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Fully integrated mobility scenarios within sustainable futures for Germany

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Abstract:

Transport has been analysed as a sector and service fully embedded in the overall economy in Germany using a validated economy-environment model (Panta Rhei). Two contrasting scenarios for potential future macro-economic policies in Germany until the year 2020 have been analysed. Both scenarios result in economic and transport volume growth. Transport volumes are strongly driven by increasing international trade and diversification of labour. Moderating this trend appears as a key factor to influence transport volume growth.

A decoupling of carbon dioxide emissions from economic growth appears only feasible with significant efficiency gains. Current markets have no sufficient incentives to realise these gains by themselves. If price signal shall be set, a long-term doubling of fuel prices and road charges seems necessary in order to cut the fleet fuel economy by two and to induce higher transport productivity. Furthermore, if economic growth by transport growth as well as reductions in carbon dioxide emissions shall be achieved, then the emissions from car travel, with two thirds the biggest emitter, must – and can - reduce strongly in order to compensate for the desired growth in freight transport.

Maximal half of the transport emissions can be attributed to mobility demands of the end user. In particular the diverse and growing 'leisure and tourism' activities are very (car) transport intensive. The other half must be allocated as a transport service, among which goods transport for building and food production. Hence policies affecting (private) transport or leisure activities have stronger links, while (freight) transport is linked with a variety of other fields.

Emissions from vehicle production, including all product chains, add another 50% to the carbon dioxide balance from vehicle operation for Germany, services add another 30%, which has rarely been established quantitatively. These sectors represent important and increasing areas for reduction measures. Total employment and gross-value added in the transport sector hinge to about half on vehicle production and services. However production shifts to foreign countries while services increase domestically. But despite their growth most employment and value in vehicle production will be generated outside Germany.

Keys-words: Sustainable development, explorative scenarios, macro-economic modelling, transport, indicators, interactions, assessment, Germany

Main topic area: Assessment, appraisal and scenarios
Sub-topic: Speculative future, sustainable transport

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1. Introduction

Often studies on sustainable development either treat all sectors of society but give little detail on individual sectors like transport or, when treating transport, miss out on the overall picture and other sectors of society. However at least the most important interactions of transport with other sectors need to be accounted for to identify strengths and weaknesses with respect to sustainable development, to properly assess potential measures and to balance trade-offs e.g. between socio-economic and environmental impacts. Here we present selected results from a three-years' collaboration on sustainable futures by five major German research centres (Grunwald et al. 2001; Coenen, Grunwald 2003). This consolidated effort has made it possible to address a number of questions for the first time in a comprehensive and quantitative manner for Germany:

- What transport developments, integrated in overall future approaches, appear possible?
- What is the importance of vehicle use relative to all other transport related activities?
- What are the important drivers for the future transport development?
- How large are domestic and foreign effects and what is transport's trade balance?
- How much of transport is used for which other consumer purposes?
- What measures appear effective to approach a sustainable mobility?

The main economic and environmental interactions have been modelled quantitatively with a number of various indicators. Here we present detailed results only for the emissions of carbon dioxide as central environmental indicator, for the employment as key social indicator, and for gross-value added as key economic indicator. Furthermore we present only modelling results for 2000 and two strongly contrasting scenarios for a possible development until 2020, while results for an intermediate scenario are omitted here. Full details are given in Keimel et al. (2004).

2. Method

2.1. Macro-economic and environment model

The entire society is modelled quantitatively based on and compatible with the system of national accounting, a closed system which is linked to similar accounting systems of other countries. For the scenario quantification an economic-ecological model ("Pantha Rhei") is used which contains the whole economic system and data on energy use by 22 primary and secondary energy carriers and 58 economic branches with the addition of private households. The behavioural equations are derived from regression analysis of time series and linked by identities of national accounting systems. As the economic part belongs to a world wide family of similar Models (the Inforum group) the international part stems from linked runs of all these models. As a result, the development and reaction of the economy depends especially on reactions to price changes and time trends. Different scenarios are implemented by changing time trends and tax rates leaving the interdependencies of the economic model intact. Additionally, a transportation part was estimated and implemented that explicitly models the transport development, vehicle stocks, fuel consumption and their interaction with the economic system. For a detailed description of Pantha Rhei see Meyer et al. (1999).

To investigate the interaction of technological and behavioural changes eight "activity fields" are defined within the input-output-tables. These activity fields – mobility and transport, housing and construction, nutrition and agriculture, tourism and leisure, etc. – reflect human needs and encompass all production branches which are functionally related;

they include the whole chain of primary and intermediate goods. Cumulated values - which include the whole process chains - for sustainability indicators are calculated for whole fields of activity and their parts using input-output-methods. This does not only provide the possibility to investigate the interaction of different sectors within the overall economy, but does also allow to link very detailed technical and behavioural analyses to macroeconomic modelling. As Pantha Rhei calculates whole input-output-tables the resulting data can be used to derive cumulated numbers in the same way as for past data. The results presented here below stem from these calculations or directly from Pantha Rhei. For details on the central input-output-methods used and on the definition of fields of activity see (Klann, Schulz 2001). However, the high aggregation and economic bias of the data limits to some extent the interpretation with respect to social and environmental aspects. As often, second best indicators must be used because of these data limitations.

The activity field 'mobility and transport', which is in focus here, encompasses all effects related to the operation of the vehicles, the provision of the respective transport fuel or electricity, the construction, maintenance and disposal of vehicles and of the infrastructure with their complete pre-chains as well as diverse services like insurance activities, running public service stations or private garage building. The pre-chains account for all activities outside Germany but which are ultimately used for domestic purposes, e.g. the extraction and refinement of primary materials like oil and iron ore or semi-finished products. Vice versa, domestic activities for export purposes, including the respective pre-chains, are earmarked to be allocated to foreign final use. Special care is given to treat the interactions between different activity fields.

