CECILIA 2050

OPTIMAL EU CLIMATE POLICY

Choosing Efficient Combinations of Policy Instruments for Low-carbon development and Innovation to Achieve Europe's 2050 climate targets

Impact of the current economic instruments on economic activity

Understanding the Existing Climate Policy Mix

Funded by the European Union

SEVENTH FRAMEWORK PROGRAMME

AUTHOR(S)

Mr Mark Meyer, GWS

Mr Bernd Meyer, GWS

With contributions by:

Martin Distelkamp

With thanks to:

Tomas Wyns, Director Center for Clean Air Policy (CCAP) Europe

Massimiliano Mazzanti, University of Ferrara

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LIST OF ABBREVIATIONS

CGE	Computable General Equilibrium
ETR	Environmental Tax Reform
ETS	European Trading System
GDP	Gross Domestic Product
WIOD	World Input Output Database
WP	Work Package

1 Executive summary

This study applies the global economic environmental model GINFORS to analyse the economy wide effects of current policy instrument mixes concerning **economic instruments**. GINFORS belongs to a class of models which is appropriately designed for this task.[1] The model has a deep country and sector structure depicting the international as well as the inter-sectoral interdependences with flexible price dependent structures. The relations between energy use, resource use and economic development are reported in deep sector detail, which allows for a realistic analysis of policy impacts. This ability is further underlined by the empirical evaluation of the model: GINFORS is an econometric model with parameters estimated over the period 1995 – 2009. This means that the theory behind the model has been evaluated and that only those equations enter the system, which pass statistical testing.

The selected method to identify the impacts of the present policy mix is a counterfactual simulation. First a baseline is calculated over the estimation period of the model including the current developments of the economic instruments of climate policy. The alternative solutions of the model have been created for the same period, but now climate policy instruments of the EU have been removed. A comparison between the results of the baseline and the alternative solutions gives all direct and indirect effects of the policy change for the 27 EU Member states.

We measure the impact of climate policy in a relative sense: How did policy change during our observation period (1995 – 2009) and which economic and environmental impacts followed from this? It was a period of climate policy innovations in Europe: Environmental tax reforms (ETR) have been created in some EU countries, the EU ETS established tradable emission rights and some European countries started to pay subsidies for the investment in renewable energies. Of course this also means that we do not analyse the impact of policies outside this period.

Three classes of economic instruments of climate policy can be observed: Taxes, tradable permits and subsidies. Three main assignments of these instruments have happened in Europe: Taxes as instruments of climate policy have been used in the EU primarily for energy goods demand, tradable permits concerning CO_2 emissions have been introduced for several sectors with the EU ETS, and subsidies have been installed primarily with the “feed in tariffs” and “green certificates” for the supply of renewable energies. Our simulations stick on these main assignments of the economic instruments in Europe. This means that other uses of economic instruments like subsidies for investments in the insulation of buildings are not in the focus of our analysis. Further CO2 taxes as production taxes are not under the scope of our study. This is not a problem since this instrument has been introduced outside our observation period in only some European countries (Ekins & Speck, 2011).

In a first alternative simulation we remove only the tax rates on energy goods use to the level of the beginning of our observation period including recycling of the tax revenue, in a second we analyse only the effects induced by the EU ETS. The third simulation gives only the impacts of the introduction of subsidies for the investment in renewable energies. Results

[1] For a detailed discussion of the methodology of the economic environmental ex-post analysis see Schumacher et al., 2012.

from the sector studies WP 2.1 (electricity supply) and WP 2.4 (food and agriculture) support the pure modelling exercise.

The paper starts (chapter 2) with a short introduction into the model GINFORS[3]. The historical simulation for the period 1998 – 2008 is presented in chapter 3. Pindyck & Rubinfeld, 1998, p. 383, characterize the historical simulation as the most powerful test for the evaluation of econometric models. Only the exogenous variables enter with their historical realizations the simulation, whereas all endogenous variables (including the lagged endogenous) enter with their calculated values. Since GINFORS has a very high degree of endogenization this is a challenge. The comparison between history and the simulated development of the economy and the environment answers the question whether the model is able to reproduce the economic and environmental development.
The historical simulation is further used as the baseline for the counterfactual simulation, which is presented in chapter 4. In all simulations the results are discussed for the main economic indicators like GDP and employment and central energy and emissions indicators. Further a sectoral perspective will be given for the total effect to show the winners and the losers of the current policy mix.

The first simulation analyses the impact of a reduction of the taxes on final energy demand. What would have happened, if the tax rates of 1998 would have **been frozen at the level of that year 1998** for the whole period till 2008? Purchaser's prices for energy would have been lower and the whole economy would have enjoyed lower prices inducing higher domestic and international demand and GDP. On the other side energy efficiency would have been lower which means higher imports of fossil fuels and less value added and GDP. A third effect concerns the public budget: Debt neutrality demands either higher taxation of different subjects or a reduction of public spending. In any case this effect would have been negative for economic development. Without a model simulation which quantifies the different counter effects the result on economic activity is unclear. We come to the following result: Environmental tax reforms sometimes pay a double dividend in terms of lower CO2 emissions and higher GDP and employment figures. Higher taxes on energy certainly reduce competitiveness, but the recycling of the tax revenues by the reduction of social security contributions or income taxes over compensates the negative effects on GDP. Our study shows that for most countries this compensation is given to a large extent, but not totally. The results are slight reductions of GDP combined with either slightly reduced or even rising employment. The latter effect is expectable, if the reduction of social security contributions is part of the tax recycling.

In the second simulation we ask what would have happened to the European economies, if the EU ETS would **not** have been installed. The direct effects are clear: The ETS sectors and their followers in the product chain would have had lower costs and lower prices which would have induced a higher domestic and international demand. On the other side energy efficiency of these sectors would have been lower and additionally the shares of fossil fuels and thus the imports of fossil fuels would have been higher which would have induced less value added and GDP. Our simulations show that in a world without ETS the effect on GDP induced by lower prices would not have been totally compensated by higher coal, gas and oil imports. So the clear rise of CO2 emissions would have been accompanied by a slight rise of GDP. This means that the introduction of the ETS brought a significant reduction of CO2 emissions, but also a slight reduction of competitiveness.

In the third alternative scenario we analyse the effect of the subsidies on green electricity supply and the general economic performance. What would have happened, if **no** guarantees for investment in renewable energies in form of the feed in tariffs or green certificates would have been given? The direct effects are clear: CO2 emissions and the imports of fossil fuels would have been higher and total macroeconomic investment demand and the supply of electricity production would have been lower. The purchaser's price of electricity would have been lower because the subsidies would not have to be paid by the demanders of electricity, on the other side the basic price of electricity would have been higher because the enlargement of the electricity supply would not have happened. The macroeconomic total effect is unclear. Our simulation results allow this assessment of the policy: The subsidies for investment in renewables have induced the strongest reductions of CO2 emissions of all instruments. Electricity prices have risen, but the effect on GDP and employment has been over compensated by rising investment demand, so that the effects on GDP and employment have been positive. Losers of this policy are the producers of electricity from fossil fuels and the deliverers of these carriers. All other sectors are winners.

Summarizing the following conclusions can be formulated: If the European countries **would not have had introduced** in the late 1990 and early 2000 years ETR's, the EU ETS and subsidies for renewables, the CO2 emissions of the member states would have been in the year 2008 up to 12% - 13% higher than historically observed. The concrete numbers differ between the countries due to their specific structures of production and the intensity of taxation of energy goods and the intensity of their promotion of investment in renewable energies. If these climate policy innovations would **not** have been installed in Europe, we would have had probably lower but certainly not higher figures for GDP and employment in most European countries. Exemptions may have been some smaller transition countries.

2 General Characteristics of the Model GINFORS

2.1 Methodological Annotations

From a methodological viewpoint GINFORS might be characterised as a dynamic Input-Output simulation model which is based on a comprehensive MRIO database. GINFORS evolved from the COMPASS model (see Meyer & Uno, 1999, or Uno, 2002, for references with regards to the COMPASS model) in the course of the MOSUS project.[2] As a global input-output simulation model, aims and scope of the GINFORS model are generally closely related to GTAP applications. However, whereas the later follows a standard Computable General Equilibrium (CGE) approach, GINFORS does not rely on long run equilibria of competitive markets or Say's law for a macroeconomic closure. Moreover, GINFORS assumes that agents have to make their decisions under conditions of bounded rationality on imperfect markets.
Yet, this section is not intended to echo relevant distinctive features with regards to CGE models. Interested readers are referred to Giljum et al., 2009, for a short comparison of

[2] The MOSUS project was funded by the Fifth Framework Programme (FP5) of the European Union. In this project GINFORS was used to simulate sustainability scenarios until 2020. See http://www.mosus.net/ for details.

