%. This difference results from ship transport between Italy and France loosing also close to -3% while in the other direction ship transport is nearly not affected. This seems to be caused by differences in the export structure between the two directions (e.g. Italy-France chemicals exports account for 16% while in the opposite direction it is only 6% and in turn France-Italy machinery accounts for 17% while in the opposite direction it is only 9%) and different elasticities of the modal-choice functions. The second strongest reaction of road freight transport can be observed for France-Austria in both directions with road reducing about -3.5% and rail gaining about +8%.

TABLE 2 Changes of Freight Transport Demand (tons) Compared to BAU in Year 2020

ROAD							
[% to BAU]	Scenario	Austria	Belgium	Spain	France	Italy	Portugal
Austria	New rail only (RIO)	0.00	0.01	-0.68	-2.70	0.03	0.00
	New rail plus road toll (RIPT)	0.00	0.01	-0.72	-2.90	0.03	-0.05
Belgium	New rail only (RIO)	0.01	0.00	0.06	0.16	-1.17	0.03
	New rail plus road toll (RIPT)	0.01	0.00	0.06	0.15	-1.36	0.02
Spain	New rail only (RIO)	-0.75	0.05	0.00	0.01	-1.07	0.01
	New rail plus road toll (RIPT)	-0.78	0.05	0.00	0.03	-1.16	0.01
France	New rail only (RIO)	-3.96	0.30	0.04	0.00	-1.97	0.41
	New rail plus road toll (RIPT)	-4.29	0.27	0.04	0.00	-2.80	0.36
Italy	New rail only (RIO)	0.09	-0.88	-0.98	-8.78	0.00	0.31
	New rail plus road toll (RIPT)	0.08	-1.03	-1.20	-10.07	0.00	0.19
Portugal	New rail only (RIO)	-0.10	-0.02	0.01	-0.20	-0.29	0.00
	New rail plus road toll (RIPT)	-0.15	-0.01	0.01	-0.16	-0.33	0.00
RAIL							
[% to BAU]	Scenario	Austria	Belgium	Spain	France	Italy	Portugal
Austria	New rail only (RIO)	0.00	-0.01	3.68	8.32	-0.12	2.01
	New rail plus road toll (RIPT)	0.00	-0.01	3.71	8.71	-0.12	2.01
Belgium	New rail only (RIO)	-0.01	0.00	-0.36	-0.09	3.20	-0.55
	New rail plus road toll (RIPT)	-0.01	0.00	-0.36	-0.10	3.21	-0.56
Spain	New rail only (RIO)	3.57	-0.40	0.00	-0.45	10.98	-0.05
	New rail plus road toll (RIPT)	3.66	-0.41	0.00	-0.43	11.18	-0.06
France	New rail only (RIO)	7.76	0.14	0.45	0.00	22.70	0.56
	New rail plus road toll (RIPT)	8.20	0.08	0.34	0.00	24.87	0.46
Italy	New rail only (RIO)	-0.02	4.96	6.80	23.07	0.00	2.89
	New rail plus road toll (RIPT)	-0.03	5.09	6.85	24.94	0.00	2.84
Portugal	New rail only (RIO)	1.90	-0.80	-0.08	-0.59	4.47	0.00
	New rail plus road toll (RIPT)	1.92	-0.80	-0.08	-0.55	4.59	0.00

Source: ASTRA results in scenarios

For passenger transport the changes on the country level are not that significant (see TABLE 3), which is plausible since passenger transport has more options for alternative route choice than freight transport. As expected the strongest reactions on the road occur between France and Italy in both directions with -1,4% and -2,8%, while rail is gaining up to 11% compared to BAU, which is plausible due to the difference in the absolute levels for the modes which is about three times higher for road than for rail.

Especially for the country pairs France-Italy and Italy-France also air transport is loosing demand with -0,75% for the former and -0,6% for the latter direction both compared to BAU. This number seems to be too low, since this OD-pair involves the Milan-Paris flows, which should be of high relevance for current air transport between France and Italy and which can be expected to change significantly due to the large time savings by the high-speed rail.