2.2. Explorative scenarios: General and specific transport sector assumptions

In total three explorative scenarios of potential developments for Germany until 2020 as a whole are constructed and quantitatively modelled; we present here only the two extremes that represent different macro-political approaches and attitudes. Within each scenario, complementary developments of the transport sector are defined. The impact of each scenario is modelled using endogenous input- and emission-coefficients in the whole economy. One assumption is that the internal German developments are compatible with the international developments and not isolated; clearly an increased globalisation can only work when European and other countries participate, and vice versa, Germany cannot just for itself reduce international trade without similar international developments.

Explicitly, we do not make any judgement to what extent these developments are desirable or plausible; we simply explore consequences – based on observed past behaviour and trends - which might happen if certain measures or developments occur. Aspects of a concrete implementation are not treated.

One scenario, 'Liberalised markets and globalisation' (LIB), explores the consequences of a supply driven economy with increasing globalisation and liberalised market forces. The contrasting scenario, 'Social and regional orientation' (REG), explores the consequences of a demand driven economy with stronger regional trade flows and high emphasis on social and environmental objectives. The key general assumptions for the two contrasting scenarios are given in the Appendix (Table 6), the transport specific assumptions in Table 1.

Assumptions for scenario 'Liberalised markets and globalisation'

This scenario assumes that the (economic) market is the main decision forum and driver of developments: Market forces (shall) become more global and liberalised. National regulations are reduced, production patterns become increasingly international, and

trade and capital flows increase. There is a fierce global competition for production places and strong pressure on prices of goods and commodities. The nation states take a supply driven economic approach and reduce taxes and social security charges on the economy.

With respect to Germany specifically a reduction of taxes and social security charges for enterprises is assumed. Public social welfare per recipient is reduced and private social insurance is encouraged by the state. Following this line of thought taxes on transport fuels are kept constant at 2003 levels and road toll is levied from 2004 only at federal highways for heavy duty vehicles above 12 t maximum weight at on average 13 cent (real) per kilometre.

Table 1: Transport specific assumption for fuel taxes and road tolls in the two scenarios by 2020.

Assumptions for the transport sector	**LIB 2020**	**REG 2020**
Increase in fuel tax (compared to 1998) (€/l) (nominal) 0,06 in 2000	0,15	0,36
CO_2-tax	no	184 (€/t) equals Otto: 0,43 €/l; Diesel: 0,48 €/l
Road toll for commercial vehicles € per km (real)	Highways: HDV 0,13	all extra-urban: HDV: 0,26 LDV: 0,08
Vehicle tax	equal in both scenarios	

Assumptions for scenario 'Social and regional orientation'

The scenario 'Social and regional orientation' assumes a demand driven economy with stronger regional trade and production patterns. Social and environmental objectives are high on the political agenda and, e.g. drastic measures against climate change are implemented and accepted. Pensions are from tax revenues; jobs for social and community work are publicly alimented. For climate protection the energy and fuel taxes are continuously increased in this scenario. In addition a CO_2 tax is charged from 2010. Road toll is levied on all extra-urban roads and increased to 26 cent (real) per kilometre for heavy duty vehicles and 8 cent (real) per kilometre for light duty vehicles.

3. General results

3.1. General economic development

For the analysis of the economic development we distinguish between the absolute growth and the relative shares of the individual components according to the scenario assumptions (Appendix, Table 7).

The scenario with highest emphasis on economic stimulation and market forces ('Liberalised markets and globalisation') returns the highest growth rates for the gross domestic product: 1,8% on annual average until 2020 resulting in an increase of 43% compared to 2000. For the scenario with highest emphasis on social and environmental objectives ('Social and regional orientation') the economic growth rate is at 1,4% on annual average, resulting in an overall increase by 33% compared to 2000. Sensitivity analysis reveals that the higher growth rate is not due to the dedicated liberal economic policy but could also be achieved by a more moderate approach essentially emphasising technological improvements and efficiency. By contrast, in the scenario 'Social and regional orientation' growth is halted by the restriction on imports. In consequence, the German economy shifts towards services or non-tradable goods. These sectors, however, will grow slower than import and export demand by the fast growing economies and generally show lower productivity gains. Both factors result in slower economic growth. To a minor degree the same effects are caused by the ecological taxes.

The different economic policy approach in the two contrasting scenarios is reflected in the relative growth of international trade on the one hand and government consumption on the other hand. 'Liberalised markets and globalisation' unleashes, as intended, a very strong growth in international trade and high investments in machinery; on the other hand the government consumption goes down substantially. Contrary, in 'Social and regional orientation' all components of the consumption develop more uniformly. This means, compared to the market oriented scenario, growth in international trade is more limited, as intended, though still above average, and government consumption grows proportionally and continues as an important consumption category. The considerable growth in investments in 'Social and regional orientation' are a consequence of the ecological taxes which induce enterprises to invest in ecologically less damaging processes and to substitute existing equipment quite early.

With respect to the different production sectors, both scenarios reflect a marked shift from production to services. Hence, if past macro trends continue, an important structural change can be expected regardless of the explicit policy. The different economic policies only modulate this trend: In 'Social and regional orientation' the shift to services is amplified, because production sectors are more energy intensive than service sectors, and hence have a higher tax load, and because Germany's important export industries, chemistry and machinery, are particularly hit by less international trade, as modelled. Construction and transportation sectors, though relatively energy intensive, profit from insulation activities and increased public transport, stimulated to avoid CO_2-taxes. Therefore, their relative share is about equal in both scenarios.