COMPASS/GINFORS with GTAP or the related annotations of Wiedmann et al., 2007, in this regard. We would rather like to point out that the modelling of bounded rationality is not a straightforward task: Apparently, the models' reaction functions cannot be derived explicitly by applications of plain optimisation calculus. According to our view, an empirical analysis of historical developments therefore represents the natural starting point for model calibration. Economic theory provides competing behavioural hypotheses which, for each reaction function under consideration, are subject to statistical falsification tests. Accordingly, GINFORS is often also classified as an econometric model (see, e.g., Wiedmann et al., 2007).[3]
From this follows, that the availability of historical time series datasets constitutes a necessary condition for the implementation of our bounded rationality philosophy. Up to now, essential model building efforts therefore had to be devoted to the (more or less preparatory) compilation and maintenance of sufficient datasets. We do not intend to recapitulate individual challenges and possible shortcomings of this extensive and time consuming traditional practice but rather annotate that the GRAM-accounting method is basically rooted upon identical practice. Interested readers might therefore, e.g., look-up Wiebe et al., 2012, and their corresponding annotations with regards to the construction of their latest database. Apart from that, technical details of selective former GINFORS implementations were, e.g., also documented by Meyer et al., 2007, or Barker et al., 2011.
But when we started our latest revision model, this situation had changed tremendously. Hence, the empirical backbone of $GINFORS_3$ is now given by the fully harmonized annual set of national Supply and Use Tables (SUTs) as outlined by Dietzenbacher et al., 2013. The WIOD (World Input Output Data Base) contains these time series and further a consistent set of environmental time series data including energy demand and supply and emissions documented by Timmer, 2012.
Having completed this set of bottom up information with population and SNA datasets of the UN Statics Division as well as financial data of the International Monetary Fund, our model now enables us to simulate global developments until the year 2050, especially with regards to:

- the evolution of 35 industries in 38 national economies and a Rest of World region,
- international patterns of trade for 59 products,
- the resulting effects on main economic aggregates of national economies (e.g., public debt or disposable income of private households),
- emissions stemming from 28 energy carriers
- and global resource demand (incl. water demand and agricultural land use).

This list already reflects that GINFORS features a high degree of endogeneity. Actually, only national population growth rates as well as world market basic prices for fossil fuels and minerals have to be determined exogenously. The computational implementation is then based on an iterative solve algorithm. However, as we rather prefer to provide our readers

[3] This paper should not be occupied by lengthy taxonomic discussions. Thus, we will retain to this well established label. But for being precise, we like to annotate that other research disciplines would most likely prefer a distinction between econometric textbook models, and (i.a.) models of the INFORUM type as suggested by Almon, 1991. Actually, GINFORS accrued from the INFORUM philosophy which is characterized by a comprehensive mapping of variable Input Output Coefficients by means of econometric regression techniques.

with an adequate representation of the contents of $GINFORS_3$, a detailed discussion of the underlying C++ environment is omitted.

2.2 The General Structure of GINFORS

From a logical perspective, four interdependently linked modules can be distinguished: The economy module, the bilateral trade module, the energy-emissions module and the resource use module. The following paragraphs provide introductory insights into the respective modelling approaches. Please note that summary information with regards to country coverage, underlying classification schemes and the full set of endogenised environmental pressure variables have also been tabulated in the appendix of this paper.

2.2.1 The economy module

For 38 national economies and a Rest of World region the economic relationships are modelled by individual **economy modules** with market clearing mechanisms. Suppliers set mark-up prices with regards to local currency denominated unit costs and demanders take these prices as one determinant of their decisions. Suppliers produce the demanded volumes. This structure ensures a balanced influence of supply and demand on the solution of the model avoiding the supply dominance of neoclassical modelling. All macro variables like GDP and its components as well as aggregate price indices or employment are calculated by explicit aggregation from the sectoral variables. In this sense the model has a bottom up structure as outlined below.

As regards the **supply side,** the following modelling scheme applies for any of the 35 industries of a given national economy:[4] The 35 industries are an aggregation of 59 product groups. The aggregation scheme is variable and defined by a time series of so called supply matrices. Input Coefficients for intermediate inputs are modelled as price dependent variables. In the case of energy inputs these coefficients are driven by the inputs of related energy carriers (which are predetermined in physical units by the energy module). The capital stock is calculated from gross investment and the depreciation rate by definition. Gross investment is explained by gross production and the interest rate. Labour input in hours depends on gross production and sectorial real wage rates which are influenced by an average macroeconomic wage rate (Phillips curve approach). Compensation of employees is given by definition; the number of persons engaged can be derived from the average working time per person and the employment in hours. Unit costs are given by definition. Basic prices for sectors agriculture as well as mining and quarrying are calculated by definition from the aggregation of 8 exogenous product prices for fossil fuels, minerals and agricultural products. For all other 33 industry prices, unit costs and prices of competing import goods represent the relevant drivers. Domestic prices for 51 product groups are disaggregated from the industry prices via the make matrix. Basic prices for the 59 product groups are defined as weighted averages of import prices and domestic prices. Purchasers' prices for the 59 product groups are derived from basic prices adding tax rates and transport and trade margins. For all 35 industries value added can be calculated subtracting the sum of intermediate inputs from gross production. For 59 product groups total use is defined as the sum of intermediate and final demand. Import shares are depending from the relation of the import price and the basic price. Gross output for the 59 product groups can be calculated

[4] The Rest of World region is exhibits a slightly less complex modelling scheme.

subtracting imports from total use. The imports in local currency are converted into dollars and given to the bilateral trade model.

With regards to the **demand side,** the following impacts are explicitly captured by our modelling scheme: Intermediate demand of 59 product groups for 35 industries is implicitly given by the inputs of intermediate demand in the 35 industries. Final demand for each of the 59 product groups is sub-divided to private consumption, public consumption, gross fixed capital formation, inventory investments and exports. For each product group of private consumption real consumption per capita is explained by real disposable income per capita and relative prices. Special attention is given to private mobility in relation to mobility services, which are separated for land, water and air traffic. Energy product groups are explained in the energy module. Water demand is driven by physical water demand estimated in the resource use module. Real public consumption per capita is explained by the real sum of disposable income and net lending of the government and by relative prices of the product group. Gross fixed capital formation for 59 product groups can be calculated using the vector of gross fixed capital formation for 35 industries (see above) and a capital transformation matrix. Inventory investment is estimated by the change of gross output of the 59 product groups. Exports are given by the bilateral trade module (see above).

The internally consistent bottom-up presentation of the flows of goods and services within the economy as well as the use of primary inputs within the production process inside the Input-Output system is completely embedded in the sequence of national accounts and balancing items for the institutional sectors for 36 countries in units of local currency. Missing countries are Malta, Turkey and Rest of the World. This second major internally consistent national accounts data set provides a synthesis of the entire institutional sector accounts and it shows the amounts of uses and resources of each institutional sector for all transactions and thus providing figures with regard to the extremely policy relevant variables like disposable income of households, net lending / net borrowing of general government, which directly affects national debt. The following section 3 explains this key feature in more detail.

2.2.2 The bilateral trade module

The **bilateral trade module** takes for 59 product groups the export prices and the import values from the country models and converts them from local currency into dollars. For each product group the shares of the exports from the delivering countries into the imports of the receiving country are depending from the relation between the export price and the aggregated import price for that product in the receiving country. Multiplying the trade shares with imports and summing up over importing countries gives the exports by definition. The import prices are calculated as a weighted average of export prices with the trade shares as weights.

2.2.3 The energy and emissions module

For each country the demand of 35 industries and private households for 28 energy carriers in physical terms (TJ) is explained by the **energy and emissions module**. In a first stage total energy demand of an industry is explained by gross production of the sector and the aggregated energy price in relation to the basic price of the industry. In the second stage the shares of the different carriers in total energy demand are determined by the relation of the price of the carrier in relation to the aggregated energy price of the industry. Energy demand for private households is in the first stage separated for the three purposes heating and cooling, mobility and household appliances. The energy intensity for heating and cooling is defined as the gross energy use per real capital stock of the real estate services industry. It´s evolvement is tested for dependency on relative price developments and time trends. Multiplication of the energy intensity with the real capital stock gives energy demand. Energy for mobility is explained by real disposable income of private households and the relation between the aggregated energy mobility price and the aggregated price for mobility services. Energy demand for household appliances depends from real disposable income and the relation between the household's electricity price and the price for aggregated private consumption. In the second stage in each purpose the relative prices of the energy carriers determine the structure of demand. At his point, energy demand and it´s structure have been determined for private households and all 35 industries except the electricity supply industry. Therefore, the structure of electricity and heat production has to be explained in a subsequent step. The corresponding calculations feature an explicit distinction between energy generated by renewable technologies and energy generated by nuclear energy plants. For seven renewable technologies the decision to install new capacities is modelled in dependency from investment and operating & maintenance costs, feed-in tariffs, the carbon price and market prices for electricity and heat. Installation as well as permanent shut-down of nuclear capacities is treated as an exogenous policy variable. Given these installations, the total amount of electricity and heat that has to be produced from conventional (fossil) energy carriers can then be calculated straightforwardly with allowances for efficiency and the conversion losses. The structure of energy carriers within this are again determined by relative prices.

Energy demand in physical terms feeds back into the economic module as has been shown for intermediate and final demand. The gross energy used is transformed into CO_2-emissions for 35 industries (and private households) and 14 energy carriers assuming constant emission factors as well as constant relations between gross energy uses and emission relevant energy uses. Last but not least the module explains the emissions for 7 further air pollutants (N2O, NOx, SOx, NMVOC, NH3, CH4) in 35 industries and private households using the information from the energy use side as well as from the economy and the resource use module.

