Impacts of Climate Mitigation Policies on Sectoral Distribution Effects and overall Economic Growth in Germany

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This paper describes the macroeconomic impacts of impulses from technological sectoral models for climate protection policies. The analysis was done with ASTRA-D, a System Dynamics model of the German economy, and the time horizon is 2050. We present here the results of this integrated assessment regarding consumption, investments and employment. Included in the assessment are second round effects and effects of energy expenditure changes on intermediate deliveries and price changes of goods and services. The results indicate an acceleration of economic growth; however, shifts in sectoral demand lead to mixed results in employment. We also discuss the financing of additional climate protection investments and their implementation in ASTRA-D and some of the related problems with that. Finally we review the results in the light of some sensitivity tests.

------------ *Introduction*-------------

Climate mitigation policies have a long list of international negotiations and agreements. The most important international agreement is probably the Kyoto protocol. Industrial countries have also agreed to the objective to reduce their GHG emissions until 2050 by at least 80% compared with 1990, though this is not fixed by any international protocol.

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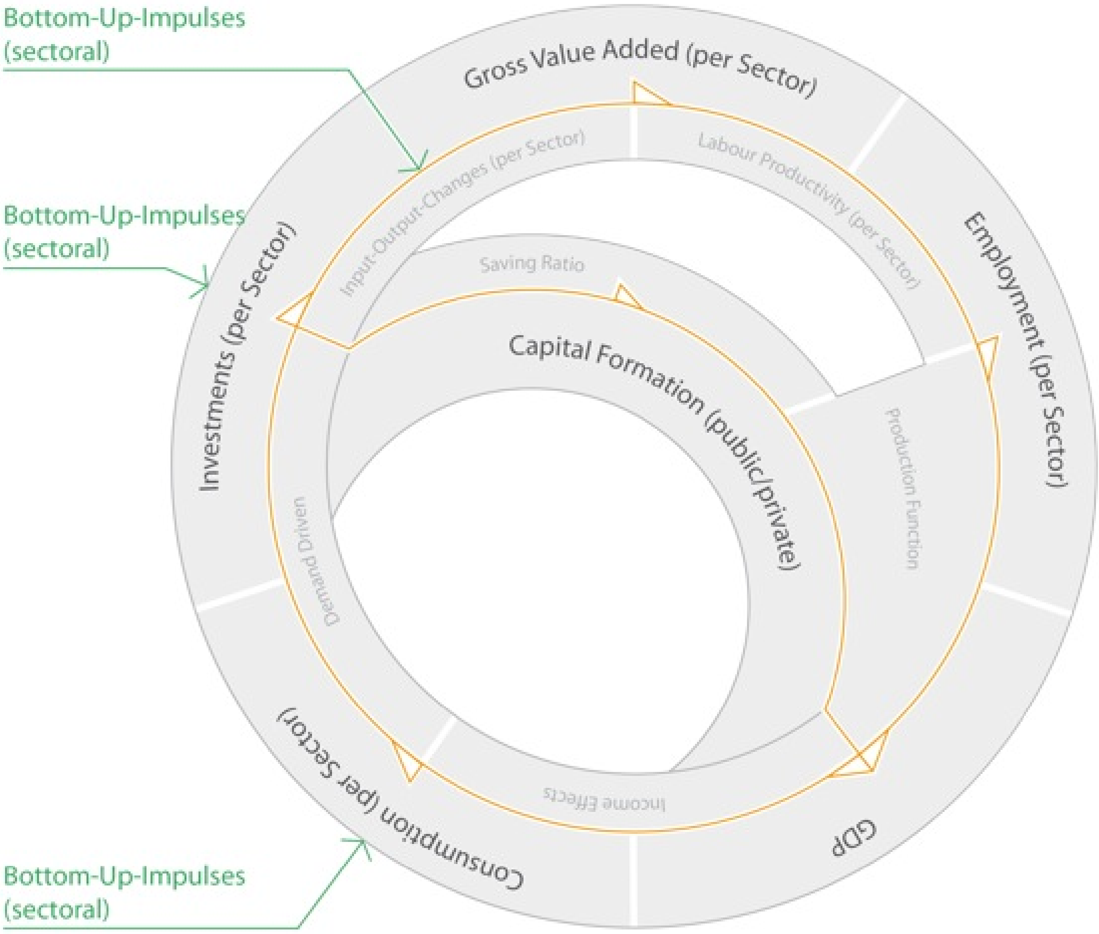
On national level, the German government has also agreed to intermediate reduction goals aiming for a decarbonisation of the economy, of which the most prominent is the GHG emission reduction of 40% until 2020 compared with 1990 (BMU, 2011). Regarding this background the German Federal Ministry for the Environment, Nature Conversation, Building and Nuclear Safety has contracted a consortium composed of Öko-Institut and Fraunhofer ISI to model scenarios with different levels of greenhouse gas (GHG) emissions reduction goals for analysing the following questions: What measures and strategies are necessary in order to achieve climate protection goals and what are the effects of those pathways on the economy?

For answering the first question the analysis drew upon detailed technology-based bottom-up models for each relevant economic sector; however, the second question could only be tackled with an integrated economic assessment model. We used ASTRA-D for this assessment, a macroeconomic System Dynamics (SD) model and implemented the economic output of each detailed sectoral model within our SD model. Here we describe the macroeconomic integration and evaluation process and point to the results and critical points in this analysis.

Our analysis was undertaken with ASTRA-D, a System Dynamics model of the German economy. ASTRA-D is a further development of the European ASTRA model ("Assessment of Transport Strategies") for Germany, which was constructed within the framework of several research projects and dissertation theses assessing transport strategies (Schade, 2005; Krail, 2009). The degree of analysis has been substantially refined for the German version; the individual sectors have been separated based on the German Federal Statistics Office's 2003 classification of economic activities (Destatis, 2003).

ASTRA-D tries to picture the economy as a closed loop. At the core it consists of three feedback loops triggering either the demand or the supply side of GDP calculations. The causal assumptions of the individual loops basically lead to a positive feedback and eventually exponential growth in Gross Domestic Product (GDP); the endogenization of final demand of an input-output-table, which is also part of ASTRA-D, was described in (Meadows and Robinson, 1985). Figure 1 shows in a simplified manner this positive feedback loop: GDP drives consumption, which influences investments; both together with exports and government expenditures forms final demand; final demand triggers intermediate deliveries as well as gross output and (subtracting imports) again GDP (demand side). Starting also from GDP, then consumption influences investments which add to the capital stock and has also an impact on total factor productivity, whose stimuli are being inputs to estimate GDP on the supply side. The third loop changes of final demand, which is endogenous to the model, drives a sectoral input-output table, which is made dynamic with the help of the System Dynamics methodology to estimate value-added and employment influencing GDP on the supply side. Differences between GDP on demand and supply side may cause dampening or accelerating influences on GDP (e.g. if supply < demand investment activities will be increased to accelerate the supply side).

Figure 1: Macro-economic modeling logic in ASTRA-D*



* Green: Implementation of policy impulses

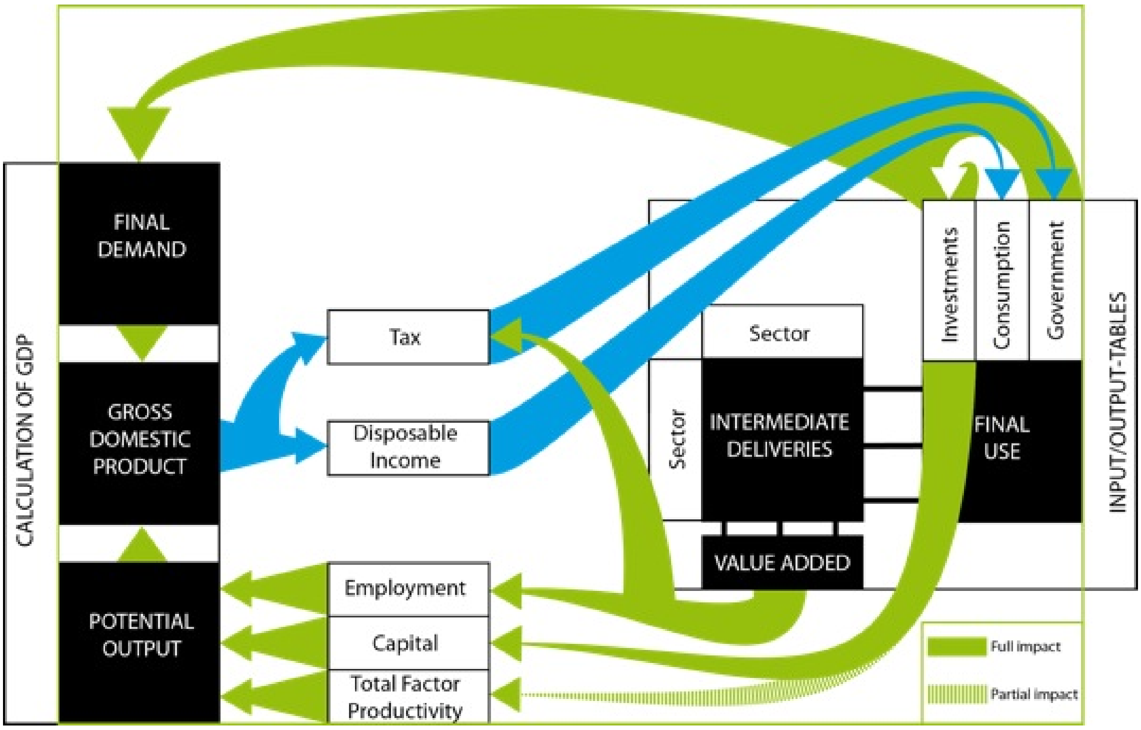
Source: Hartwig et al. (2012)