TABLE 3 Changes of Passenger Transport Demand (trips) Compared to BAU in Year 2020

			ROAD				
[% to BAU]	Scenario	Austria	Belgium	Spain	France	Italy	Portugal
Austria	New rail only (RIO)	0.00	0.00	-0.01	-0.13	0.00	-0.03
	New rail plus road toll (RIPT)	0.00	0.00	-0.01	-0.13	0.00	-0.03
Belgium	New rail only (RIO)	-0.02	0.00	0.00	0.02	0.00	0.04
	New rail plus road toll (RIPT)	-0.01	0.00	0.01	0.02	0.00	0.03
Spain	New rail only (RIO)	0.00	0.00	0.00	0.01	-0.01	0.00
	New rail plus road toll (RIPT)	0.00	0.00	0.00	0.01	-0.01	0.00
France	New rail only (RIO)	-0.85	-0.06	-0.09	0.00	-2.80	-0.14
	New rail plus road toll (RIPT)	-0.83	-0.05	-0.08	0.00	-2.79	-0.13
Italy	New rail only (RIO)	-0.02	-0.07	-0.20	-1.40	0.00	-0.07
	New rail plus road toll (RIPT)	-0.02	-0.07	-0.20	-1.40	0.00	-0.07
Portugal	New rail only (RIO)	0.00	0.00	0.00	0.00	0.00	0.00
	New rail plus road toll (RIPT)	0.00	0.00	0.00	0.00	0.00	0.00
			RAIL				
[% to BAU]	Scenario	Austria	Belgium	Spain	France	Italy	Portugal
Austria	New rail only (RIO)	0.00	-0.02	2.62	3.12	-0.04	7.16
	New rail plus road toll (RIPT)	0.00	-0.02	2.61	3.12	-0.04	7.15
Belgium	New rail only (RIO)	-0.03	0.00	-0.25	-0.09	4.43	-0.49
	New rail plus road toll (RIPT)	-0.02	0.00	-0.25	-0.10	4.43	-0.51
Spain	New rail only (RIO)	1.27	-0.10	0.00	-0.05	2.95	-0.01
	New rail plus road toll (RIPT)	1.27	-0.10	0.00	-0.06	2.95	-0.01
France	New rail only (RIO)	5.19	0.08	0.05	0.00	11.89	-0.19
	New rail plus road toll (RIPT)	5.14	0.05	0.03	0.00	11.89	-0.19
Italy	New rail only (RIO)	0.08	5.39	2.61	8.83	0.00	2.37
	New rail plus road toll (RIPT)	0.06	5.37	2.61	8.83	0.00	2.36
Portugal	New rail only (RIO)	2.22	-0.21	-0.01	-0.06	4.57	0.00
	New rail plus road toll (RIPT)	2.22	-0.22	-0.01	-0.06	4.57	0.00

Source: ASTRA results in scenarios

5.2 Trade impacts

This section deals with the question if such a transport infrastructure improvement is able to evoke measurable export changes on country level. The first analysis concentrates on France and Italy as the two countries potentially benefiting most from the new infrastructure. Looking at FIGURE 3 we observe that the two analysed scenarios generate different patterns of export changes. The infrastructure only scenario is always positive for both countries generating finally in the year 2020 an export increase of +0,55% for France and +0,15% for Italy. In absolute terms this amounts to an increase of exports by 2,4 Bio Euro for France and 2,1 Bio Euro for Italy over the next 15 years. For this number one has to consider that the new link is then fully operational only for six out of these 15 years.

The pattern of the infrastructure plus pricing scenario reveals that during the first decade, when only the pricing policy is implemented and the new link is not completed exports are slightly decreased compared to BAU. With the completion of the link this changes such that also the change of exports moves to the positive side.