2.2.4 The resource use module

For each country the **resource use module** explains material extractions for 12 kinds of material in tons, agricultural land use for four types in hectares and freshwater abstraction in cubic meter. The general approach for the modelling of the extraction of materials is that first an intensity in relation to an economic driver in local currency and constant prices is defined, which can be observed historically. In the forecast the multiplication of this driver with its corresponding trend dependent intensity gives the extraction in physical terms. Due to the global coverage of GINFORS_3 it is possible to calculate not only the domestic part of the resource use indicators but also the indirect uses due to imports of semi-finished and finished products. The general approach for the modelling of agricultural land use is that a land coefficient in hectare per ton of biomass links land use to agricultural production. For each of the 38 countries and rest of world freshwater abstraction is determined for the public water supply sector, the manufacturing industries and the electricity supply sector (cooling only).

3 The historical simulation

3.1 Some technical remarks

Three methodological questions have to be answered before the results of the historical simulation can be discussed: The first is whether there are reasons to exogenize some of the endogenous variables. The second is, on which variables we should focus our attentions, the third is how to evaluate observed deviations between historical and simulated values.

3.1.1 The exogenous variables

In the short run financial intermediaries like banks, insurance companies and other institutions of the finance markets and the monetary authorities have severe influence on the transformation of savings into investment, which heavily varies due to changes in expectations and other speculative movements as the recent financial crisis has shown. GINFORS is a long run model describing the real part of the economy and its relations to the environment. Of course investment is a central variable in that context, but its long run dynamics should be governed by determinants like capital stock needs to close the gap between supply and demand of the sector in question. During our observation period there has been first an exogenous shock in 2001 and then in the following years an overinvestment induced by financial instabilities and then the correction in a breakdown in 2008/2009. This development cannot be depicted by a long run modelling approach. If we would have tried this, we would have had to endogenize financial instabilities up to 2050. For the purpose of an appropriate model evaluation we should exogenize in the historical simulation the vector of gross fixed capital formation in local currency and constant prices for all countries and sectors.

During the observation period the exchange rates between the currencies have been influenced strongly by financial markets developments. Here the same arguments for exogenization are given as in the case of gross fixed investment.

All public activities like individual tax rates and government spending should be also set exogenous, because these variables are typical scenario variables concerning the assumed behaviour of the government.

Finally, demand developments in the Rest of World area as well as the implied trade in services patterns have been exogenized.

Since the production of electricity by nuclear power is strongly depending from policy decisions the input of this energy is exogenous in the model GINFORS. Insofar we have to deal with this variable in the same way in the counterfactual simulation.

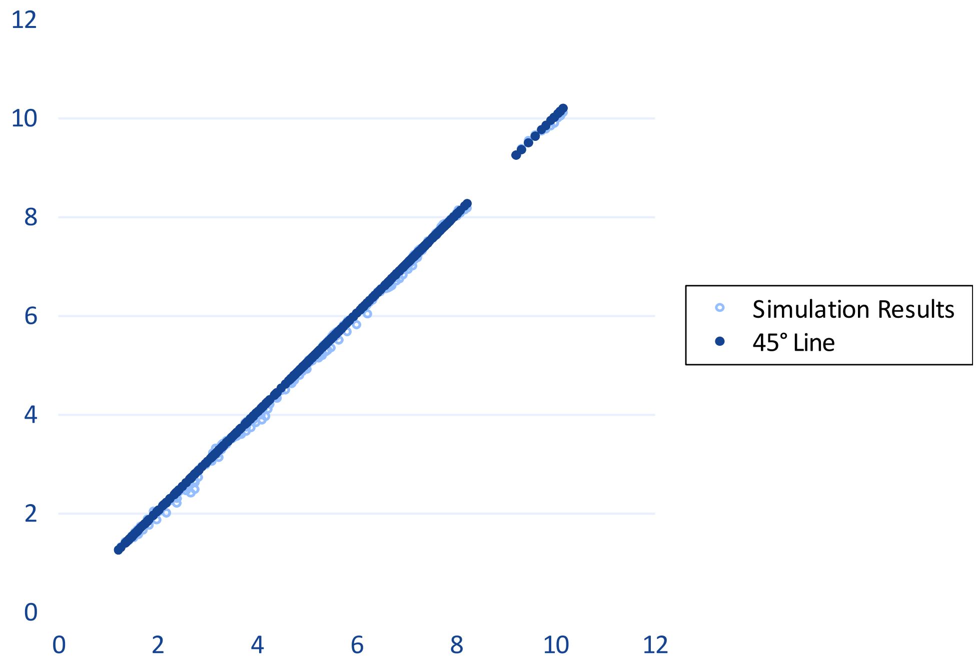
3.1.2 Which variables?

As already mentioned GINFORS has about 1.6 million variables. So the full picture of looking at each of them is not possible. To avoid getting lost in details we should concentrate on macro variables for the 27 EU countries which are in the focus of the counterfactual simulations. The variables should be the main indicators for economic and social development and climate impacts: We choose GDP in local currency, employment in 1000 people and CO_2 emissions in tonnes.

3.1.3 How to evaluate observed deviations?

This deliverable is not intended to provide a methodological review of well-established forecasts evaluation metrics (see, e.g., Diebold, 1998, in this regard). Moreover, we have to point out that the setup of our ex post simulation study inhibits an analysis of more than 11 realisations per series. As a matter of fact, most applications of sophisticated statistical testing procedures might therefore generate more or less ambiguous results only. We thus decided to consider a selective choice of generally accepted test statistics which might hopefully be able to provide basic hints towards potential model-miss-specifications. In this regard, Figure 1 exemplarily illustrates the task of judging the findings of our historical simulation.

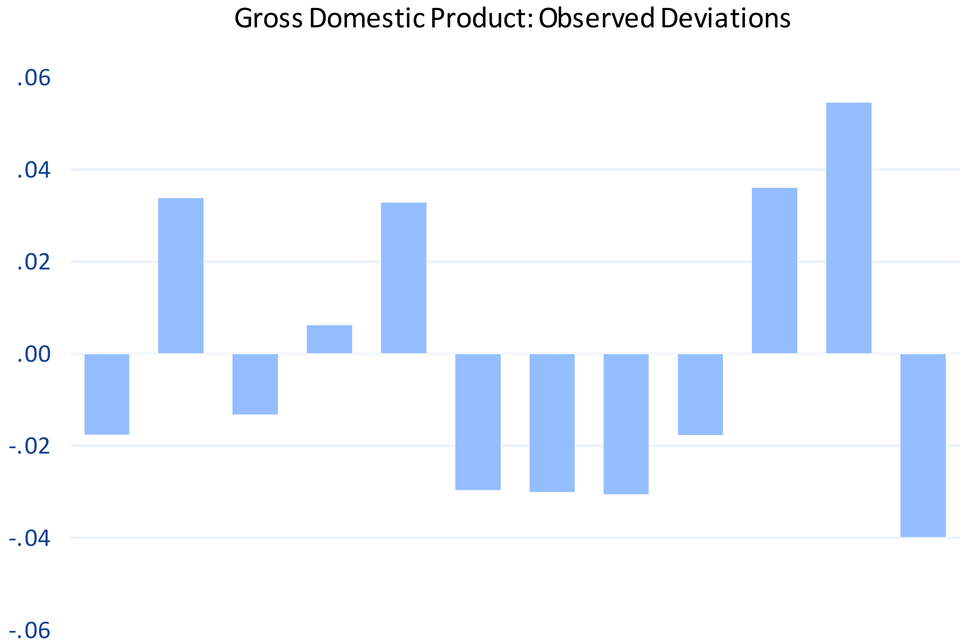
Figure 1: Gross Domestic Product - GINFORS Simulation Results for EU27 Member States 1998 - 2008



The historical simulation run starts in 1998 and ends in 2008. Thus, the model generates eleven time series observations for each endogenous variable. Figure 1 assembles the subset of resulting nominal GDP outcomes for 27 Member States: Shown are 297 (i.e., 11 annual values per Member State) combinations of historically observed logged GDP values (abscissa) and simulated logged GDP values (ordinate). Dark bullets mark the 45° line. Hence, if each simulated value (represented by light blue bullets) had exactly reproduced its corresponding historical value, all light bullets would be exactly located on this line. Of course, this is not observed. Nevertheless, apparently all simulated values seem to be placed reasonably close to the 45° line.

Figure 2 confirms this first impression. Shown are differences between logged model results for the year 2008 and corresponding logged historical GDP values in Austria, Belgium, Finland, France, Germany, Italy, Netherlands, Portugal, Spain, Denmark, Sweden and the UK. Figuratively, this graph therefore enables us to expose the distance between selected light bulks of Figure 1 and the 45° line. Given that individual simulation errors tend to accumulate over the entire simulation period, these findings are, at least, encouraging: In the end, even the observed over-estimation of Swedish GDP (according to the next-to-last bar of Figure 2, GINFORS over-estimates the year 2008 value of Swedish GDP by about 5%) might therefore be matched by an annual over-estimation of Swedish GDP growth rates by less than half a percentage point.