Figure 2 shows how both sides of the economy are implemented in the model. All macroeconomic values are split according to the classification of economic activities. The 57 sectors differ in their productivity, their need of intermediate inputs and their impact on technical progress, shown as an aggregate of total factor productivity. Furthermore, there is a difference between sectors that are mainly producing investment goods and sectors that are more focused on consumption goods. These relationships are partly calibrated on historical datasets, partly future developments are assumed.

The use of input-output tables and the subsequent sectoral splits enable the integration of “bottom-up” impulses to assess policy measures by sector including any possible second-round effects. This is the core of our work described here and discussed in more detail below. The coupling of external inputs to ASTRA-D has been done before in the context of a transport-related project (Zimmer et al., 2012), but in this project it was the first time that input from all other models of relevant economic sectors were fed into ASTRA-D.

ASTRA-D is not limited to a certain macroeconomic theory, but connects elements such as the neoclassical production function for modelling economic growth with Keynesian demand impulses. An important characteristic is allowing for imbalances to occur between demand and supply. However, certain elements are estimated on econometric time series, so ASTRA-D may not be as “pure” an SD model as the national model, as it fails to produce cyclic behaviour (Forrester, 2003), but its feedback structure is nevertheless nonlinear. Also for this reason ASTRA-D is not an optimization model.

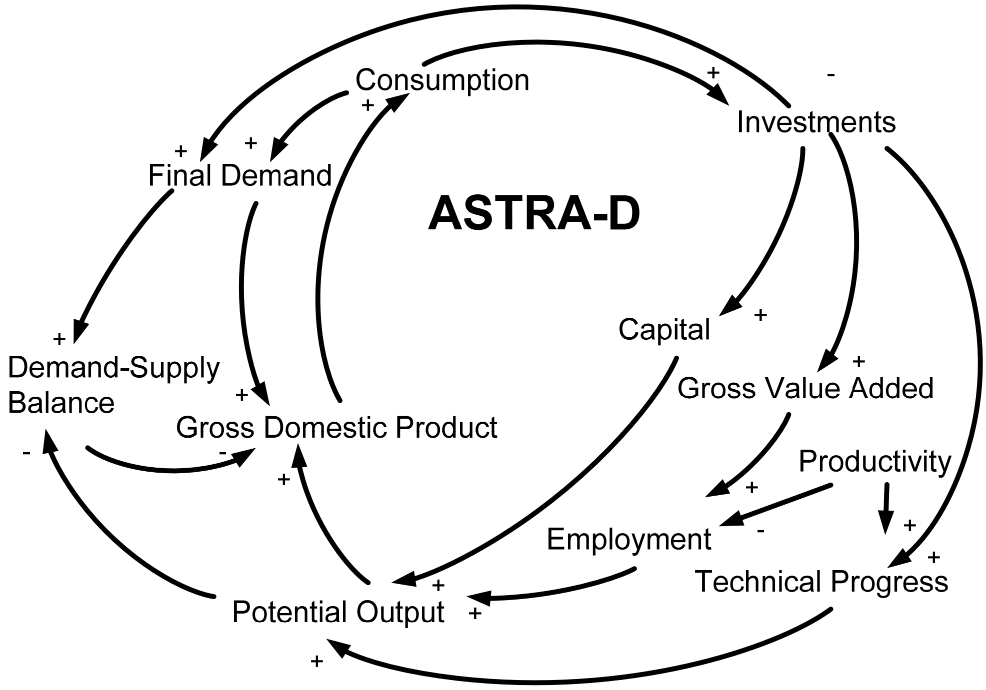
Figure 2: Details of the macroeconomic core of ASTRA-D



Source: own illustration

Figure 3 shows a causal loop diagram with the main core variables of ASTRA-D. Reinforcing feedback loops dominate, but there are also balancing feedback loops which dampens exponential growth tendencies. Assumed exogenous productivity gains in labour productivity are also implemented, which lead to lesser labour demand in the future. Employment is also matched with potential labour force, which is a result of the population development and as a result, unemployment also exists within the model. Unemployment, on the other hand, has a negative impact on income and dampens consumption.

Figure 3: Causal-loop-diagram of core variables



Source: own illustration

Unfortunately, it is not possible to list the equations of the model here, but they can be found in (Schade, 2005), together with a deeper discussion on the feedback loops inherent in the model.

------------ ***Input data***-------------

ASTRA-D runs from 1995 to 2050 and is calibrated according to historical time series (with the Federal Statistical Office as main data source, both for economic indicators as well as population); GDP growth is adjusted to the projected growth rates from *OECD Economic Outlook 2012/1 preliminary Version* (OECD, 2012) with a reduction of 0.3 percentage points. Together with own estimations, e.g. for the development of sectoral labour productivity or the activity rate of the population, this projection formed the base scenario (or deficit scenario DS). The output of the DS (e.g. population, employment) was used as an input for the detailed sectoral models, also called bottom-up models (BUM). It was accomplished by assumptions on future energy price developments concerning crude oil, gas and coal, which were on the basis of the World Energy Outlooks

(IEA, 2011). The prices for heat and electricity, however, were the outputs of one BUM and inversely implemented in ASTRA-D.

Two more scenarios were evaluated: the minimal climate protection scenario (MS), which is linked to the minimum emission reduction goal of 80% reduction until 2050 as stated in (BMU, 2011), and the 2°-scenario (2G) which achieving a reduction of 90% GHG emissions until 2050 would be promising to keep global warming below 2 degrees (of course, assuming that other countries also would achieve their reduction objectives).

The following questions were sought to be answered by our modelling endeavour:

- What are the effects of climate mitigation policies of the two alternative scenarios (MS and 2G) on the following macroeconomic indicators: GDP-growth, sectoral employment, sectoral outputs?
- What are the differences of sectoral "bottom-up" (BUM) changes and an integrated assessment, provided by a model which allows evaluating second-round effects and the passing on of altered energy prices on intermediate inputs?
- How sensitive is the model regarding the funding of investments by partially foreign sources and are isolated effects of consumption or investment changes identifiable?

The last question is relevant in the context of the predominant economic modelling technique used for integrated assessment: computable general equilibrium (CGE) models. In the context of measuring the economic effects of greenhouse gas emissions, emissions are usually determined exogenously and investments or gross output are determined endogenously. The driver of CGE models are relative prices of goods and services produced in different countries. A climate investment is translated into a price increase causing negative effects for the economy, but neglecting the two stimulating effects of investments: (1) increase of final demand, and (2) increase of capital stock and productivity, which both are modelled in ASTRA-D. Furthermore, as the parameters of CGE models are often calibrated against one single base year, it is difficult to account for technological changes. For example making investments in the transportation sector dependant on GHG emissions, reducing the emissions within this sector substantially leads to higher prices and investment constraints; thus, investments are no longer made in the country in question but somewhere else in the world where price effects are lower. In ASTRA-D it is possible to feed in exogenous investments taking into account the cost increases and assuming that through international price effects part of that capital investment may shift.

We collected the inputs of the following detailed "bottom-up" models (BUM) concerning changes in consumption, investments, energy and heating expenditures, changes affecting the trade balance, and subsidies. We stressed in our request that we sought for a systemic implementation of all effects, i.e. that all effects should be financed either through savings of energy expenditures, government spending or forced by regulatory effects, e.g. new standards. However, in some cases few changes were explained by changes in preferences.