3.2. General social development

Employment develops markedly different in the two scenarios (Table 2): In 'Liberalised markets and globalisation' the growth in GDP goes parallel with increasing labour productivity while average annual labour hours remain almost constant. In consequence hardly any additional employment is generated and the unemployment rate stays at around 10%. Contrary, the scenario 'Social and regional orientation' assumes that the average annual labour hours are significantly reduced, mainly through part time work arrangements. Together with growth in GDP, though more moderate than in the other scenario, the total work is shared between more employees and jobs particularly in the social sector are created. Hence the unemployment rate drops to around 3% in 2020. Labour productivity grows as average wages increase significantly.

Table 2: Key labour indicators for Germany 2000 and the two scenarios for 2020.

Labour indicators	**Germany 2000**	**LIB 2020**	**Change**	**REG 2020**	**Change**
Persons engaged (in mio.)	33,9	34,4	1%	37,1	9%
Unemployment rate	10,3 %	9,7 %	-6%	3,3 %	-68%
Average annual labour hours	1.478	1.484	0%	1.261	-15%
Total volume of work (1.000 h)	50.163	51.064	1%	46.772	-7%
Average gross wage rate ($€_{2000}$/h)	19,50	26,00	33%	31,00	59%

However for both scenarios the existence of working poor cannot be excluded: While average wages increase in 'Social and regional orientation' the working time decreases; in 'Liberalised markets and globalisation' the working income decreases relative to capital income. Hence even the reduction of unemployment, here brought about by a redistribution of the total work volume with less working time per capita, does not preclude income poverty.

3.3. Development of transport volumes and private expenditure

The total transport volume is taken as a rough indicator for the general developments in the transport sector. In 'Liberalised markets and globalisation' the high private consumption and economic growth on the one hand and moderate fuel prices on the other hand result in a strong increase in road transport, which determines the absolute development. Freight transport volumes are driven by the very strong increase in international trade. According to this economic policy the total transport volume would expand by more than 30% for passenger and 50% for freight transport by 2020[2] (Figure 1 and Appendix, Table **8**).

Total transport volumes also grow according to the alternative scenario 'Social and regional orientation', but significantly less than the gross domestic product: 22% for passenger and 16% for freight transport. Road transport, as the vastly dominant mode, again drives this expansion, but - opposite to the other scenario - public transport modes grow above average, thereby slightly increasing their modal share. The moderate growth in transport volumes is explained as a reaction to the significant increase in transport fuels' prices due to a carbon tax and, in the case of freight transport, additional road infrastructure toll on all extra-urban roads, besides a more moderate general economic growth. Only these measures, applied in a significant manner, seem to be successful to achieve the political objective to decouple growth in transport volume from growth in gross domestic product.

The different policies indeed significantly influence the absolute growth in transport volume as well as its pattern. The two scenarios have strongly different transport price assumptions. In the case of 'Liberalised markets and globalisation' the fuel tax and the resulting fuel price remains relatively low (1,39 and 0,98 € per l gasoline and diesel fuel respectively, compared to 0,99 and 0,80 € per l in 2000) and road toll is only levied for heavy duty vehicles on federal highways and remains throughout at its first introduction level. On the contrary, 'Social and regional orientation' assumes significant fuel and carbon taxes such that the consumer price is more than twice as high (2,91 and 2,69 € per l gasoline and diesel fuel respectively), doubles the road toll and extends it to all commercial vehicles on all extra-urban roads. In consequence the equilibrium between economic and transport volume growth, fuel or transport price increase and increases in fuel efficiency as well as disposable incomes and expenditures on transport differ very strongly: In 'Liberalised markets and globalisation' the high growth in transport volume is almost entirely (>90%) driven by private car travel and lorry transport, i.e. individual road transport. Private expenditure on transport increases both in absolute and relative terms, as more upper class vehicles are bought. The average fleet fuel economy improves only slightly: 6,5 and 6,0 l per 100 km for gasoline and diesel cars respectively, compared to 8,8 and 7,4 l per 100 km in 2000. All public transport modes, except air travel, decline in both absolute and relative terms.

The strong transport price increases in 'Social and regional orientation' induce very different reactions and significantly stimulate efficiency gains: For passenger travel the car fleet doubles its energy efficiency, not least through a significant replacement of gasoline by more efficient diesel cars together with down-sizing, trips by car are replaced by public transport and finally there are more passengers per trip and less absolute distances. All in al the strong price increases are more than compensated and total private expenditure for

[2] Growth rates are highest for air transport (63% each), however, its absolute volume remains small (when measured over the territory).

travel remains at 14% of total, as in the year 2000 (Table 3). For freight transport the price increase – together with the general economic development - induces a higher capacity utilisation and leads to only one quarter of the road transport growth estimated for the high economic growth scenario. As freight transport has proven more price sensitive in the past a higher impact of economic measures is seen in this sector and a significant decoupling from general economic development can be achieved.

Table 3: Private expenditure for travel purposes in Germany 2000 and according to the two scenarios for 2020.

	Germany 2000		**LIB 2020**		**REG 2020**	
	10^9 €$_{2000}$	**share**	**2000=100**	**Share**	**2000=100**	**share**
Vehicles	68	41%	194	50%	147	47%
Fuels	30	18%	108	12%	46	6%
Public transport	21	13%	125	10%	177	18%
Other	48	29%	157	28%	131	29%
Total transport expenditure	167	100%	159	100%	128	100%
Total private consumption	1.176	14%	145	16%	129	14%

4. Development of key environmental, social and economic indicators of 'Transport and mobility'

We can now analyse the consequences of these developments for a few central indicators, the emissions of carbon dioxide (CO_2), the employment and the gross-value added. However, the definitions which are here well adapted to the carbon dioxide emissions, do not suit equally well for the other two indicators. This is already a first important result, namely that the indicators are not proportional to each other but rather complementary and that therefore a complete picture of developments demands for these diverse indicators, which have however rarely been used all together.