Figure 2: Gross Domestic Product - Deviations of Logged Series for Selected Member States in 2008



However, our previous introductory annotations also indicate that a visual inspection of selected Member State results will hardly emerge to an overall assessment of the simulation properties of the GINFORS model. We therefore decided to report the following test statistics for the observed outcomes of GDP, employment and CO_2 emissions in any Member State:[5]
For any historical time series value X_t and its corresponding model projection P_t, the observed simulation error at time t, e_t can be defined as

$$e_t = P_t - X_t \ .$$

Letting T denote the sample range, the Mean Squared Error (MSE) can then be defined as:

$$MSE = \frac{1}{T}\sum_{t=1}^{T} e_t^2 \ .$$

This metric circumvents any balancing effects between negative and positive simulation errors. Yet, an apparent drawback is given by the fact that squared simulations errors do not feature the same dimension as the underlying time series. Therefore, MSE-metrics have to be compared to historically observed time series variances. However, a somewhat more intuitive metric is given by RMSE which is defined as follows:

$$RMSE = \sqrt{MSE} \ .$$

[5] To avoid any distortions due to instationary time series properties, the following calculations have generally been based on first differences of logged level series.

RMSE-figures feature the same dimension as the underlying time series and might therefore be straightforwardly compared to historically observed time series standard deviations. Letting σ_X denote the historically observed sample standard deviation of time series X, our results tables thus always report a RMSE-Ratio, defined as:

$$RMSE\ Ratio = {}^{RMSE}/_{\sigma_X}\ .$$

Appart from these descriptive statistics, a simple test for the overall unbiasedness and efficiency of a given projection P can be based on a regression setup as follows (see, e.g., Granger & Newbold, 1973, in this regard):

$$P_t = \beta_0 + \beta_1 X_t + \varepsilon_t\ ,$$

Obviously, unbiased projections have to meet the restriction $\beta_0 = 0$. With $\beta_1 = 1$, this equation then represents an "ideal" simulation where observed simulation errors are only due to random stochastic error terms, i.e.: $e_t = \varepsilon_t$. Thus, an F-Test of the joint hypothesis $H_0: \beta_0 = 0\ , \beta_1 = 0$ provides hints towards significant simulation deviations.

Our results tables therefore represent these F-Statistics together with their corresponding significance levels for any time series projection under inspection. Accordingly, the last column of Table 1 indicates weak simulation properties for the DGP series of Cyprus, Greece, Ireland, Slovak Republic, Slovenia, Latvia, Lithuania, Poland and the United Kingdom.
In the case of Cyprus, this might be attributed to the distinctive features of a small economy where isolated shocks have the potential to induce very volatile macroeconomic reactions. See also the RMSE-Ratio above 1 in this regard, which indicates that the simulated GDP-series exhibits a higher volatility than historically observed.
With regards to Greece and Ireland we might assume that exceptional pre-crisis expansion phases cannot be reproduced by the GINFORS model. See, e.g., also the upper-left time series plot of Figure 3 in this regard. Apparently, the surging 2000-2005 period is not mapped by the GINFORS simulation. Nevertheless, until 2008, the observed gap between simulated series and historical developments narrows significantly. Reminding our readers of the underlying long run modelling philosophy of the GINFORS model, which is not intended to capture short to medium term business cycle developments by definition, we therefore do not think that Figure 3 documents unacceptable ex post simulation results in this regard.
Similar arguments hold in case of the UK. Indeed, the upper-right time series plots of Figure 3 indicate strong pre-crisis UK economic growth, which consecutively exceeds the simulated GDP series. Hence, the F-Test strongly rejects the null hypothesis of an "ideal" projection. Nevertheless, also in this case the gap between simulated series and historical observations again narrows at the end of our simulation sample. Thus, whereas we would have liked to observe a better fit between historical and simulated GDP series, we cannot identify any indications of severe model miss-specifications in the UK case.

Finally, the lower panels of Figure 3 exemplify the challenges of modelling economies in transition. In Latvia as well as in Lithuania we observe a very strong nominal GDP growth, which is accompanied by relatively high inflation rates.[6]
Apparently, as GINFORS has been calibrated to provide reliable long-run projections up to the year 2050, historically observed features of economies in transition cannot be captured very

[6] For giving an example: The implied GDP-Deflator of Latvia historically rose about 2.5 times faster than the German GDP-Deflator over the 1995-2009 period.

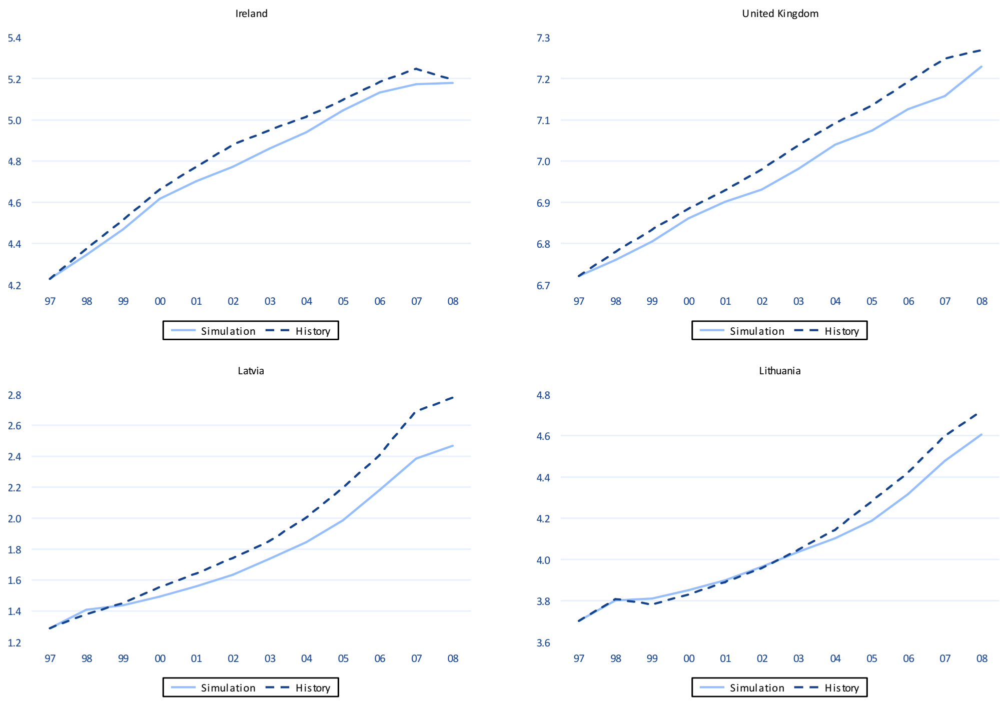
well by this modelling approach. Nevertheless, whereas these unique findings might appear unfortunate, we rather prefer to refrain from any attempts to "over-fit" these observation. The subsequent subsection briefly documents the related findings with regards to employment and CO_2 emissions.

Table 1: Gross Domestic Product - Evaluation Statistics for First Differences of Logged Series

Country	Variance	MSE	StdDev	RMSE-Ratio	F-Stat
AUT	1.28	1.38	1.13	1.04	0.99
BEL	1.07	1.17	1.03	1.05	0.41
CYP	2.29	6.25	1.51	1.65	10.37***
EST	23.42	32.53	4.84	1.18	0.92
FIN	5.25	2.12	2.29	0.63	0.12
FRA	0.73	2.17	0.85	1.73	1.62
DEU	1.38	1.57	1.17	1.07	0.27
GRC	2.57	5.87	1.60	1.51	3.30*
IRL	31.91	7.47	5.65	0.48	6.84**
ITA	1.17	0.81	1.08	0.83	0.45
LUX	10.10	40.89	3.18	2.01	0.26
MLT	7.25	2.98	2.69	0.64	1.15
NLD	2.82	1.66	1.68	0.77	0.21
PRT	4.85	2.56	2.20	0.73	0.52
SVK	1.64	16.26	1.28	3.15	3.81*
SVN	3.79	3.12	1.95	0.91	3.50*
ESP	1.81	1.98	1.35	1.04	0.90
BGR	25.84	16.28	5.08	0.79	1.86
CZE	3.36	5.79	1.83	1.31	2.62
DNK	1.84	4.60	1.36	1.58	0.96
HUN	14.19	7.62	3.77	0.73	0.43
LVA	43.93	15.32	6.63	0.59	9.39***
LTU	29.92	5.32	5.47	0.42	4.62**
POL	12.45	5.33	3.53	0.65	3.55*
ROU	85.20	15.07	9.23	0.42	1.81
SWE	1.29	4.15	1.14	1.79	0.67
GBR	1.25	3.96	1.12	1.78	10.82***

F-Stat significance levels indicated by asterisks:
* significance at the 0.1 level, ** significance at the 0.05 level, *** significance at the 0.01 level.
Source: own calculations

Figure 3: Gross Domestic Product - Time Series Plots of Selected Logged Series



3.2 Further historical simulation results

Figure 4: Employment - GINFORS Simulation Results for EU27 Member States 1998 - 2008