The following sectors had detailed bottom-up models (BUMs):

- energy
- F-gases
- buildings
- craft, trade and services
- industry
- private households
- agriculture
- LULUCF (land use, land use change and forestry)
- industrial processes
- conversion processes
- transport

While the inputs of these models were quite diverse, it was necessary to transform those inputs and make them consistent for ASTRA-D. This transformation comprised segmenting to the nomenclature of economic activities of the input-output-tables used in ASTRA-D (Destatis, 2003), finding adequate sectoral split factors for investment and consumption and normalising the inputs – where necessary – to the development of the base scenario. Especially the segmentation activity was not trivial, as some models, e.g. the energy producing sector, generate their outputs according to the implemented technologies and not to the sectors involved in producing those technologies. This meant that each technology had to be split into cost components and those cost components were then assigned to the investment delivery of the according economic sector.

As it is our explicit goal to assess the economic impacts of the changes that arouse from the bottom-up models (BUMs) with ASTRA-D in a consistent as well as complete form, the financing of investments is crucial. The BUMs are detailed models on a sectoral level, but financing a climate investment does not necessarily mean that this happens only with the affected sector. Therefore, the financing options in ASTRA-D are discussed in more detail.

Within ASTRA-D four options are possible:

(1) The investments are paid by subsidies and thus increase the government deficit. This is usually the least preferred option and we asked explicitly the BUM modellers for which measures this option should be used and in which size.
(2) The investments are paid by foreign institutions. This option takes the internationalisation of the capital market into account. Since the international capital market is not modelled in ASTRA-D, this financing option reduces overall final

demand, but still has an effect on the intermediate deliveries. So additional investments are added in final use, but also subtracted in final demand (compare to figure 2).

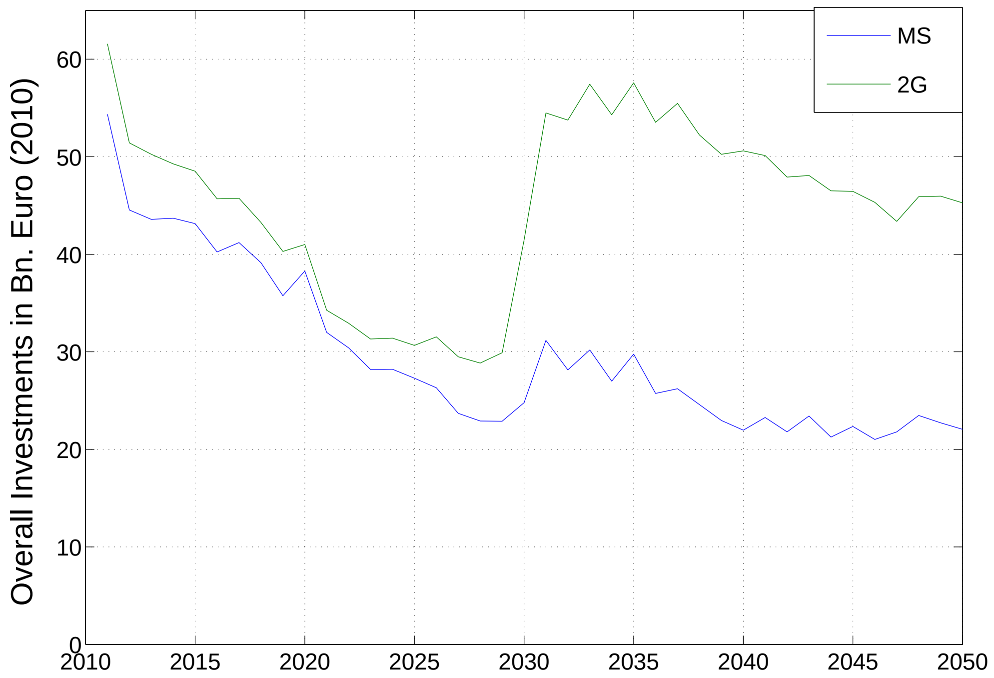
(3) The investments are paid by credit uptake or reduced earnings. While this option may seem reasonable for some of the investments in high profitable sectors, it is quite difficult to argue for that. As earnings are not explicitly modelled in ASTRA-D, using this option may be seen as “manna from heaven”. However, there might be still good reasons for using this option in the case where legal standards require investments in GHG emission reduction technologies and none of the three other options seems plausible.

(4) The investments are paid by energy savings or price increases. This option is the most widely used within all BUM impulses, but it is also the most problematical one. Usually it requires a set of accompanying assumptions either about the implicit internal rate of return (which may differ through the impulses and sectors) or the world-wide competitive position of the industry which determines whether it is possible to raise product prices or use some of their earnings.

The sum of all inputs from the BUM for the two scenarios (MS and 2G) formed then the impulses implemented in ASTRA-D and figure 4 shows the aggregate investment figures. Included in this figure are also all avoided investments, which are investments that are solely made in the base scenario and ceased to apply in the climate protection scenarios. One example for this is the investments in fossil energy production, which are prominent in the DS, but not in the MS, or especially in the 2G which is a 99% renewable scenario.

One can see in figure 4 quite a huge level of upfront investments. Those are, by a large part, influenced by investments in buildings. For achieving substantial emission reductions in 2050, one has to intervene in the renovation cycle, which determines the need for immediate activity. After 2030 the investments in industrial processes in the 2G are substantially higher than in the MS.

Figure 4: Aggregate investments from Bottom-up models in the two climate protection scenarios



Source: own illustration

However, investments are not the only inputs from the BUM. In figure 1 the implementation of BUM impulses to assess policy measures are shown schematically with green arrows. The inputs were thus implemented in ASTRA-D at different parts of the model:

(1) sectoral investments
(2) sectoral consumption
(3) government revenues and expenditures
(4) sectoral im- and exports
(5) intermediate inputs

While (1), (2) and (4) have their primary direct effects on Final Demand, (1) has two additional direct effects on Potential Output via productivity gains which are supposed to be induced by investments and the capital stock. (4) and (5) have indirect effects on gross value added, (5) also in addition on consumption. The effects on (3) are more interwoven and affect predominantly Final Demand.

Where the inputs of (1), (3) and (4) were taken as granted from the bottom-up models, the impulses of (2) and (5) were transformed to fractional changes to the development of the underlying base scenario. The reasoning behind this approach is that the amount of consumption per year is influenced by disposable income, which, on the other hand is influenced by GDP (see also figure 2). So second round effects are already in place and do not require further external appreciation.

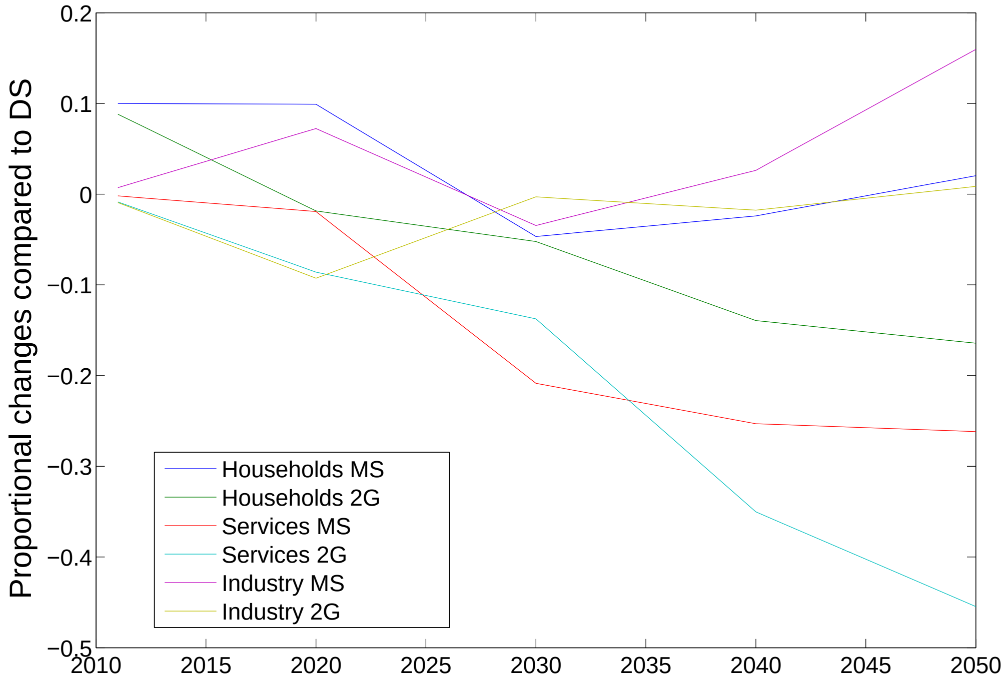
	2020	2030	2040	2050
	Proportional changes			
Agriculture	0.113	0.172	0.277	0.349
Food industry	-0.074	-0.159	-0.213	-0.275
Mechanical engineering	0.009	0.012	0.008	-0.003
Computer	0.072	0.089	0.064	-0.026
Electricity	0.004	0.005	0.003	-0.001
Communication	0.015	0.019	0.014	-0.006
Construction	-0.073	-0.007	0.055	0.024
Automotive trade	-0.061	-0.159	-0.237	-0.310
Wholesaling	0.015	0.017	0.011	-0.004
Retailing	0.006	0.007	0.005	-0.002
Ground transportation	-0.022	-0.011	-0.003	0.005
Shipping			-0.018	-0.034
Traffic services	0.003	0.003	0.002	0.002
Banking	0.001	-0.001	0.000	0.000
Insurance	-0.061	-0.159	-0.237	-0.310
Real estate	0.005		0.001	