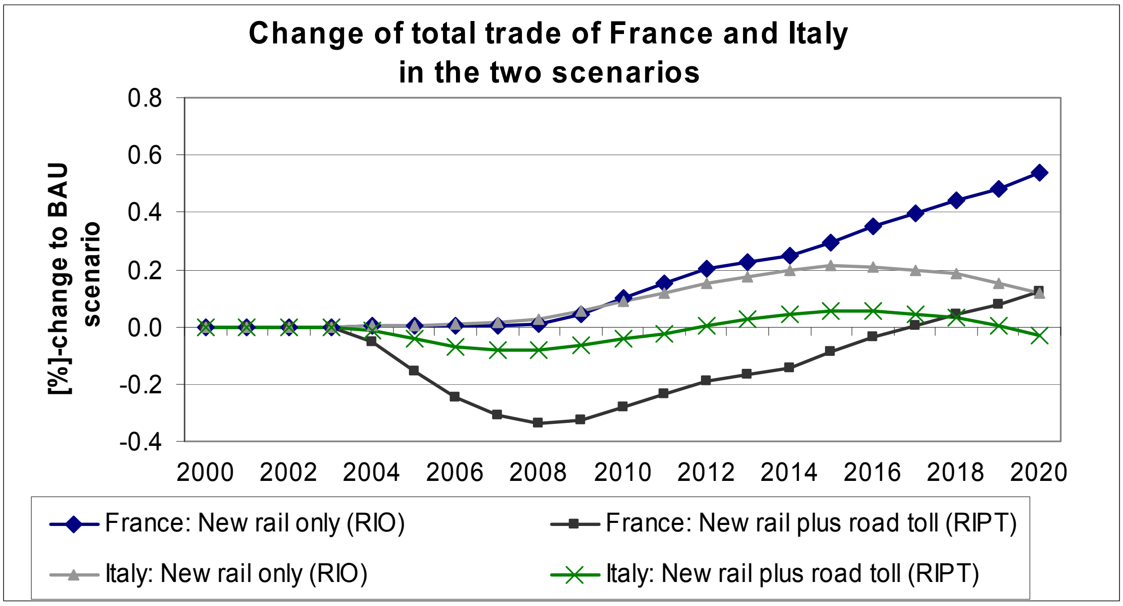


FIGURE 3 Development of total trade changes between France and Italy.

Looking at the level of country pairs for exports in TABLE 4 it can be observed that not all combinations are gaining from the infrastructure improvement. As expected France and Italy are gaining for all pairs with at maximum 0,54% of exports. On the other hand there are also significant losses e.g. for exports from Portugal to France, which is a combination not using the link at all. It seems that the modal-shift towards rail for some longer transport distances like Portugal-Austria or Portugal-Italy causes capacity problems on other parts of the rail network e.g. in France or Spain such that export flows not benefiting from the Lyon-Turin corridor but suffering from these capacity problems in other parts of France or Spain are reduced.

TABLE 4 Change of Monetary Exports for Relevant Country-pairs Compared to BAU Scenario [%-Change to BAU]

Export from	Scenario / Import to	Austria	Belgium	Spain	France	Italy	Portugal
Austria	New rail only (RIO)	0.00	0.00	0.01	0.09	-0.06	0.01
	New rail plus road toll (RIPT)	0.00	0.00	0.00	0.05	-0.05	0.01
Belgium	New rail only (RIO)	0.01	0.00	0.00	-0.06	-0.35	0.02
	New rail plus road toll (RIPT)	0.00	0.00	0.00	-0.05	-0.47	0.01
Spain	New rail only (RIO)	0.01	0.00	0.00	-0.17	-0.06	0.00
	New rail plus road toll (RIPT)	0.00	0.00	0.00	-0.14	-0.07	0.00
France	New rail only (RIO)	0.11	0.23	0.03	0.00	0.54	0.06
	New rail plus road toll (RIPT)	0.07	0.20	0.02	0.00	0.12	0.05
Italy	New rail only (RIO)	0.04	0.07	0.26	0.12	0.00	0.09
	New rail plus road toll (RIPT)	0.03	0.03	0.21	-0.03	0.00	0.07
Portugal	New rail only (RIO)	0.09	-0.03	0.00	-0.58	-0.11	0.00
	New rail plus road toll (RIPT)	0.09	-0.02	0.00	-0.49	-0.10	0.00

Source: ASTRA results in scenarios

5.3 Economic impacts

Finally, the question has to be posed if the observed significant transport impacts as well as the minor trade impacts would cause measurable economic impacts. For this analysis, two indicators have been selected for France and Italy: GDP and employment, for which in FIGURE 4 the development compared to the BAU scenario is presented. As already indicated by the trade impacts in the previous section France is developing better than Italy, and both countries show a positive change of GDP with +0,3% for France and +0,1% for Italy until 2020. The employment impacts are much smaller and follow mainly the construction process of the Lyon-Turin link, though for France a slight increase of +0,05% remains in 2020. However, looking at the trend of GDP in 2020 it seems that a continuous increase of GDP also after 2020 can be expected.