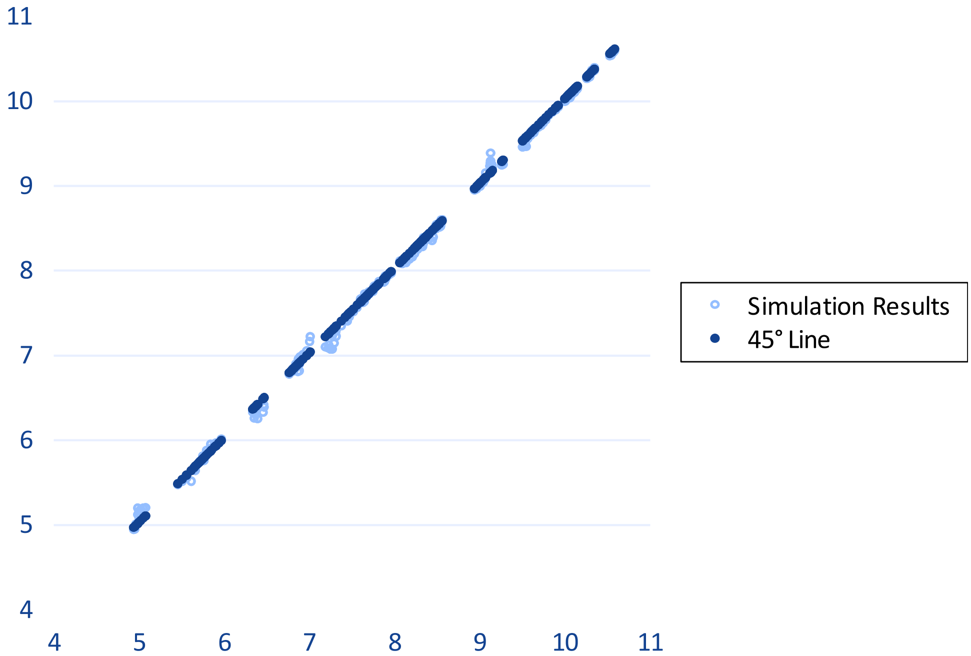


Figure 5: Employment – Time Series Plots of Selected Logged Series

The scatter plot of simulated against observed employment figures indicates reasonable labour market simulation results (Figure 4). 26 out of 27 Member States, with the exception of Romania, also pass the F-Testing-Procedure (Table 2). Thus, the overall findings appear very satisfying as indicated by the exemplary time series plots of Figure 5.

Table 2: Employment - Evaluation Statistics for First Differences of Logged Series

Country	Variance	MSE	StdDev	RMSE-Ratio	F-Stat
AUT	0.47	1.12	0.68	1.55	0.85
BEL	0.47	1.71	0.69	1.90	0.19
CYP	0.80	3.50	0.89	2.09	0.04
EST	7.05	32.48	2.66	2.15	0.15
FIN	0.55	2.50	0.74	2.14	0.14
FRA	0.66	2.98	0.82	2.12	0.24
DEU	0.85	1.42	0.92	1.29	0.25
GRC	2.00	8.38	1.42	2.05	0.56
IRL	5.96	6.06	2.44	1.01	1.69
ITA	0.39	2.04	0.62	2.29	0.38
LUX	1.49	20.71	1.22	3.73	1.06
MLT	1.53	49.66	1.24	5.70	0.13
NLD	1.54	1.32	1.24	0.93	1.87
PRT	1.28	0.81	1.13	0.80	0.84
SVK	2.94	2.32	1.71	0.89	0.07
SVN	1.31	1.55	1.14	1.09	0.24
ESP	2.09	2.02	1.45	0.98	1.62
BGR	7.09	11.72	2.66	1.29	1.13
CZE	3.00	2.94	1.73	0.99	0.03
DNK	1.29	5.54	1.14	2.07	0.16
HUN	1.53	6.66	1.24	2.09	1.17
LVA	5.09	23.19	2.26	2.14	0.61
LTU	7.20	18.88	2.68	1.62	0.24
POL	10.94	10.89	3.31	1.00	1.11
ROU	56.14	29.91	7.49	0.73	11.63***
SWE	1.36	1.97	1.17	1.20	0.15
GBR	0.10	3.33	0.32	5.67	1.95

F-Stat significance levels indicated by asterisks:
* significance at the 0.1 level, ** significance at the 0.05 level, *** significance at the 0.01 level.
Source: own calculations

Finally, CO_2 emissions tend to be over-estimated for low-polluting countries (Figure 6). Accordingly, the amount of significant F-Statistics increases: In 11 out of 27 Member States, these tests indicate significant improvement opportunities for our ex post simulations (Table 3). However, the complementary inspection of selected time series again does not expose severe miss-specifications.