Table 1: Consumption shifts in 2G scenario

Source: own calculations

Table 1 shows the aggregate sectoral consumption shifts for the 2G scenario. Results for MS are quite similar, besides changes are not as distinctive. Two remarkable changes are: firstly, motorised individual transport diminishes and therefore also the second-hand car market and services related to the industry, e.g. insurance. This consumption change is not totally compensated for public transport. Secondly, consumption of processed food, especially meat and dairy products, is lower than in the base scenario. However, people compensate for this by consuming more grain, corn, rape and potatoes. As a result, the food processing industry looses consumption shares while agriculture and forestry gain total wins.

Figure 5: Changes in energy expenditures



Source: own illustration

In figure 5 the energy expenditure changes for households, services and industry are plotted. The curves appear less smoothed since electricity prices from the BUM are only simulated for every ten years. Bigger differences between the two climate protection scenarios are to a large part caused by electricity price changes. Electricity in the MS becomes 7.3% more expensive in 2040 and 12.8% in 2050, whereas in the 2G it is 8.6% cheaper in 2040 and 30.8% cheaper in 2050, all compared to DS.

	2020	2030	2040	2050
	Mio € (2010)			
Subsidies MS	4,023	2,253	1,196	-3
Public revenue MS	341	1,057	1,962	2,828
Subsidies 2G	4,786	3,372	311	-378
Public revenue 2G	342	1,057	1,965	2,807

Table 2: Subsidies and public revenues in the climate protection scenarios

Source: own calculations

The changes in imports from the BUM only affected energy-related sectors. Imports of fossil fuels were notably lower in the climate protection scenarios. Furthermore, a change in sign of electricity exports was assumed: in the MS and 2G up to 15% of all electricity was imported. This result was an output of one of the BUM, which encompassed the electricity production of whole Europe.

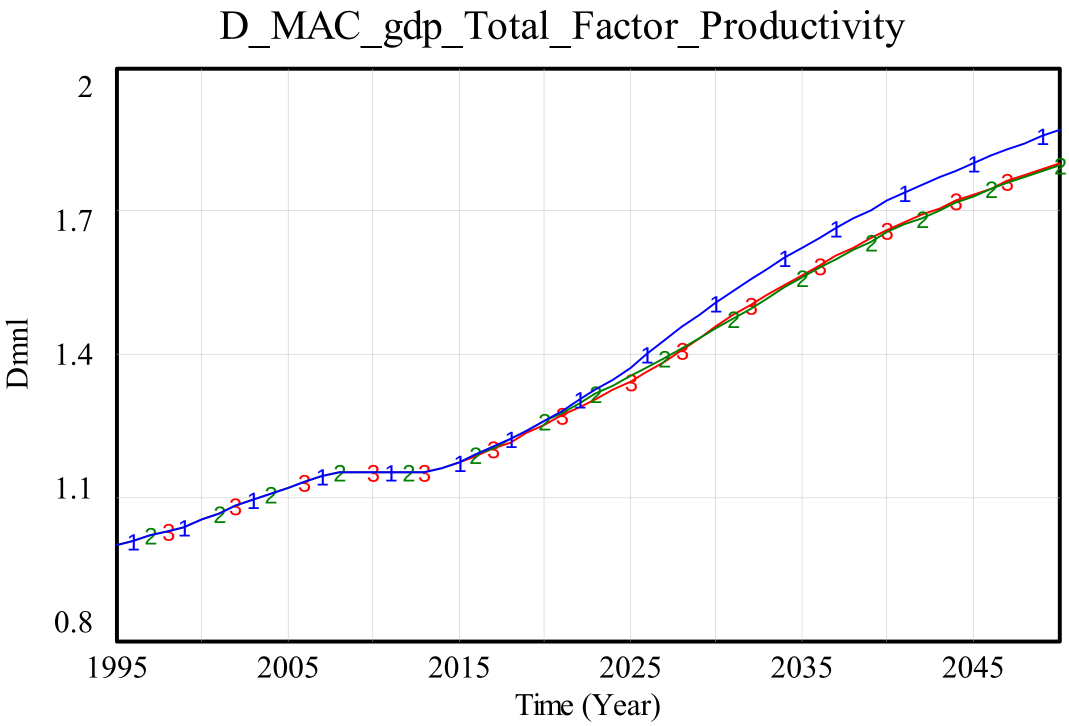
Finally, table 2 shows the changes for national budget in the climate protection scenarios. Subsidies for land use, land use change and forestry are substantially higher in the 2G in the first two decades. Basically these are compensatory payments for dispossessions of agricultural land, which is transformed into GHG emissions sinks. In the last two decades subsidies for improved insulations for real estate peak in the 2G between 2030 and 2040 (which is not shown in the table) and is more stable in the MS. Therefore, subsidies appear lower in the 2G.

------------ *Results*-------------

The input data as described in the section above were implemented in ASTRA-D. We decided to account for foreign investment financing and included a capital import share of 50% of all investments from the BUM. However, we did not assume comparative advantages of climate protection policies compared to the rest of the world. Such “first mover advantages”, which may arise from a country’s lead market and comparative technological capabilities (Walz and Schleich, 2009), can have a positive effect on exports, since the emergence of new technologies is more probable in environments with intensified research, which can be reflected by higher investments. Thus, we consider our assumptions being relatively moderate and taking only events with a higher probability into account.

Innovative effects of investments, on the other hand, are not totally neglected within the logic of ASTRA-D: higher productivity is an explicit model output. Investments in energy-saving technologies influence investment-induced technical progress, which is one part of the endogenous technical progress and total factor productivity. Regarding the supply side of the model a rise in investments leads both to a higher capital stock and a higher total factor productivity of the Cobb-Douglas production function.

Figure 6: Simulated total factor productivity for all three scenarios*

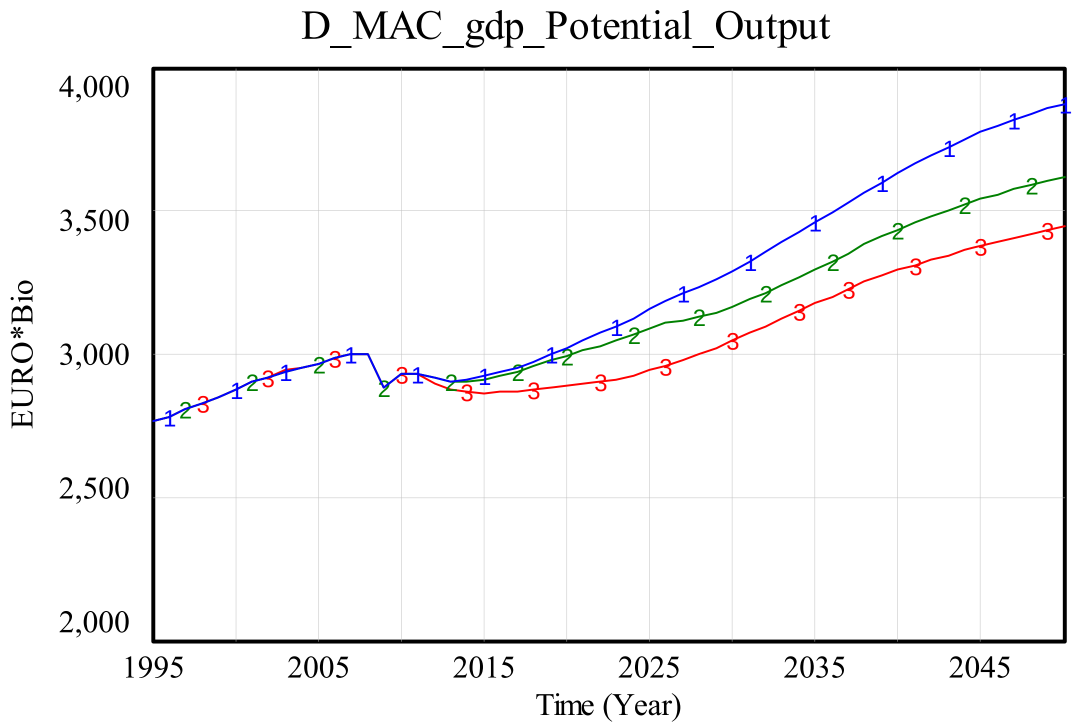


* Legend: -1- scenario 2G; -2- scenario MS; -3- scenario DS (base run)