We distinguish between the direct fuel use, the provision of the transport fuels and driving electricity, the vehicle production with its prechain and additional services including infrastructure built and maintenance. As seen above, the production sectors undergo significant changes and the economic activities in the two contrasting scenarios can be realised with strongly differing transport volume developments, especially for road transport, and vice versa. Both effects increase carbon dioxide emissions according to the policies in the one scenario, while they decrease when different policies are implemented (Figure 2). The growing transport volume also drives the expansion of the social and economic indicators. However the structure as well as the relative development are markedly different from the carbon dioxide emissions: Vehicle production and services each account for about half of employment and gross-value added (Table 4). While carbon dioxide emissions strongly depend on absolute growth and technological development, gross value added is mainly determined by the general economic development spelled out above and employment is additionally affected the reduced average working time in the case of 'Social and regional orientation'.

a) Pre-processes significantly contribute to the carbon dioxide emission balance of the transport sector (Table 4): It is well known that the provision of fossil transport fuel adds about 10 to 15% to the emissions from vehicle operation, as is the case here. However what has rarely been calculated in a consistent manner for a whole country is the additional contribution from the vehicle production: In the case of the year 2000 baseline about 50% have to be added to the emissions directly from vehicle operation (this figure includes also emissions from the production of export vehicles, see below). An additional 30% result

from the running of public transport stations, from maintenance and repair services and products, and to a remarkably small degree (3%), also from built and maintenance of the infrastructure. Taking this large view of the transport sector, the carbon dioxide emissions from vehicle operation account only for 50% of the total.
Most transport emission balances published so far omit the large contribution from all supporting production and services and hence underestimate total emissions by a factor of two. Often the respective emissions from all supporting production and services are allocated to e.g. the industrial sector thereby loosing the direct relation and transparency of their origin.

Table 4: a) Emissions of carbon dioxide, b) persons engaged and c) gross-value added in the whole activity field 'transport and mobility' for Germany 2000 and according to the two scenarios for 2020.

	Germany 2000		**LIB 2020**		**REG 2020**	
a) CO_2 emissions	**10^6 t**	**share**	**2000=100**	**share**	**2000=100**	**share**
Fuel consumption	184	53%	123	53%	69	47%
Fuels/electricity production	23	6%	105	6%	88	7%
Vehicle production[a]	88	25%	121	25%	79	26%
Infrastructure/services[b]	55	16%	124	16%	97	20%
Total	*350*	*100%*	*122*	*100%*	*77*	*100%*
b) Persons engaged	**1.000**	**share**	**2000=100**	**share**	**2000=100**	**share**
Fuel consumption	n.a.	-	n.a.	-	n.a.	-
Fuels/electricity production	144	2%	109	1%	109	1%
Vehicle production[a]	4.038	47%	138	50%	137	48%
Infrastructure/services[b]	4.428	51%	122	48%	130	50%
Total	*8.610*	*100%*	*129*	*100%*	*133*	*100%*
c) Gross value added	**10^9 €$_{2000}$**	**share**	**2000=100**	**share**	**2000=100**	**share**
Fuel consumption	n.a.	-	n.a.	-	n.a.	-
Fuels/electricity production	25	5%	116	3%	52	1%
Vehicle production[a]	267	48%	194	51%	164	49%
Services/Infrastructure[b]	263	47%	181	47%	171	50%
Total	*555*	*100%*	*185*	*100%*	*162*	*100%*

a: Without freight transport for production purposes or business trips.
b: Without vehicle production and transport.

Compared to carbon dioxide emissions the structure of the employment and gross-value added indicator is completely dominated by vehicle production and services. While the importance of direct manufacturing for these social and economic issues might not be surprising, it has rarely been determined in quantitative terms that the sum of the diverse services is about as high. This clearly indicates that a purely energy or emission based analysis does not have a justification to pass judgements on these economic or social issues, in fact that they would be misleading because of the largely different structures. And vice versa, economic analysis is not sufficient to reveal the crucial elements for an environmental assessment. The differences in the shares of 'provision of fuels' for value added and persons engaged especially stems from the amount which has to be paid to the owner of the resources ("quasi-rents"). In 'Social and regional orientation' the difference decreases as the ecological taxes will drive the net capital yield of existing plants below zero, which will be reversed in the long run and shares as in the other scenario are likely to be seen again. It should be remembered that persons engaged and gross value added give world wide figures. For comparison with other findings and for a closer analysis another decomposition is required. This will be given below for the most important part: Vehicle production.

b) The absolute and relative development of CO_2 emissions differ strongly in the two contrasting scenarios (Figure 2): In 'Liberalised markets and globalisation' the total emis-

sions increase by 22% until 2020; all factors contribute to this increase and only the provision of the transport fuel becomes less carbon intensive (per unit fuel). Hence in this scenario the structure of the emissions remains constant and direct vehicle operation contributes about half of the total, vehicle production a quarter.
Contrary, in 'Social and regional orientation' emissions in all segments decrease, despite a significant increase in transport volume and vehicle production, and the total CO_2 emissions go down by 23% compared to 2000, with the direct vehicle emissions even decreasing by 30% due to downsizing, a doubled fuel economy and less mileage[3]. Consequently, the overall emission structure changes, pre-processes become relatively more important and direct vehicle operation account for slightly less than half of the total emissions, at a significantly lower level.
The increased general energy tax in this scenario has also lead, a.o., to major energy savings, efficiency improvements and a shift to regenerative sources in the electricity production. Not least the vehicle production sector benefits of this development. Put differently: Emission control strategies in the transport sector are well targeted when addressing both direct fuel use and the vehicle production.
The development of the social indicator in the two contrasting scenarios is remarkably similar, with about 30% more persons engaged in the whole transport sector (defined in the large meaning). Gross-value added is slightly less in 'Social and regional orientation', in line with the somewhat lower total GDP.