Figure 6: CO_2 - GINFORS Simulation Results for EU27 Member States 1998 - 2008

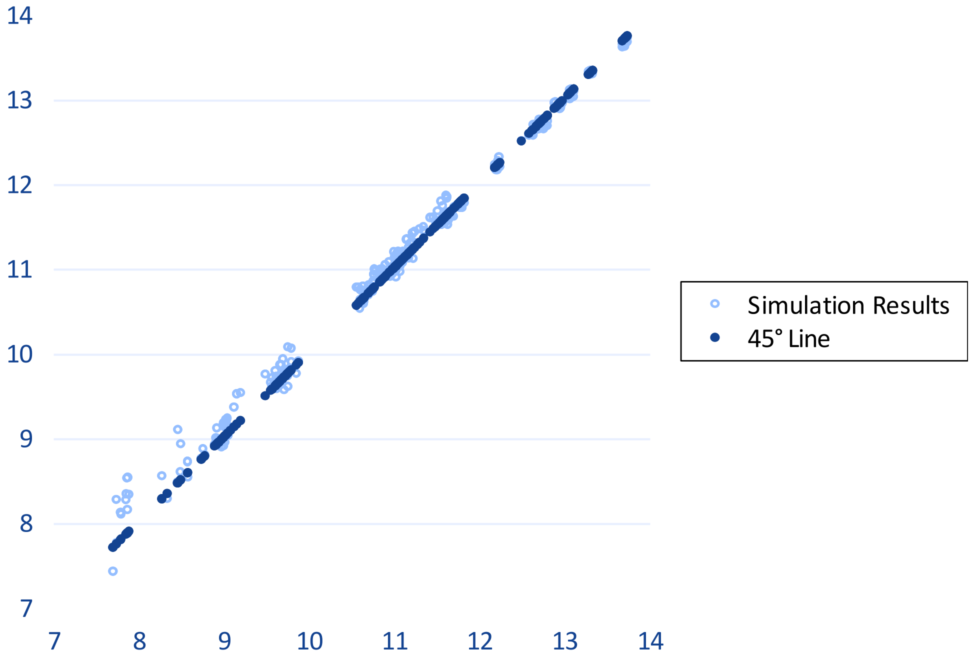


Figure 7: CO_2 – Time Series Plots of Selected Logged Series

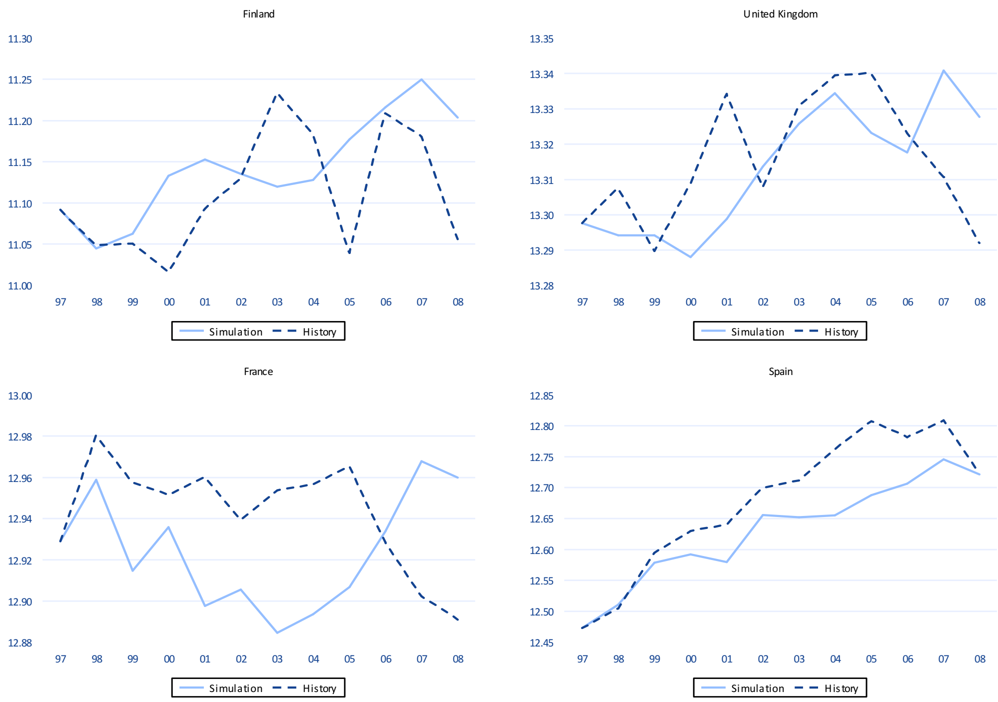


Table 3: CO_2 - Evaluation Statistics for First Differences of Logged Series

Country	Variance	MSE	StdDev	RMSE-Ratio	F-Stat
AUT	12.37	22.19	3.52	1.34	7.57**
BEL	8.02	18.68	2.83	1.53	3.12*
CYP	17.88	17.05	4.23	0.98	0.05
EST	73.30	127.47	8.56	1.32	0.28
FIN	89.11	90.66	9.44	1.01	26.72***
FRA	6.04	12.48	2.46	1.44	3.84*
DEU	2.57	8.17	1.60	1.78	4.71**
GRC	8.85	19.97	2.97	1.50	0.15
IRL	9.61	17.80	3.10	1.36	1.04
ITA	2.92	14.53	1.71	2.23	2.17
LUX	274.61	312.24	16.57	1.07	1.42
MLT	7.56	563.68	2.75	8.64	0.74
NLD	2.50	18.67	1.58	2.73	4.52**
PRT	36.29	17.19	6.02	0.69	0.31
SVK	7.04	20.04	2.65	1.69	1.67
SVN	15.02	22.18	3.88	1.22	11.74***
ESP	21.73	9.50	4.66	0.66	5.16**
BGR	49.51	45.09	7.04	0.95	5.19**
CZE	27.95	12.38	5.29	0.67	0.85
DNK	46.53	52.51	6.82	1.06	21.61***
HUN	5.77	16.94	2.40	1.71	0.74
LVA	37.78	26.16	6.15	0.83	3.65*
LTU	64.55	87.53	8.03	1.16	3.20*
POL	11.47	18.66	3.39	1.28	1.53
ROU	56.81	110.32	7.54	1.39	0.26
SWE	7.34	42.78	2.71	2.41	2.02
GBR	3.51	4.28	1.87	1.10	10.82***

F-Stat significance levels indicated by asterisks:
* significance at the 0.1 level, ** significance at the 0.05 level, *** significance at the 0.01 level.
Source: own calculations

4 The counterfactual simulations

The historical simulation is now the baseline for the counterfactual simulations. We start our simulations in the year 1998 and not in the first year 1995 of our observation period, because the model has some dynamics which should all be working from the beginning of the simulation. For the identification of results we compare the baseline and the counterfactual simulation for the year 2008. We exclude the year 2009 from our analysis, because it was a year of the greatest economic crisis since 1929 with abnormal behaviour of the agents. We first ask which economic development would have happened in Europe, if the tax rates for energy demand would have been stable. In the second simulation we look at the electricity supply. What would have happened, if no feed in tariffs or green certificates for investments in renewable energies would have been given? In the third simulation we ask, what would have happened, if the EU ETS would not have been installed.

4.1 Taxes on energy demand

4.1.1 The assumptions

In this simulation it is assumed that the tax rates on the energy carriers which purchasers have to pay for intermediate and final use, stay at the number they have had in the year 1998 for the whole period till 2009. These carriers are

coal,
crude petroleum and natural gas,
mineral oils,
electricity.

For intermediate and final products different tax rates are possible. In reality these tax rates typically have the dimension of local currency per physical unit (litre, kg, kWh etc.). In the monetary dataset of the input output relations this is transformed into the dimension of local currency per monetary volume, which is measured in local currency at constant prices. Since the policy may have started later than 1998 we allowed to take the historical tax rates till a rise is observable. From that data point on the tax rates have been set constant.

During the observation period and already before in some Northern European countries (Czech Republic, Finland, Sweden, Denmark UK, Germany, Netherlands) environmental tax reforms (ETR) have been introduced with rising energy taxes and recycling of the revenue by reduction of other taxes. The comprehensive study of Ekins & Speck, 2011, on ETR in Europe has shown that the design of taxation and recycling was very different in the countries and not always complete.[7] To have a common basis for our interpretation of results we assume a full recycling of the revenue by income taxes, which gives a simplified version of the real design of recycling. Compared with the reduction of contributions to social security we neglect the reduction effect on labour costs which means that we underestimate positive effects on employment. In that sense we have a conservative modelling design. The fact that Southern European countries did not introduce ETR's is commented by Mazzanti and Montini, 2010 as a hugely relevant fact in environmental policy in Europe.

[7] For a detailed discussion of the ETR in Europe see Ekins & Speck, 2011, Sauer et al., 2011, and Agnolucci, 2011.

4.1.2 The results

If the analysed countries would not have introduced the environmental tax reform, they would have had lower energy prices and higher income taxes. Lower energy prices reduce energy demand and raise CO2 emissions. Lower energy prices reduce also the general price level and generate more competitiveness and higher real GDP. On the other side higher income taxes reduce final demand and real GDP and also indirectly energy demand and CO2 emissions. What we see in table 4 is the net effect: In most countries we observe a slight positive effect on GDP and a stronger positive effect on CO2. Without the ETR GDP would have been a bit higher, but CO2 emissions would have been substantially higher. The latter is the case also in the Czech Republic, but it would have been combined even with a loss of GDP. A loss of GDP would have been also the result in Sweden combined with stable CO2 emissions.

A special case is given in Estonia. For this small transition country the result can only be interpreted as follows: The lower prices create a higher GDP, but higher income taxes reduce especially energy demand and CO2 emissions.

Concerning employment measured in persons we observe for all countries (exception: Estonia) either a constant value or a slight reduction. Neglecting the special case Estonia we can summarize: The introduction of the ETR in the analysed countries did not jeopardize their competitiveness but contributed to a significant reduction of their CO2 emissions. The reduction of CO2 emissions has been reached by a rise in energy productivity, which may be interpreted as technical progress induced by a rise of relative energy prices. The employment effects of the introduction of the ETR have been either neglectable or positive. If we would have analysed a compensation of social security contributions instead of income taxes the employment effects would have been positive. The reason is that a reduction of social security contributions reduces labour costs, which induces a reduction of labour productivity.

Table 4: Scenario No ETR. Deviations from the baseline in the year 2008 in percent for selected macro variables in selected European countries.

Country	GDP	Employment	CO2
Czech Republic	-0.31	-0.32	1.62
Denmark	0.38	0.02	0.18
Estonia	1.06	1.51	-1.26
Finland	0.25	0.01	1.45
Germany	0.31	0.01	1.44
Netherlands	0.21	-0.26	1.38
Sweden	-0.50	-0.31	-0.07
United Kingdom	0.08	-0.16	1.72

Source: own calculations

A look at the detailed sectoral results for gross production in constant prices for selected countries in table 5 confirms the impression which we got so far: Without the ETR nearly all sectors would have had either a stable or a lower gross production. The expansive effect of lower energy prices is more or less compensated by the impact of higher income taxes. Especially in the service sectors the latter effect is stronger. Of course electricity production and mining and quarrying would have produced more due to lower electricity prices. A bit

strong but in the right direction is the rise of gross production of water transport in the Czech Republic.
Our result that the introduction of an ETR would not affect competitiveness is in line with the ex-ante modelling results of Bach et al., 2001, for Germany and the comprehensive study of Ekins & Speck, 2011, who gave a literature overview and ex ante modelling results.
The list of the 35 industries – as given in table 5 – does not explicitly show the energy intensive iron and steel industry and the cement industry. They are important parts of other named industries: The cement industry is part of "other non-metallic minerals" and the iron and steel industry is part of the "basic metals and fabricated metal".

Table 5: Scenario No ETR. Gross production in constant prices. Deviations from the baseline in the year 2008 in per cent for all industries in selected countries.

Industry	Czech Republic	Germany	Spain
Agriculture, Hunting, Forestry and Fishing	-1.50	-0.13	-0.07
Mining and Quarrying	4.81	2.08	-0.04
Food, Beverages and Tobacco	-0.84	-0.42	-0.09
Textiles and Textile Products	-0.70	0.32	-0.86
Leather, Leather and Footwear	-0.91	0.87	0.18
Wood and Products of Wood and Cork	-0.29	0.19	0.04
Pulp, Paper, Paper , Printing and Publishing	0.29	0.10	0.04
Coke, Refined Petroleum and Nuclear Fuel	1.54	0.99	0.12
Chemicals and Chemical Products	1.91	1.26	0.56
Rubber and Plastics	-0.11	0.12	-0.06
Other Non-Metallic Mineral	-0.23	0.24	-0.05
Basic Metals and Fabricated Metal	0.88	0.25	-0.05
Machinery, Nec	0.28	0.28	-0.43
Electrical and Optical Equipment	-0.32	0.20	-0.31
Transport Equipment	-0.74	-0.06	-0.03
Manufacturing, Nec; Recycling	-0.67	0.03	-0.08
Electricity, Gas and Water Supply	4.64	7.60	1.18

Construction	-0.15	-0.04	-0.14
Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	3.27	-0.11	0.06
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	-0.65	0.11	-0.15
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	-1.22	0.04	-0.03
Hotels and Restaurants	-5.19	-0.28	0.08
Inland Transport	-0.34	-0.75	0.07
Water Transport	33.67	-1.10	-0.62
Air Transport	0.05	-0.31	-0.21
Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	0.62	-0.22	0.17
Post and Telecommunications	-0.31	0.01	0.10
Financial Intermediation	-1.66	-0.03	-0.01
Real Estate Activities	-3.72	-0.63	0.06
Renting of M&Eq and Other Business Activities	-0.55	0.30	-0.01
Public Admin and Defence; Compulsory Social Security	-0.11	0.28	-0.16
Education	-0.22	-0.11	-0.32
Health and Social Work	-0.17	-0.04	-0.12
Other Community, Social and Personal Services	-1.83	-0.11	-0.01
Private Households with Employed Persons	-0.41	-0.07	NA

Source: own calculations

4.2 The EU ETS

4.2.1 The assumptions

During the observation period the following sectors of the WIOD classification belonged to the EU ETS:

Pulp, paper and printing,
Coke, refined petroleum,
Other non-metallic minerals,
Basic metals and fabricated metal,
Electricity production.