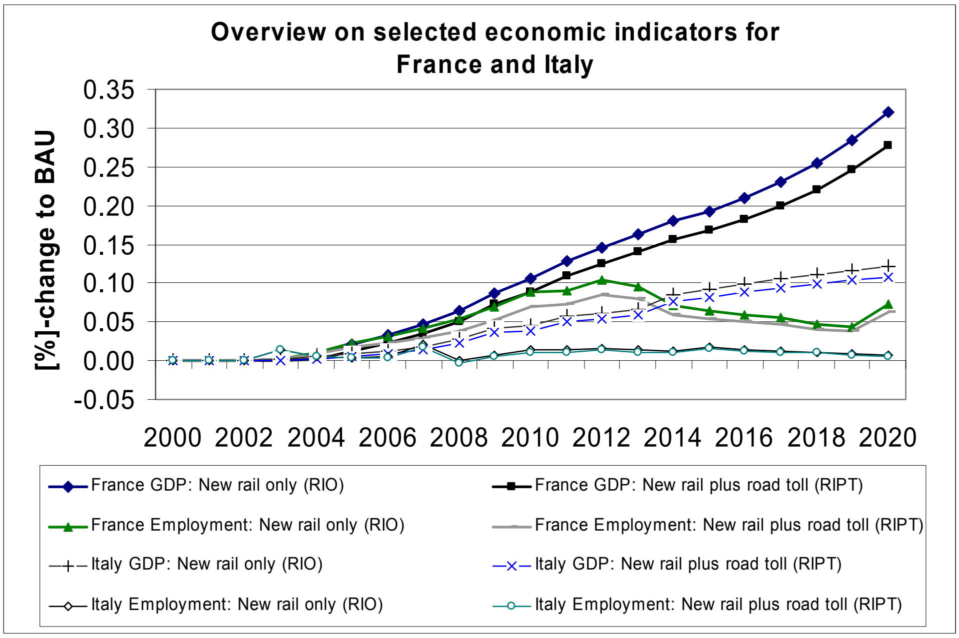


FIGURE 4 Changes of economic indicators for France and Italy.

Having a glance at changes at the aggregate EU15 level in FIGURE 5, we observe small changes in relative terms. However, accumulating the changes over 15 years and looking at the totals e.g. the change of undiscounted GDP would reach 61 Bio*EURO and the additional employment amounts to 275.000 person years.

More meaningful than absolute values in this case are the trends where we observe the time improvements for average rail transport time that go in line with each single step of completing the Lyon-Turin link. These average time improvements are calculated by aggregating the networkwide freight travel time and the total tkm and dividing the totals such that it is a real network wide figure that reveals the impact of one single corridor.