c) There are essentially only two important determinants for the development of the emissions from transport fuel use, i.e. from vehicle operation plus fuel provision[4]: On the one hand increasing fuel efficiency strongly reduces carbon emissions per distance driven. On the other hand the general increase in transport distances counteracts.
In 'Liberalised markets and globalisation' efficiency is increased essentially for technology, with minor improvements in capacity utilisation and productivity. A shift to increased road and air travel together with a strong transport growth, driven by economic expansion, vastly over-compensates these gains. In consequence total carbon dioxide emissions are 20% above the 2000 level and even 70% above the level of the alternative scenario for 2020, which results from a stringent reduction policy.
In 'Social and regional orientation' (fossil) transport fuels are relatively more expensive. This stimulates both, much higher technical gains in fuel efficiency and consumer choice towards more efficient (and usually smaller) cars. High technological improvements are triggered in all transport modes, not least in aviation. But higher transport costs induce furthermore a higher organisational efficiency, namely a higher capacity utilisation, higher transport productivity and a more favourable modal shift. All gains in technological, organisational and structural efficiency together could reduce carbon dioxide emissions from vehicles by more than factor of two in the two decades. They thus more than offset the transport volume growth, brought with the general economic growth. Overall, according to this scenario, there could be about 30% less emissions compared to the 2000 baseline.

d) Sensitivity analysis reveals that almost 90% of the efficiency gains of 'Social and regional orientation' can already be realised by moderate fuel tax increases and strong incentives for technological innovation, notably for non-carbon fuels. Hence this important determinant is not utilised strongly in the presumably market-oriented liberalisation sce-

[3] Note, that regenerative transport fuels do hardly play a role in this scenario. All emission reductions are due to savings in the conventional fossil fuel chain.

[4] See Formula 1 for factor analysis.

nario. Second, private transport has the highest potential for improvement, while freight transport's potential for gains is more limited, because companies have already calculated fuel economy. Consequently, third, if both, reductions in carbon dioxide emissions and economic growth by transport growth shall be achieved, then emissions from car travel must reduce strongly in order to compensate for the desired growth in freight transport. Fourth, growth in transport volume or increasing number of trips and distances respectively, can apparently only be addressed by significant fuel price increases, unless a behavioural change sets in autonomously. No other measure has proved successful in reducing transport volumes in this modelling approach.

e) As seen above, the emissions from vehicle production have a sizeable share of total transport sector's emissions. This merits a closer look: First, more than 90% of them are related to road vehicle production. Second, the division and outsourcing of production processes means that pre-processes or semi-finished products account for more than half of the total production emissions, with increasing trend. Hence when looking at this sector, its network of inter-dependencies cannot be neglected. Third, about 40% of the total production emissions are for export vehicles, with increasing share in both scenarios (Table 5a). However the absolute emissions go up in the high growth scenario, while they go down in the other. The share of domestic emissions decreases strongly because of the shift of carbon intensive production to foreign countries. Fourth, the share of services in the whole value chain, and consequently the related products and emissions, is increasing to about 15 to 20% of the total. So far, conventional process chain or life cycle analysis often neglects this part and, if continued, will therefore in the future underestimate the product consequences markedly.

Table 5a: Carbon dioxide emissions from vehicle production for Germany 2000 and according to the scenarios in 2020, differentiated by domestic and foreign shares.

	Germany 2000	**LIB 2020**		**REG 2020**	
a) CO_2 emissions from vehicle production	**10^6 t**	**10^6 t**	**2000=100**	**10^6 t**	**2000=100**
Total emissions (≡A1+A2≡B1+B2)	103	134	130%	79	77%
A1) Emissions from imported vehicles	23	46	200%	26	113%
A2) Emissions in Germany (≡A2.1+A2.2)	80	88	110%	53	66%
A2.1) foreign emissions (pre-products)	*24*	*36*	*150%*	*24*	*100%*
A2.2) German emissions	*56*	*52*	*93%*	*29*	*52%*
B1) Emissions for foreign end use	42	59	140%	34	81%
B2) Emissions for German end use	61	75	123%	45	74%
Numbers here include emissions due to transport in the whole production chain. In Table 4 the respective emissions had been allocated to 'fuel consumption' and 'provision of transport fuel'.					

The development of employment and gross-value added in vehicle production is determined by the growth in transport volume (Table 5b, c). At the end of the two decades the growth in turnover does not suffice any more to compensate for the growth in productivity and hence no new employment can be generated. In both scenarios the import and export of vehicles grows stronger than average, though at different rates according to the general conditions. This growth is due to an increasing intra-industrial trade in vehicles which is generally explained by a demand that values diversity in combination with economy of scales in production. Looking at the upstream chain of vehicle production the evolving international division of labour tends to shift manufacturing activities abroad while services, which are in general relatively labour- but less energy-intensive, increase on the domestic side. In consequence however, though the total i.e. global employment and gross-value added increase significantly in both scenarios, the domestic share (component

A2.2. in the table) does not profit proportionally. Accordingly, foreign production gains most.

Table 5b, c: Employment and gross value added from vehicle production for Germany 2000 and according to the scenarios in 2020, differentiated by domestic and foreign shares.