Source: ASTRA-D

Figure 6 shows the simulated total factor productivity of all three scenarios. The effect of climate protection investments are, as expected, highest in the 2G. Between MS and DS there is not much of a difference; indeed, productivity gains in the MS are lower than in the DS. This is due to the fact that firstly not all investments have a substantial productivity effects (e.g. investments in the construction sector are somewhat negligible) and secondly labour productivity is lower in the MS as a result of shifts in sectoral consumption patterns towards sectors with lower labour productivity.

Figure 7: Simulated Potential Output for all three scenarios*

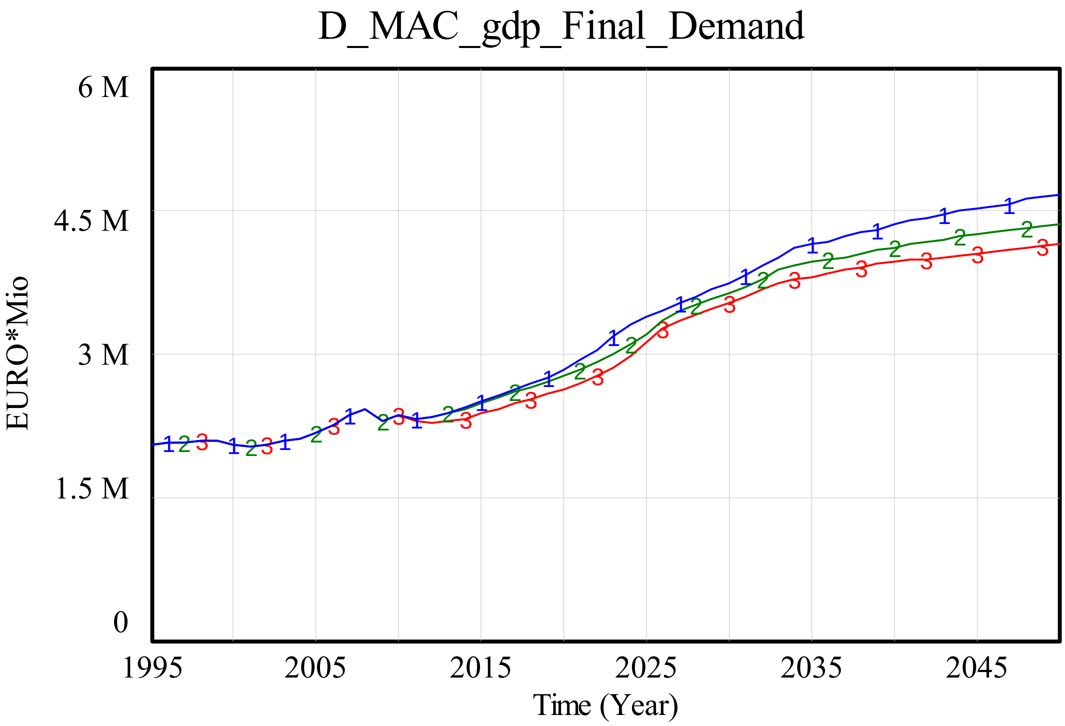


* Legend: -1- scenario 2G; -2- scenario MS; -3- scenario DS (base run)

Source: ASTRA-D

The results of the differences in capital stocks can be seen in figure 7. Here, the values for MS are much higher than in the DS. This variable is calculated with a Cobb-Douglas production function and forms the one pole of the GDP calculation (see also figure 2, where Potential Output reflects the supply side of the economy).

Figure 8: Simulated Final Demand for all three scenarios*



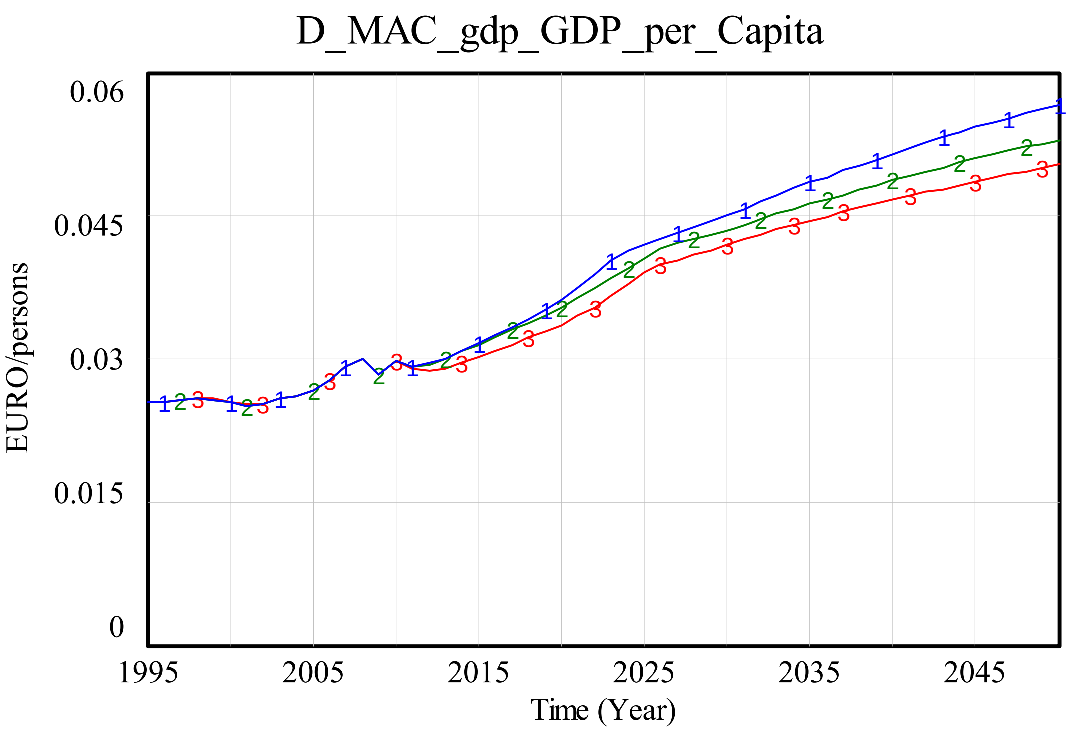
* Legend: -1- scenario 2G; -2- scenario MS; -3- scenario DS (base run)

Source: ASTRA-D

The demand side is composed of consumption, investments, government consumption and the trade balance. Simulation results are shown in figure 8. For past behaviour this variable is much smaller than Potential Output and GDP, since not all production capacities are in use. However, this situation changes in the course of the simulation towards nearly full employment of all production factors. Part of the reason for this is that population goes back from 80.6 m persons in 2010 to 74.0 m persons in 2050 and labour supply accordingly from 53.8 m in 2010 to 43.0 m in 2050.

As both components of GDP calculation are positive, GDP itself goes up, too, even measured in terms of GDP per capita as shown in figure 9.