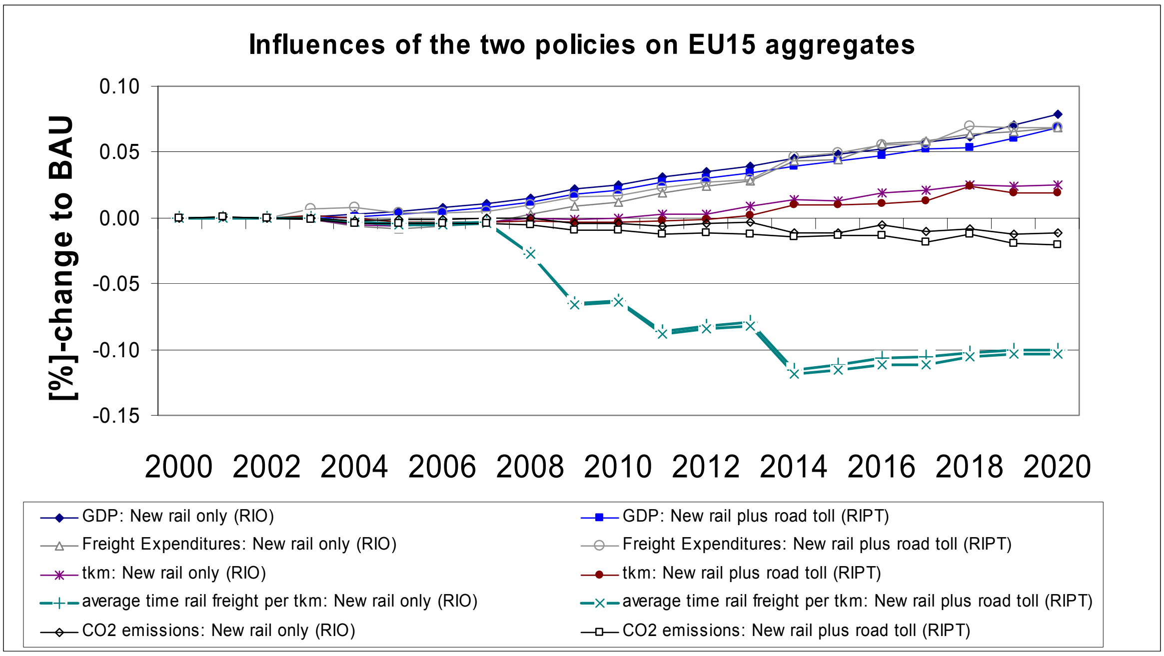


FIGURE 5 Changes to BAU at the EU15 level for selected indicators.

It has been shown that six major impact chains in ASTRA link transport impacts to the economy ([17], [9]) of which four impact chains prove to be more important if a transport policy measure changes expenditures for transport, while two other impact chains are more influential when a transport policy measure alters transport times. In principle, these two major impact chains in ASTRA could be decisive for the positive economic development through the Lyon-Turin corridor:

- impact chain: new infrastructure -> transport time↓ -> accessibility↑ -> exports↑ -> GDP↑, or
- impact chain: new infrastructure -> freight time↓ -> total factor productivity (TFP)↑ -> GDP↑ -> imports↑ -> exports↑.
-

For an analysis of importance of each chain in ASTRA, selected impact chains can be switched off in the model and be replaced by the BAU results. Applying this switch-off analysis to find out if the link accessibility to exports is more important or the link freight time to TFP the conclusion can be drawn that the influence of the time improvements on productivity is about four times more relevant then the influence on exports.

6 CONCLUSIONS

Two questions have been in the focus of this paper: first, if with the aggregated OD-matrix approach of ASTRA an assessment of single infrastructure projects of European significance can be performed, and second, would there be measurable economic impacts identified by ASTRA. To answer these questions the Lyon-Turin corridor has been selected since one of the TEN-T projects runs through this corridor, which is a high-speed rail link that reduces passenger travel times on the link by 2,25 hours and allows for a strong increase of capacity for rail freight on this link.

Besides a business-as-usual (BAU) scenario considering the major policy measures as defined in the European Transport Policy White Paper [2] two policy scenarios have been defined of which the first includes only the implementation of the Lyon-Turin high-speed railway, while the second additionally imposes a road freight charge on this link to encourage modal-shift towards rail by cost incentives.

The first question if the analysed policy packages cause significant transport changes that can be detected by ASTRA can be positively answered. Modal-shifts predicted by ASTRA reach levels up to -10% for road freight demand and +25% for rail freight demand compared to the BAU scenario, which is a significant change though still less optimistic than expectations raised in the official plans. Here, ASTRA could underestimate the impacts due to its aggregate approach.

The second question, which is the more interesting one for ASTRA can also be answered positively, though it has to be taken into account that economic changes remain small such that the trend indications provide more relevant tools for analyses than the absolute values. On the country level export changes compared to BAU can reach +0,6% in 2020 and GDP changes +0,3% in the case of France, which is the country benefiting most from this project. On the level of the EU15 a comparison between the investment cost of 13 Bio EURO and the aggregated increase of GDP over 15 years until 2020, which reaches 61 Bio EURO, seems to indicate a reasonable usage of public money, though it should be mentioned that in this paper no alternative usages are considered for comparison.

Looking at the mechanisms causing this positive impact it seems that the influence on the supply side caused by the freight time savings driving productivity, as freight transport is part of today´s production chains, is more relevant than the influence on the demand side, which works via accessibility gains induced by the new infrastructure affecting then exports flows.

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