	Germany 2000	**LIB 2020**		**REG 2020**	
b) Persons engaged in vehicle production	**1000**	**1000**	**2000=100**	**1000**	**2000=100**
Total (≡A1+A2≡B1+B2)	4.358	6.160	141%	5.722	131%
A1) producing imported vehicles	1.059	2.207	208%	1.935	183%
A2) production in Germany (≡A2.1+A2.2)	3.299	3.953	120%	3.787	115%
A2.1) producing abroad	*543*	*885*	*163%*	*966*	*178%*
A2.2) producing in Germany	*2.756*	*3.068*	*111%*	*2.821*	*102%*
B1) vehicles for foreign end use	1.804	2.693	149%	2.498	138%
B2) vehicles for German end use	2.554	3.467	136%	3.224	126%
c) Gross value added in vehicle production	**10^9 €$_{2000}$**	**10^9 €$_{2000}$**	**2000=100**	**10^9 €$_{2000}$**	**2000=100**
Total (≡A1+A2≡B1+B2)	286	573	200%	460	161%
A1) imported vehicles	69	203	294%	153	222%
A2) production in Germany (≡A2.1+A2.2)	217	370	171%	307	141%
A2.1) production abroad	*37*	*90*	*243%*	*83*	*224%*
A2.2) production in Germany	*180*	*280*	*156%*	*224*	*124%*
B1) vehicles for foreign end use	118	250	212%	200	169%
B2) vehicles for German end use	168	323	192%	260	155%

Once again when taking a closer look at the vehicle production sector, the 'places' of carbon dioxide emissions on the one hand and of employment and gross value added on the other hand differ markedly: While CO_2 is emitted mainly in relation to electricity production and the pre-products (25% and 56% in 2000), employment and gross value added relate to final production, pre-processes and services (36%, 38% and 25% respectively in 2000)[5]. This is another example that e.g. life cycle or product chain analysis, which are well adapted to the material or environmental aspects, are not capable to draw valuable conclusions on the related social or economic issues within the product chain, and vice versa. In particular, the increasing importance of the service sector poses a considerable challenge for analytical tools.

f) About half of transport is a service, when measured according to its carbon dioxide emissions. Only half of the total emissions, including the respective vehicle and fuel production with their prechains, can be attributed to the final consumer and his transport needs, in particular for 'leisure and tourism'. The rest of the emissions mainly result from goods transport and business travel, with the most pronounced demand from the building sector and the production of food. Vice versa, of the total carbon dioxide emissions attributed to 'leisure and tourism' in the macro-economic model, almost 60% result from driving (Germany 2000). In other words, this activity is transport intensive. For 'food and agriculture' the transport share was about 20%, i.e. sizeable but not dominant. In consequence, measures affecting passenger transport have immediate and strong repercussions for leisure activities, and vice versa. On the other hand, measures affecting goods transport broadly

[5] NB: Hence, for every employee and every euro value added in the vehicle factories there are two further employees and euros in the related pre-chains and service sectors.

will have first order consequences for building and food production, while their impact on other sectors is more indifferent.

5. Summary

Transport has been analysed as a sector and service fully embedded in the overall economy in Germany; all flows from pre-products and services in the transport sector and with other activities have been allocated quantitatively using a comprehensive and validated input-output model (Panta Rhei). Two contrasting scenarios for potential future macro-economic policies and developments in Germany until the year 2020 have been constructed: One scenario assumes a supply driven economic policy with increasing globalisation and liberalised market forces. The contrasting scenario assumes a demand driven economic policy with stronger regional trade flows and high emphasis on social and environmental objectives. The consequences of these policies have been calculated and results are presented here for Germany 2000 as a baseline and the two scenarios in 2020.

Both scenarios result in economic growth: GDP grows on annual average by 1,8% in the 'Liberalised markets and globalisation' scenario, while growth results in 1,4% p.a. in 'Social and regional orientation'. The growth is strongly driven by international trade and hence is sensitive to the diversification of production chains and places. Structural change continues, namely the shift of production to outside Germany and the increasing share of services inside. Macro-policies can modulate this trend, but without drastic measures not change it. No significant additional employment is stimulated by the economic growth itself; only when the given work volume is divided onto more shoulders, e.g. by part-time arrangements, additional people find labour.

Total transport volumes grow in both scenarios, however the different policies strongly influence the absolute increase and the modal structure: With liberalised market forces and low transport prices, the volumes may increase by 30% for passenger and 50% for freight transport. Growth is concentrated on the road sector, with high private consumption expanding car and air travel and high international trade driving road freight transport. According to the alternative scenario 'Social and regional orientation' transport growth can be decoupled from economic growth, with 22% and 16% increase until 2020 for passenger and freight transport respectively. Road transport, as the vastly dominant mode, again drives this expansion, but two fifths of the absolute growth fall onto public transport modes, opposite to the other scenario. The moderate growth in transport volumes is a reaction to the halt in international trade and the significant increase in transport prices, linked with a more moderate economic growth.

The interaction of fuel prices, transport expenditures, efficiency improvements and transport demand not only determines the resulting transport volumes, but to a much larger extent fuel consumption and related carbon dioxide emissions: In the high growth and low transport price scenario only half of the possible efficiency gains are stimulated, which are twice outweighed by the transport growth, and vehicles' CO_2 emissions increase by 20%. Contrary, the high transport prices of the other scenario stimulate major gains in fuel efficiency, productivity and capacity utilisation, which together with a much lower transport volume growth results in 30% less CO_2 emissions from vehicles. Significant efficiency gains could also be achieved by a policy stimulating technological innovation, accompanied by moderate fuel price increases. Yet, without external stimulation, markets, as they are structured today, have no sufficient incentives to realise these gains by themselves.

Emissions from vehicle production, including all product chains, add another 50% to the carbon dioxide balance from vehicle operation, services add another 30%. About 40%

of emissions from vehicle production, almost exclusively road vehicles, are for export vehicles. For a complete understanding of the transport sector, and not just of vehicle driving, the contributions from vehicle production and, increasingly, from services cannot be neglected, nor their strong international involvement. Vice versa, they appear as important areas for reduction measures, though general economic structural change leads to a transfer of carbon intensive activities outside Germany.

Maximal half of the transport emissions can be attributed to mobility needs of the end user. In particular the diverse and growing 'leisure and tourism' activities are very transport intensive. The other half must be allocated as a transport service to other purposes, notably goods transport for building and food production.