Figure 9: Simulated GDP per capita for all three scenarios*



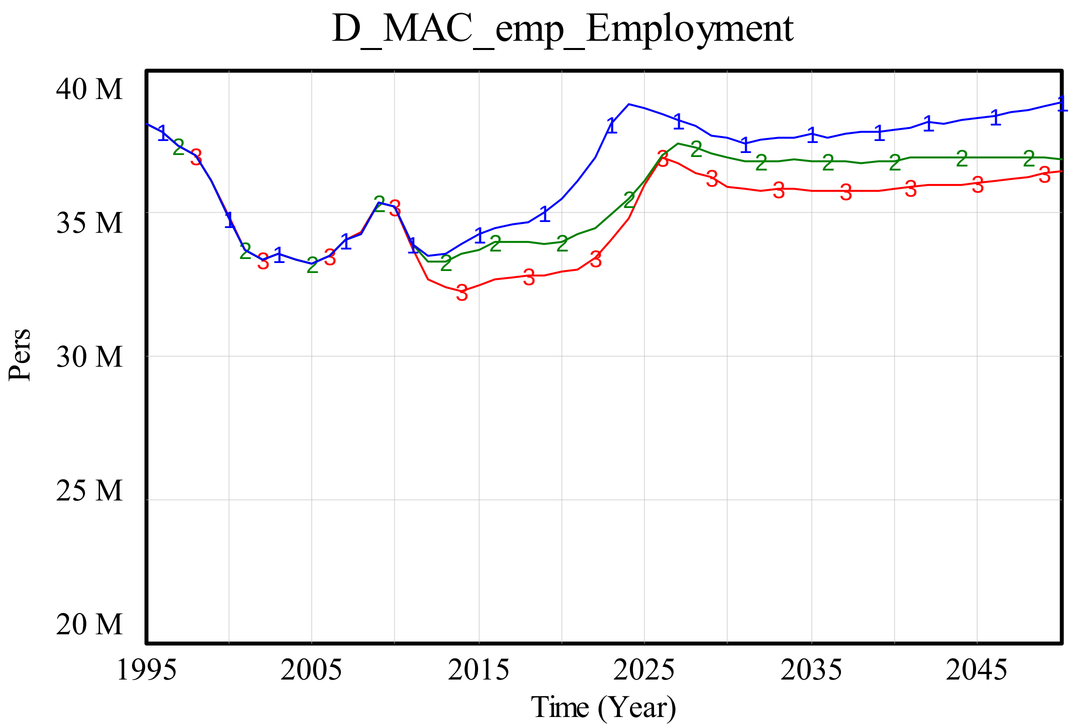
* Legend: -1- scenario 2G; -2- scenario MS; -3- scenario DS (base run)

Unit: Mio Euro per person

Source: ASTRA-D

Though GDP is positive in the climate protection scenarios, the results for employment are somewhat mixed. Figure 10 shows the results of overall employment, measured in fulltime equivalences. Here, the effects of sectoral shifts in the economy are more prominent: employment in 2G is well above DS, but in MS it is so only for parts of the simulation period, especially between 2010 and 2020, where there are the bulk of climate protection investments. Later on, the two curves converge.

Figure 10: Simulated overall employment for all three scenarios*

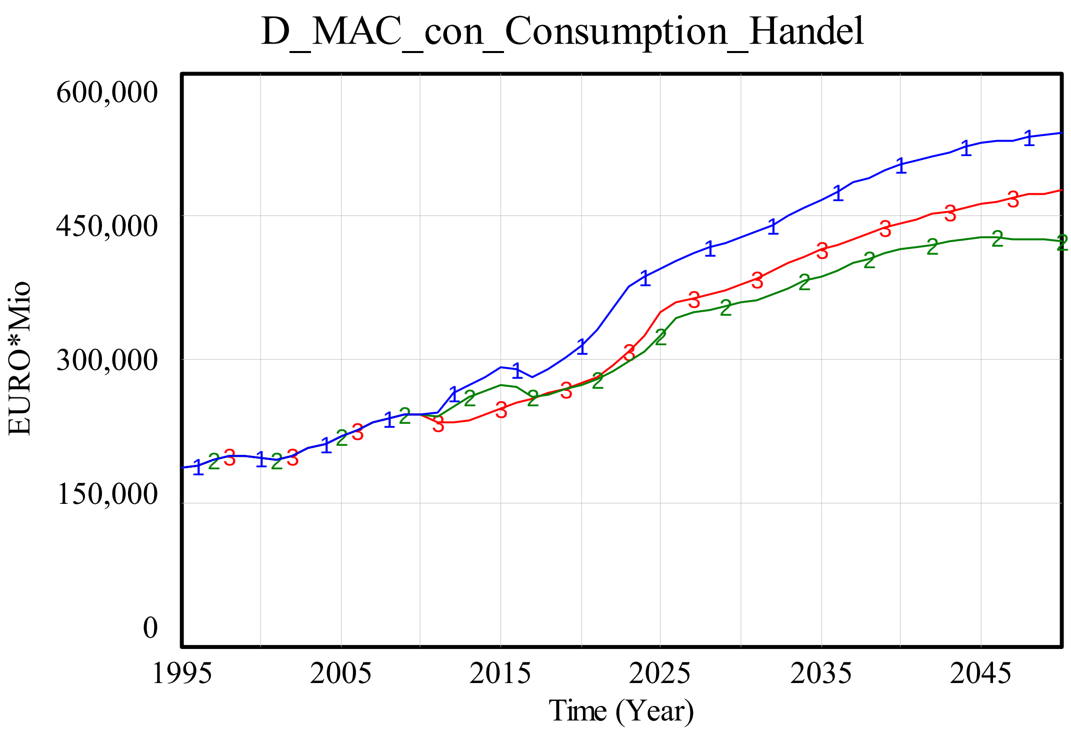


* Legend: -1- scenario 2G; -2- scenario MS; -3- scenario DS (base run)

Source: ASTRA-D

One of the reasons is shown by figure 11. Consumption of distributive trades, which is the aggregate of wholesaling, retailing and automotive trade, is lowest in MS. These sectors usually have a high employment per gross value added, which means that a lower demand for these sectors has a negative impact on employment figures.

Figure 11: Consumption of distributive trades for all three scenarios*

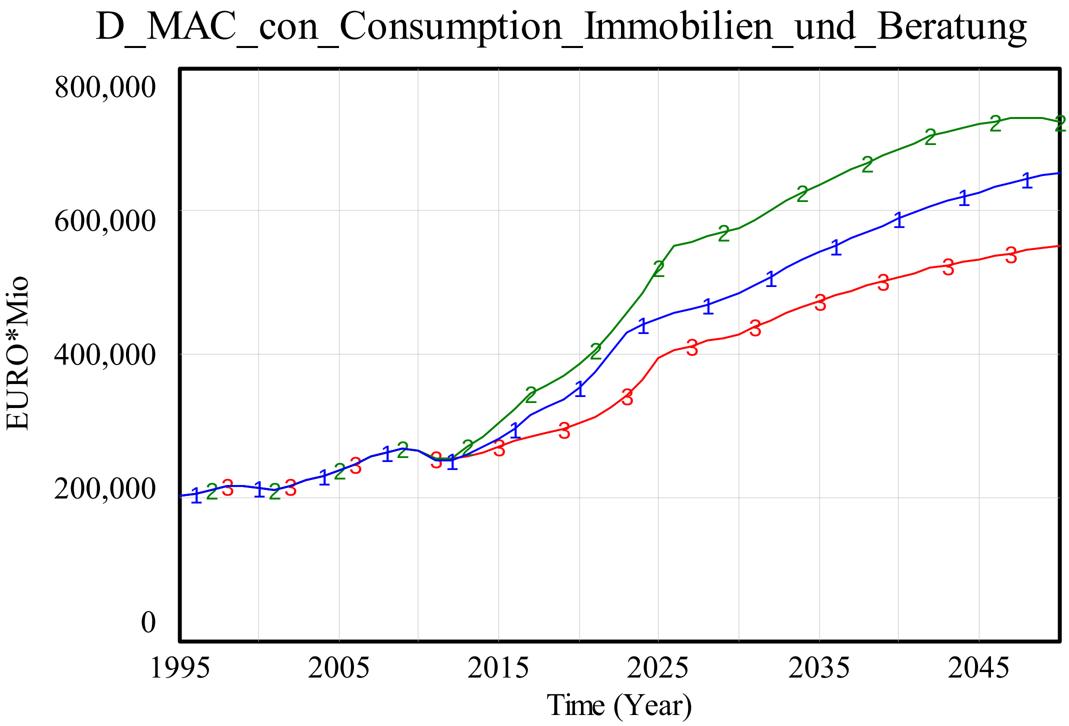


* Legend: -1- scenario 2G; -2- scenario MS; -3- scenario DS (base run)

Source: ASTRA-D

Consumption of sectors with a high labour productivity and thus lower labour demand is higher in the MS. Figure 12 is an example for this consumption shift. It shows the consumption of real estate and consulting, which includes also real estate-related services like rent and leasing, but also data processing services, research and development services and all services related to business like consulting or advisory (where the bulk of demand lies admittedly in investments and not consumption). For this aggregation level demand in MS is highest of all three scenarios, while and 2G is in the middle.