The cap on CO2 emissions and the demand of the firms for the emission rights creates a market clearing carbon price, which is influencing the behaviour of the firms in the mentioned sectors in two ways. First the opportunity costs for the emissions raise the basic product price of the industry; second the producers will mention the carbon price in their demand decisions for fossil fuels: They will calculate with “shadow prices” which contain the market price plus the carbon costs which are included in one unit of the fuel. Both price effects will induce a great number of indirect income and price effects which the model will calculate.

4.2.2 The results

For most countries the renunciation of the introduction of the ETS would have meant a rise of emissions between 1% and 3 %. This result is in line with Anderson & Di Maria, 2011. Two effects create this result: the first is that substitution of fossil fuels depending on their carbon content takes place, because the shadow price of the carrier rises with its carbon content. This effect happens in electricity production. In the other sectors technical progress in total energy use is induced by a rise of the shadow price of total energy. Depending from their economic structure some countries would have had nearly no CO2 effect, for others – like France – the high share of nuclear energy would have avoided reactions on CO2 emissions. Extraordinary strong reactions are given for Cyprus, Estonia, Latvia and Romania.
The effects on real GDP and employment would have been all positive but small for the older member states. Some transition countries (Estonia, Slovak Republic and Bulgaria) would have had higher GDP figures between 2% and 3% and also significant positive effects on employment.
But we have to be careful with the interpretation of the impact on competitiveness, because the shock of the ETS with rather low carbon prices in only three years of the observation period was not very strong, and because we have in all countries a negative impact (positive in the counterfactual simulation) on GDP. If this instrument has to play a central role in future climate policy, the carbon prices and also their impact on GDP would be much higher.

Table 6: Scenario No ETS. Deviations from the baseline in per cent for selected macro variables of all European countries.

Country	GDP	Employment	CO2
Austria	0.18	0.07	3.26
Belgium	0.02	0.01	0.71

Cyprus	0.53	0.46	5.05
Estonia	2.91	2.17	9.16
Finland	0.05	0.08	2.19
France	0.01	-0.00	0.22
Germany	0.14	0.04	1.96
Greece	0.10	0.08	0.53
Ireland	0.08	0.03	0.35
Italy	0.06	0.05	0.31
Luxembourg	0.05	0.01	1.15
Malta	-0.14	0.38	0.72
Netherlands	0.06	0.11	0.58
Portugal	0.05	0.09	1.07
Slovak Republic	2.03	0.51	2.52
Slovenia	0.72	0.31	1.79
Spain	0.22	0.27	1.31
Bulgaria	3.04	0.28	3.89
Czech Republic	0.19	0.35	1.53
Denmark	0.17	0.08	-0.06
Hungary	0.31	0.48	2.30
Latvia	1.11	0.90	4.18
Lithuania	0.32	0.19	1.43
Poland	0.43	0.40	2.15
Romania	0.10	1.24	10.56
Sweden	0.04	0.03	0.35
United Kingdom	0.71	0.56	2.06

Source: own calculations

In table 7 the structure of production is under observation for the Czech Republic, Germany and Spain. As expected the sectors "electricity, gas and water supply" and "coke, refined petroleum" would have performed better, but for nearly all other sectors of these countries slightly positive effects can be observed, which means that the introduction of the ETS has had a small negative impact on competitiveness.

Table 7: Scenario No ETS. Deviations from the baseline in per cent for gross production in constant prices of all industries in selected countries.

Industry	Czech Republic	Germany	Spain
Agriculture, Hunting, Forestry and Fishing	0.27	0.06	0.16
Mining and Quarrying	0.50	0.67	0.26
Food, Beverages and Tobacco	-0.19	0.11	0.11

Textiles and Textile Products	-0.08	-0.13	-0.09
Leather, Leather and Footwear	0.09	-0.13	-0.02
Wood and Products of Wood and Cork	0.29	0.14	0.14
Pulp, Paper, Paper , Printing and Publishing	1.03	0.12	0.42
Coke, Refined Petroleum and Nuclear Fuel	0.17	3.64	1.05
Chemicals and Chemical Products	0.42	0.11	0.35
Rubber and Plastics	0.13	0.04	0.30
Other Non-Metallic Mineral	0.46	0.96	0.73
Basic Metals and Fabricated Metal	-0.11	0.01	0.16
Machinery, Nec	0.16	0.00	0.30
Electrical and Optical Equipment	0.36	0.10	0.28
Transport Equipment	0.38	-0.02	0.07
Manufacturing, Nec; Recycling	0.25	0.07	0.18
Electricity, Gas and Water Supply	0.63	5.12	1.52
Construction	0.41	0.19	0.45
Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	0.15	0.03	0.28
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	0.05	-0.05	0.22
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	0.15	-0.05	0.04
Hotels and Restaurants	0.36	-0.22	0.12
Inland Transport	-0.08	0.18	0.17
Water Transport	0.31	0.13	0.35
Air Transport	0.26	0.12	0.76
Other Supporting and	0.23	0.08	0.28

Auxiliary Transport Activities; Activities of Travel Agencies			
Post and Telecommunications	0.23	-0.07	0.15
Financial Intermediation	0.54	0.06	0.23
Real Estate Activities	-0.56	0.04	0.23
Renting of M&Eq and Other Business Activities	0.18	0.13	0.37
Public Admin and Defence; Compulsory Social Security	0.35	0.26	0.27
Education	1.16	0.06	0.36
Health and Social Work	1.16	0.04	0.42
Other Community, Social and Personal Services	0.80	0.09	0.26
Private Households with Employed Persons	0.62	-0.02	NA

Source: own calculations

4.3 Subsidies for renewable energies

4.3.1 The assumptions

GINFORS differentiates the renewables:

- Biogas,
- solid biomass,
- hydro,
- geothermal,
- photovoltaic,
- csp,
- wind.

Since the production costs for electricity made of renewable resources in most cases have been higher than those of conventional power stations, there has been no market led incentive for investment into these technologies. With the introduction of subsidies several European countries successfully tried to push investment into these technologies. Two approaches can be distinguished – feed in tariffs and green certificates.

The general principle of the instrument feed in tariff is a guaranteed price for fixed periods for electricity production from renewable resources. This enables a greater number of investors like homeowners, landowners, farmers, municipalities and others to participate in this development (Couture & Gagnon, 2010). The remuneration for the investors has to be paid by the demanders of electricity, which means higher prices for electricity. There is a big variety in the concrete design of the instrument: Instead of a fixed feed in tariff a fixed premium may be paid on top of the electricity market price. Further the remuneration may be directly paid by the government and financed by a tax on electricity demand. This is not the place to discuss all variations in detail. An overview on this is given by Couture & Gagnon, 2010.

To combine the property of security for investors with a better economic efficiency the Netherlands developed a tradable quota model of “green certificates”, which has been adopted by several countries. The central idea is that the government obliges producers, distributors or demanders of electricity to hold a certain share of their electricity production, distribution or consumption in a certain time period as green electricity certificates, which are tradable. The producers of green electricity sell the certificates and the other participants of the electricity markets which have the obligation to hold the certificates can either produce the green electricity themselves or buy the equivalent certificates. For a more detailed discussion see Ringel, 2006.

Feed in tariffs and green certificates are the main instrument in Europe to push investments in renewable energies. The installation of feed in tariffs started in Europe in the year 2000 in 9 countries; in 2005 18 countries and in 2012 already 20 countries used this instrument. In a report commissioned by the German Ministry for the Environment Fraunhofer ISI, Ecofys and the TU Vienna came to the result that 93% of all wind onshore capacity and nearly 100% of all photovoltaic capacity installed by the end of 2010 in Europe was initiated by feed- in tariffs (Ragwitz et al., 2011, p.6). Due to the high share of fuel costs in total generation costs the long term investment security given by feed-in systems is less relevant in the case of biomass technologies, which explains why here 40% of the capacity came out of countries without feed in tariffs (Ragwitz et al., 2011).

However the subsidy for renewable electricity production is designed – in a fixed price variant or as a green certificate variant – for an appropriate macroeconomic modelling the recognition of ***three direct*** effects is essential.