Energy and emission indicators do not represent social or economic interactions, and vice versa, and hence these indicators have to be investigated with an adequate method. Employment and gross-value added results to each about half from vehicle production and services. This share stays relatively stable in the two scenarios, as their general macroeconomic trend is similar: The shift of production places to foreign countries and an increasing domestic share of services. As a consequence and despite the above average growth of both total employment and gross value added in the vehicle production sector, the growth takes place largely in foreign countries and Germany does hardly profit.

6. Conclusions

Economic growth in Germany for the next two decades can either be realised with proportionally growing transport volumes and strong increase in carbon dioxide emissions from transport if market forces are given their way, or with moderated growth in volumes and strongly decreasing carbon dioxide emissions from transport, if high gains in energy efficiency can be stimulated and international production and trade moderated. A dedicated overall environmental and employment policy with e.g. increasing transport prices is no contradiction to economic growth or private consumption: Both can be secured by increasing productivity and overcompensating savings. Contrary, expansion of the current economic system clearly contradicts environmental objectives nor has by itself the potential of broad welfare or job generation, unless strong incentives or delimitations are set.

7. References

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8. Appendix

Table 6: Key macro-economic assumptions (exogenous) for the different scenarios.

Assumptions (exogenous)	**LIB 2020**	**REG 2020**
Foreign trade		
Price index of oil and gas imports (2000=100)	98	146
Increase of imports until 2020	-	Maximal by 60%
Social security		
Pension scheme from 2000 onwards	only private (capital based)	in 2020 paid from tax revenues
Potential reductions of charges benefit…	only employer	equally employer and employee
Labour market		
Average annual working time per employee (2000=100)	endogenous	reduced to 86
Development of salaries	endogenous	coupled to labour productivity
Taxes		
Value added tax (2000=16%)	10%	20%
Tax on enterprises	abandoned	no change
Exchange rate € to US$	1,00	1,00

Table 7: Gross domestic product and gross value added, each for different components, for Germany 2000 and in the two scenarios for 2020: Absolute values (in € 2000), relative shares and absolute change.

	Germany 2000		**LIB 2020**		**REG 2020**	
	10^9 €$_{2000}$	**share**	**2000=100**	**share**	**2000=100**	**share**
Gross domestic product and consumption components	2.109	100%	143	1,8% p.a.	133	1,4% p.a.
Private consumption	1.176	56%	145	57%	130	55%
Government consumption	395	19%	112	15%	139	20%
Gross investment in construction	236	11%	140	11%	145	12%
Gross investments in machinery	210	10%	164	11%	143	11%
Exports	752	36%	200	50%	155	42%
Imports	671	32%	198	44%	160	38%
Gross value added by economic sectors						
Manufacturing	530	27%	119	22%	105	22%
Other services	418	21%	184	27%	163	26%
Government services	272	14%	96	9%	103	11%
Housing and rent	225	11%	164	13%	148	13%
Trade	185	9%	172	11%	136	10%
Rest[a]	343	16%	143	17%	137	18%

a: Construction, Transportation, Telecommunication, Supply (energy and water), Agriculture, forestry, fishery, Insurance, Mining.

Table 8: Development of transport volumes of passenger and freight transport in Germany 2000 and according to the scenarios for 2020.

	Germany 2000		LIB 2020		REG 2020	
Passenger transport	**10^9 Pkm**	**share**	**2000=100**	**Share**	**2000=100**	**Share**
Car travel	731	75%	140	79%	117	71%
Bus and coach	77	8%	90	5%	140	9%
Rail	75	8%	98	6%	140	9%
Air	43	4%	164	5%	125	4%
Pedestrians	30	3%	100	2%	117	3%
Cycle	24	2%	92	2%	167	3%
Total	*980*	*100%*	*132*	*100%*	*122*	*100%*
Freight transport	**10^9 tkm**	**share**	**2000=100**	**Share**	**2000=100**	**Share**
Road	346	71%	164		115	
Rail	76	16%	118	77%	118	70%
Shipping	67	14%	125	12%	117	16%
Air	1	0,2%	163	11%	125	14%
Total	*490*	*100%*	*151*	*100%*	*116*	*100%*

Formula 1: Factor analysis for CO_2 emission development per mode. Differentiation by specific carbon dioxide emission per distance, capacity utilisation, modal share, transport productivity and GDP growth.

$$CO_2 \text{ emission per mode} = (CO_2/\text{mileage})_{mode} * (\text{mileage/volume})_{mode} * (\text{volume}_{mode}/\text{total volume}) * (\text{volume/GDP}) * \text{GDP}.$$

Figures

Figure 1: Transport volume for passenger and freight by mode in Germany 2000 and according to the two scenarios for 2020.