Figure 12: Consumption of real estate and consulting for all three scenarios*

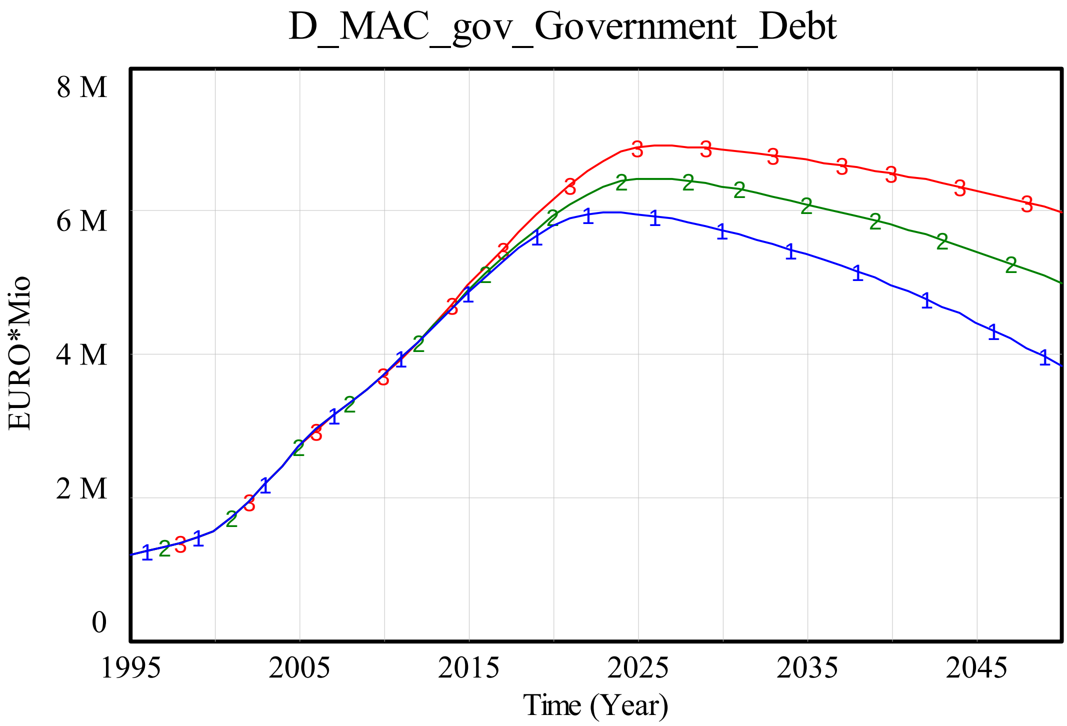


* Legend: -1- scenario 2G; -2- scenario MS; -3- scenario DS (base run)

Source: ASTRA-D

The effects of the changes stemming from the BUM on national budget can best be judged upon if one takes a look on the development of simulated government debt (figure 13). This variable includes all three sorts of debts: on municipal, regional and federal level. After 2020 the trajectories of the two climate protection scenarios outperforms the base run substantially. This happens despite the fact that in this period the inputs from table 2 indicate a greater burden for government spending; however, the positive impacts on GDP lead to higher tax incomes, which, in turn, are used for repayments. This assumption is a very conservative one, as a raise in government revenues could also be used to feed back into the economy (e.g. by lowering value added taxes and therewith inducing an extra positive impulse on consumption), but this helps to distinguish second round effects from the influences of the BUM impulses.

Figure 13: Simulated government debt for all three scenarios*



* Legend: -1- scenario 2G; -2- scenario MS; -3- scenario DS (base run)

Source: ASTRA-D

------------ ***Discussion*** -------------

ASTRA-D was initially designed to assess different transport strategies according to their impact on the economy. For this reason (as transport demand is a derived demand) a macroeconomic model was constructed with an input-output framework at its heart. Some of the shortcomings of a static input-output analysis were tackled by combining it with System Dynamics and making it dynamic. Final demand is due to this methodological combination not exogenous. The modelling logic, as presented by figure 2 and whose detailed implementation can be found in (Schade, 2005), is not restricted to analyses of the transportation system. For example, energy inputs can be treated much the same way as transportation – they have direct effects as consumption or investments alter, but also indirect effects as their inputs affect the production structure. Their inputs can – similar to transportation – not totally be substituted.

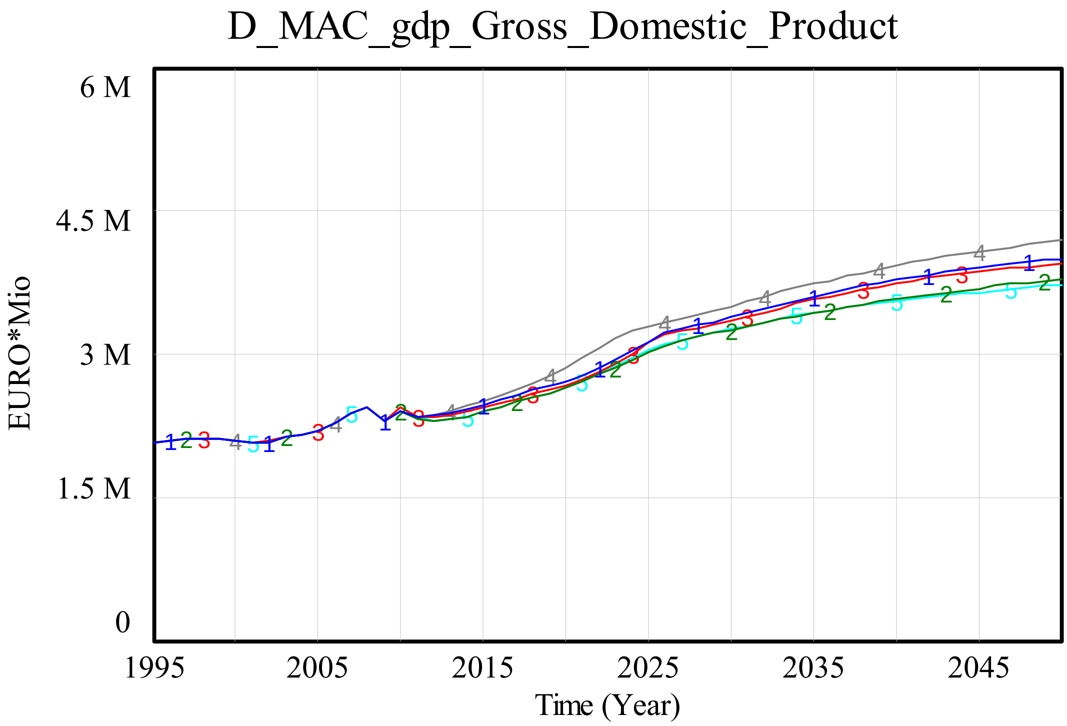
In this study we augmented the analysis of climate protection measures on all relevant economic sectors and assessed the economic outcome of two scenarios with different

GHG emission reduction goals for Germany. Though the ambitions of both scenarios differed, they had a similar implementation – effects on consumption and investments were thus not only triggered by different input values, but also by the inherent structure of the economy, represented by input-output tables.

For better being able to distinguish the separate effects of two of the factors derived from the BUM – consumption change and investments – and thereby being able to better understand the nature of the second round effect, we tried the following sensitivity tests with our model:

(1) Setting consumption exogenous. This means cutting the loop between GDP and consumption. We took the development of sectoral consumption from the base scenario (DS) and fed it back into the model. The other impulses remained the same; thus energy price and investment changes still had their impact on intermediate deliveries, investments still had an additional growth effect and so on.
(2) Leaving out investments. Here, all loops in the model were still active, but we did not consider any extra investments made. That means all changes in the economy were either due to changes in energy expenditures, shifts in sectoral consumptions or to import changes of fossil fuels.
(3) Leaving out consumption changes. In this sensitivity we did neither consider the external changes in consumption patterns from the BUM, nor the changes from energy consumption and price changes, nor the shifting of the price changes for the industry. All consumption shares are the same, compared to the DS, but the calculations allow for second round effects via the feedback loop from GDP to consumption.

Figure 14: Sensitivity tests of GDP for the 2G scenario*

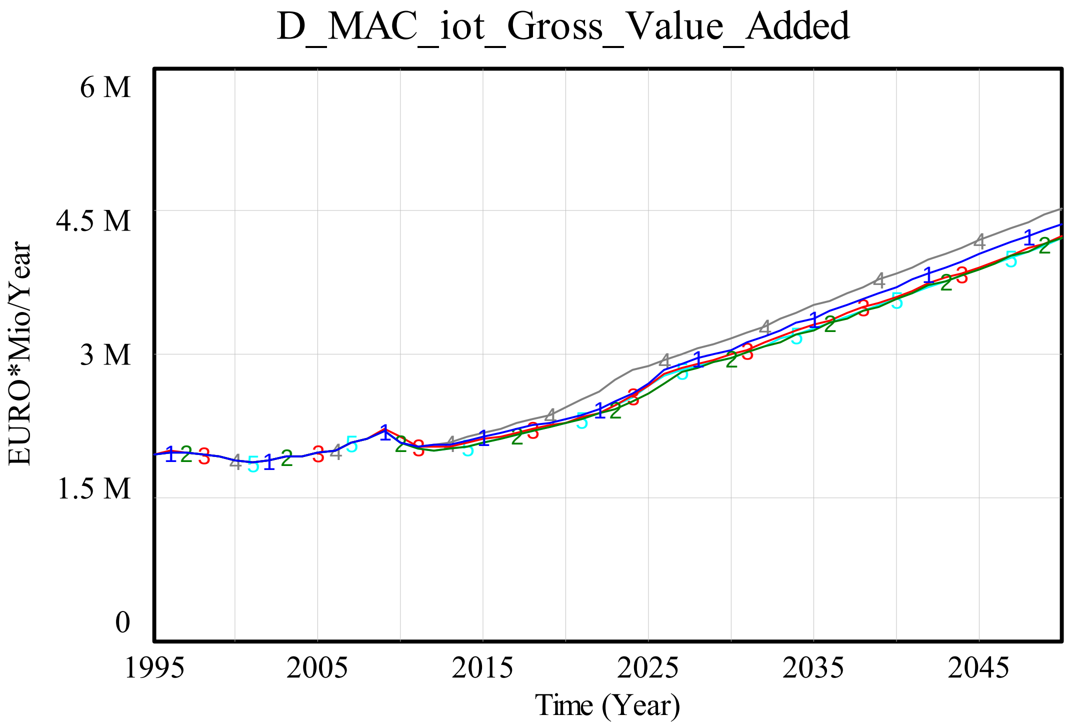


* Legend: -1- no consumption change (3); -2- no investments (2); -3- exogenous consumption (1); -4- 2G with all inputs; -5- scenario DS

Source: ASTRA-D

The results of those sensitivity tests with the BUM inputs from the 2G are shown in figure 14. Changes in GDP are, as expected, highest with all inputs active. All other sensitivities fall behind. Especially remarkable is run №°2: we find the differences between this run and the base run (DS) hardly detectible. There are few years when the sensitivity run is lower than DS, and only until the end of the simulation horizon this run slightly outperforms DS. This might be an indicator that the mechanisms that pass the changes from the input-output-tables to consumption changes – the way industry accounts for price changes of input factors and how these changes are burdened upon the consumer – are less developed in the model. This observation can best be supported by looking at the developments of gross value added in figure 15. Between 2022 and 2029 the trajectory of run №°2 is lowest. Only after then it converges to run №°5 (DS).

Figure 15: Sensitivity tests of Gross Value Added for the 2G scenario*

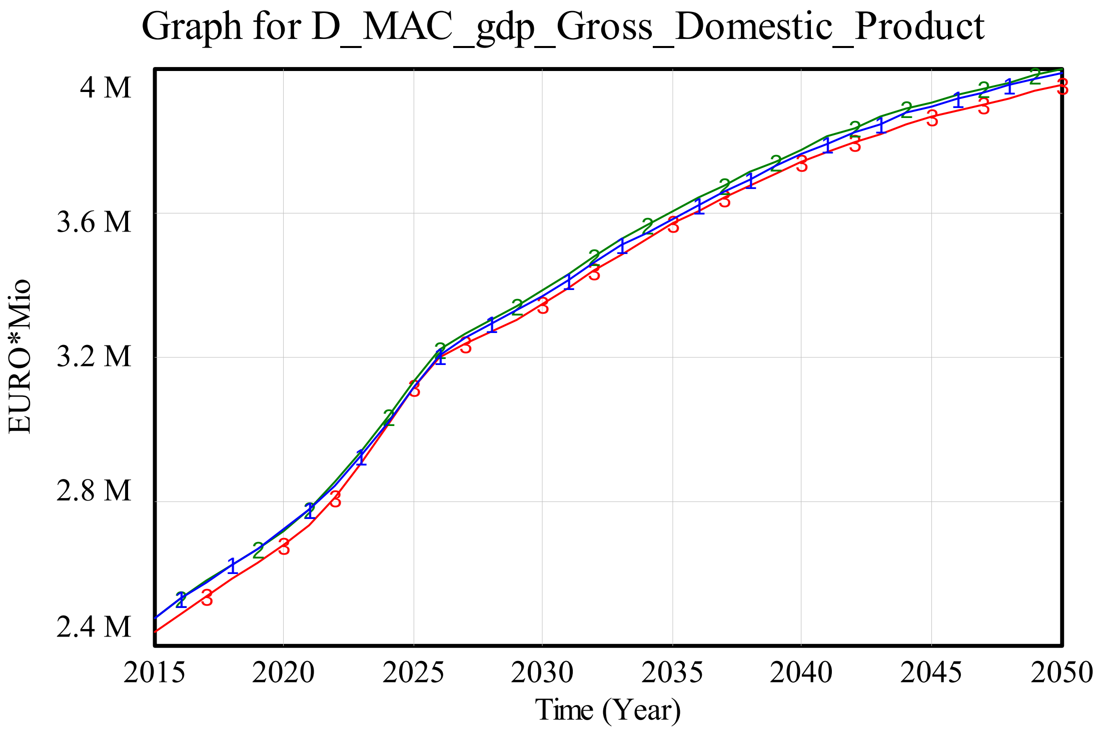


* Legend: -1- no consumption change (3); -2- no investments (2); -3- exogenous consumption (1); -4- 2G with all inputs; -5- scenario DS

Source: ASTRA-D

This view can further be supported by comparing run №°1 and 2 in figure 16: in run №°1 we switched off the price effects of higher product prices on consumption shares. This means that all changes in industrial and service production, which are affected by investment- or energy-induced price changes, absorb those changes on their intermediate deliveries and do not increase product prices for final consumption, only for investment goods. In fact, the difference between run №°1 and 2 are very marginal, so almost all differences between run №°1 and 3 in figure 14 are due to external changes in consumption preferences or patterns from the BUM and not from the influence producers exert on consumers.

Figure 16: Effect of sensitivity tests of different consumption influences on GDP*



* Legend: -1- 2G with no price effects on consumption; -2- 2G with no changes in consumption shares; -3- 2G with exogenous consumption from DS

Source: ASTRA-D

Another final remark on figure 15: It seems as if the impact of higher energy prices has an observable effect on industrial output, but at least with the means of a dynamical input-output table those effects are not that high since they are able to dampen economic growth.

------------ ***Summary***-------------

We analysed the impacts of two different climate protection scenarios on major economic indicators in Germany by collecting economic changes from detailed sectoral bottom-up models. We then combined them and transferred those changes into impulses which were suited for using them in ASTRA-D, a System Dynamics macroeconomic model of the German economy. We ran two simulations using the inputs of the bottom-up models and compared the outcome with a baseline scenario. We found positive macro-economic effects of ambitious climate policy on investments, consumption and GDP and mixed results for employment, which was the result of a different sectoral demand pattern triggered by the temporary or permanent increase of energy prices in the scenarios. This positive result of climate policy that stimulates investments is confirmed by other studies as well (e.g. Schade et al., 2009; Lehr et al., 2013).

Our analysis was able to show in which way the trajectory of economic development could develop, using a dynamical input-output table where final demand was endogenized. We discussed several sensitivity analyses revealing the magnitude of second round effects, which gives a hint on eventual rebound effects. We finally discussed some of the problems related to the effects of higher production prices and their shifting to the consumer. Further analyses should be made in order to reveal whether the level of aggregation, which is given by the classification of economic sectors of the underlying input-output table, is appropriate and whether the impulses provided by the BUMs to ASTRA-D are consistent and would not neglect any relevant impact.

This work is part of a project which extends over three years with a recurrent refinement each year. The presented results are those of the first year, so some of the above-mentioned improvements are currently implemented. Especially issues regarding the calculation of potential output are currently focussed by us. Some of these considerations are presented in another paper.

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