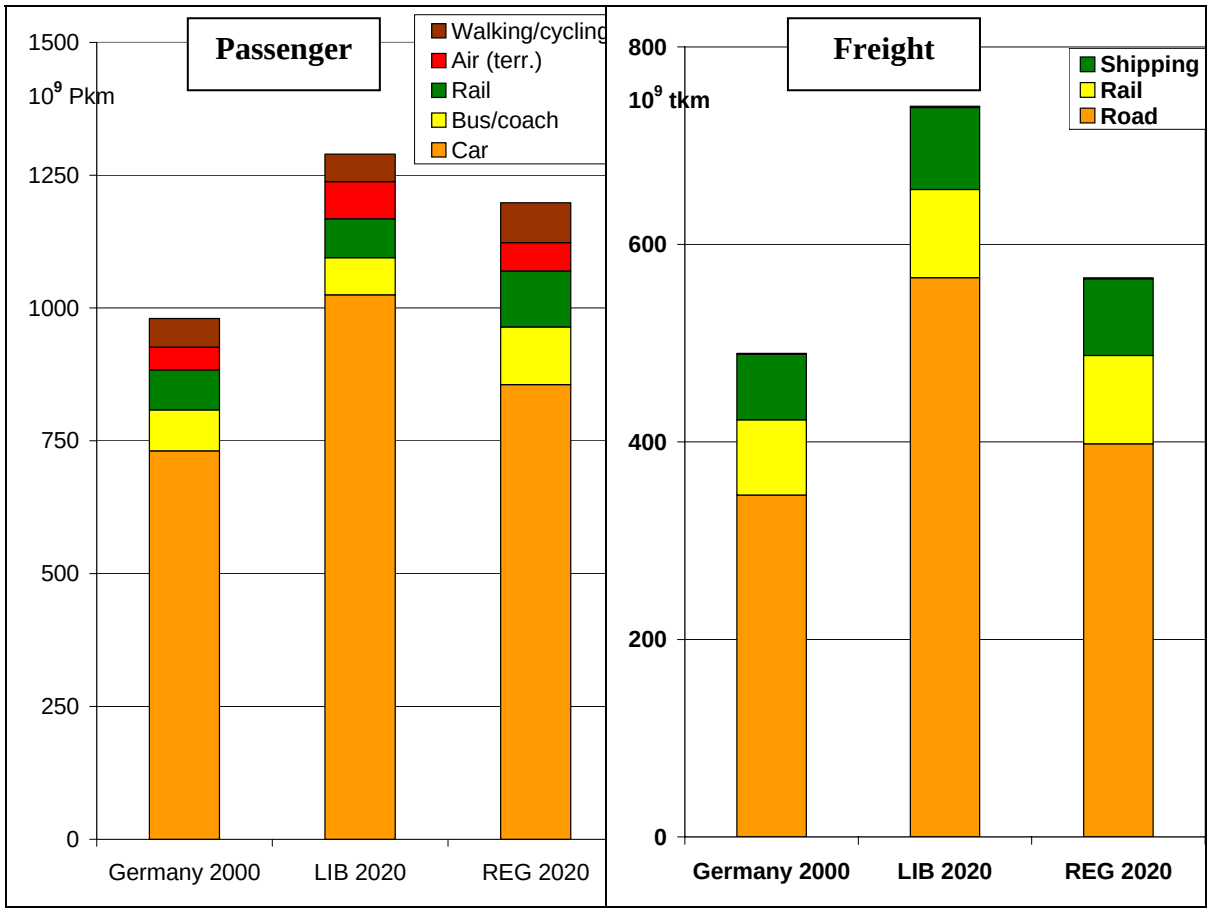

Figure 2: Carbon dioxide emissions in the whole activity field 'transport and mobility' for Germany 2000 and according to the two scenarios for 2020.

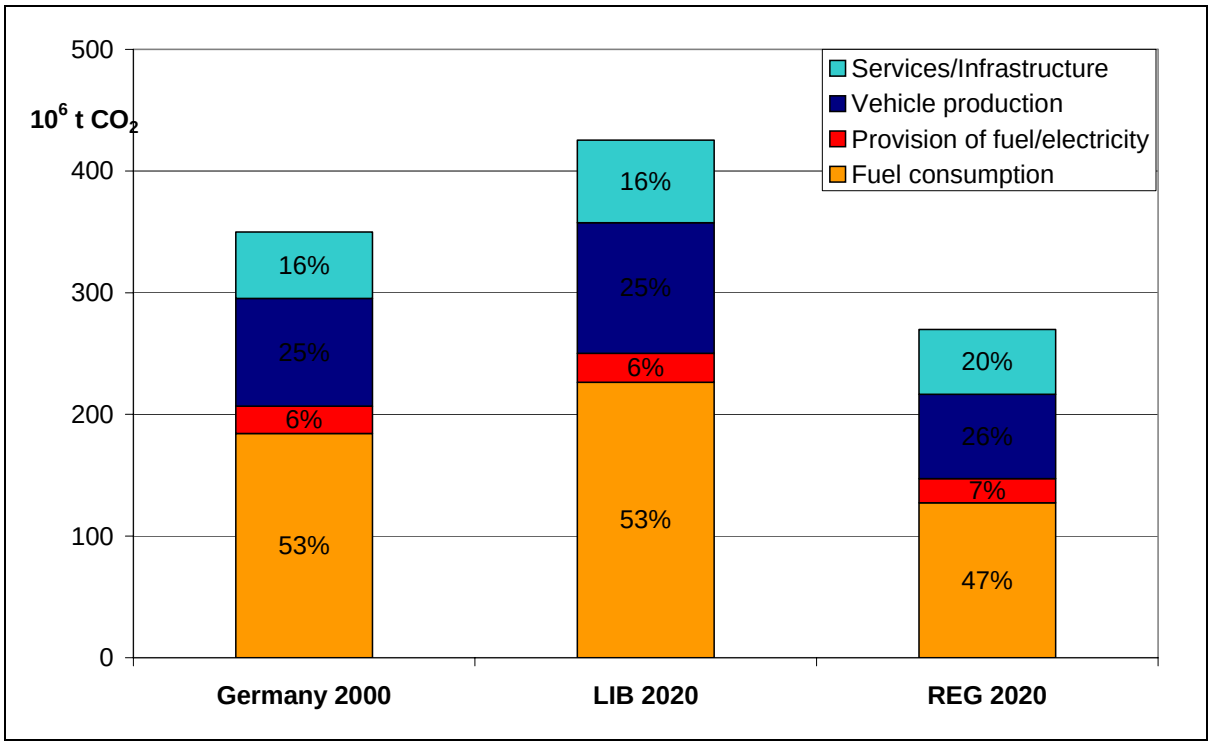

Figure 3: Determinants of development of CO_2 emissions from transport fuel use and its provision in the two contrasting scenarios for Germany 2020.