The ***first*** is the effect on the installations of the different renewable technologies in the European countries. An econometric estimation of the capacity effect is not possible since we have a big variety of the design of the instrument in the several member states combined with a too low number of observations. For the counterfactual simulation this problem can be solved easily: Since in the observation period the renewable technologies have not been profitable it seems to be plausible to assume that the capacity effect can be dedicated totally to the subsidies. This means that we set for those countries which introduced subsidies the new installations for the subsidised technologies to the level of the year 1997 before our observation period.

So our central hypothesis is that in Europe investments in renewable energies have been induced by subsidies and not by the EU ETS. This assumption is in line with the findings of the sector studies of WP 2: In WP 2.1 Agnolucci, 2013, p. 13, comes to the result: “ Hoffmann, 2007, discovered that technology-specific policies, such as feed-in tariffs, are among the most relevant decision factors for power generators to decide on RD&D plans. Four years later Rogge et al., 2011, came to an analogous conclusion. EU ETS is of only very limited relevance for sales and R&D decisions, as R&D decisions in renewable electricity in Germany were mainly driven by the feed-in tariff (Hoffmann, 2007).” For biogas WP 2.4 Kuik, 2013, shows the dependency from feed in tariffs and even realizes that the amount of the subsidy and the rate of capacity expansion are correlated.

The ***second*** is the effect on the electricity price. Independent from the type of subsidy the difference between the unit costs of the renewable technologies and the conventional electricity production has to be paid by the demanders of electricity and insofar raises the purchaser's price for electricity. On the other side the supply curve for electricity shifts to the right, which reduces the basic price for electricity. The total effect on the purchasers price is unclear, which is also a finding of WP 2.1 (Agnolucci, 2013, p. 25) and the literature cited there. Since GINFORS models both effects there are no further problems.
The ***third*** effect concerns the net effect on investment demand of the electricity sector. On the one side the installations of capacities for renewable energies induce additional investment demand. This effect is given for sure. On the other side the production of electricity from conventional carriers is reduced, which may reduce the investment in the capacities of these carriers. This effect is not sure for the short run, since without the renewables a stable electricity demand would not have needed additional capacities of conventional carriers, which alone gives a high probability for a positive net effect. One may argue that at least replacement investment for conventional carriers has been avoided. In this case the net effect would be positive since the capital intensity of renewables is higher than that of conventional carriers. Since we are not sure that in such a phase of a structural break the investment function of GINFORS for the conventional carriers is acceptable, we calculate two sub scenarios. In the first we assume that the net effect on investment is zero, in the second we allow that the there is no reduction of investment for conventional carriers. Reality is in between both scenarios, but we are convinced that it is closer to the second alternative.

4.3.2 The results

We first discuss the more unrealistic case that the effect of investment in renewables on total investment demand is compensated by not realized investments in conventional carriers. Or in other words: In this simulation we neglect the effect, that investment for renewable energies means demand for windmills etc. from the machinery industry. In a further simulation we will include this important effect.
The scenario assumes that investment in renewables is frozen at the level of the year 1998. The effects on CO2 emissions are very different, because the development of investment was very different in the member states. If this investment would not have happened, Germany would have had 9%, Portugal 7.8%, Spain 5.6% more CO2 emissions in 2008. GDP would have been in most countries higher, since the electricity price would have been lower. GDP and employment would have been in most countries slightly higher, since this scenario is assuming no net effects on total investment demand.

Table 8: Scenario No expansion of investment in renewable energies. No net investment demand. Deviations from the baseline in per cent for selected macro variables in all European countries.

Country	GDP	Employment	CO2
Austria	0.13	0.12	1.18
Belgium	0.09	0.10	3.15
Cyprus	0.14	0.11	1.98
Estonia	-0.35	-0.17	0.0
Finland	0.17	0.11	1.09

France	0.06	0.04	0.76
Germany	0.39	0.14	9.01
Greece	0.07	0.07	4.00
Ireland	0.12	- 0.04	1.41
Italy	0.08	0.14	3.01
Luxembourg	-0.03	-0.28	2.20
Malta	0.46	0.21	0.58
Netherlands	0.18	0.23	1.11
Portugal	-0.21	0.59	7.79
Slovak Republic	1.46	-0.56	0.12
Slovenia	-0.08	0.06	1.60
Spain	-0.44	-0.15	5.59
Bulgaria	0.06	0.05	0.53
Czech Republic	-0.01	0.02	0.44
Denmark	0.11	0.08	2.34
Hungary	0.32	0.33	0.78
Latvia	1.60	1.28	0.34
Lithuania	0.24	0.28	2.06
Poland	0.25	0.24	0.74
Romania	-1.16	-0.04	10.54
Sweden	0.26	0.12	1.45
United Kingdom	0.74	0.63	2.40

Source: own calculations

A look at table 9 shows the effects on gross production in constant prices. The Czech Republic has had rather low investment in renewables. Here we see only small effects, which are in many cases indirect effects from international trade. If Germany would have abstained from its strong investment in renewables, the lower price for electricity would have induced higher demand for electricity, which would have been produced by conventional carriers pushing the production of coal in the mining and quarrying sector. In Spain we would have seen in proportion to the strength of the shock also a fall of the electricity price and a rise in demand and production of electricity. But in this country the coke and refined petroleum sector would have delivered the needed input for the electricity sector.

Table 9: Scenario No expansion of investment in renewable energies. No net investment demand. Deviations from the baseline in per cent for sectoral gross production in selected countries.

Industry	Czech Republic	Germany	Spain
Agriculture, Hunting, Forestry and Fishing	-0.06	0.29	-0.38
Mining and Quarrying	0.38	4.20	-1.56
Food, Beverages and	-0.16	0.24	-0.20

Tobacco			
Textiles and Textile Products	-0.06	-0.05	0.29
Leather, Leather and Footwear	0.25	0.11	-0.06
Wood and Products of Wood and Cork	-0.04	0.23	-0.08
Pulp, Paper, Paper , Printing and Publishing	-0.33	0.20	-0.02
Coke, Refined Petroleum and Nuclear Fuel	0.14	0.32	1.88
Chemicals and Chemical Products	0.02	0.18	-0.36
Rubber and Plastics	0.11	0.18	-0.38
Other Non-Metallic Mineral	0.10	0.36	-0.26
Basic Metals and Fabricated Metal	0.17	0.28	0.18
Machinery, Nec	-0.08	0.15	-0.15
Electrical and Optical Equipment	0.04	0.46	0.05
Transport Equipment	0.02	0.18	0.03
Manufacturing, Nec; Recycling	-0.03	0.20	-0.17
Electricity, Gas and Water Supply	-0.15	10.29	4.86
Construction	0.02	0.03	-0.31
Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	0.09	0.24	-0.22
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	0.07	0.25	0.01
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	0.13	0.20	0.20
Hotels and Restaurants	0.05	-0.25	-0.23
Inland Transport	0.15	0.36	-0.07
Water Transport	-3.75	0.35	0.14
Air Transport	0.29	0.29	0.34

Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	0.02	0.27	-0.21
Post and Telecommunications	0.05	0.05	0.02
Financial Intermediation	0.06	0.28	0.06
Real Estate Activities	-0.06	0.19	-0.28
Renting of M&Eq and Other Business Activities	0.08	0.41	-0.18
Public Admin and Defence; Compulsory Social Security	0.01	0.44	-0.26
Education	0.02	0.13	-0.42
Health and Social Work	0.02	0.11	-0.40
Other Community, Social and Personal Services	0.00	0.22	-0.32
Private Households with Employed Persons	0.00	-0.03	NA

Source: own calculations

In table 10 we look at the results of the scenario with the assumption that the additional investment in renewables did not reduce the investment in conventional energy carriers. This means that additional demand is induced for the sector machinery. With this assumption the renunciation of investment in renewables would have induced less additional CO2 emissions, because there would have been less production of machinery. This effect can be shown comparing the CO2 emission figures from table 8 with those of table 10. A look at both tables further shows that now in table 10 we have in most cases negative GDP and employment figures. This means that without this investment in renewables we would have had lower GDP and employment figures: The impact of the lower electricity price on competitiveness would have been overcompensated by the impact of a lower investment in machinery on the circular flow of income and GDP and employment. This result is in line with the findings of Lehr et al., 2008.

Table 10: Scenario No expansion of investment in renewable energies. Full net investment demand. Deviations from the baseline in per cent for selected macro variables in all European countries.

Country	GDP	Employment	CO2
Austria	-0.54	-0.34	0.54
Belgium	-0.23	-0.10	2.44
Cyprus	0.04	0.04	1.85
Estonia	-0.03	0.02	0.75
Finland	-0.42	-0.14	0.57
France	-0.39	-0.06	0.36

Germany	-0.55	-0.36	7.88
Greece	-0.04	-0.01	3.82
Ireland	-0.15	-0.12	1.17
Italy	-0.65	-0.45	2.23
Luxembourg	-0.39	-0.48	1.35
Malta	0.44	0.29	0.61
Netherlands	-0.20	0.00	0.74
Portugal	-0.80	0.45	6.91
Slovak Republic	-0.25	-1.22	-1.12
Slovenia	-0.57	-0.17	1.25
Spain	-1.12	-0.74	5.03
Bulgaria	-0.31	-0.14	0.40
Czech Republic	-0.88	-0.30	-0.31
Denmark	-0.17	-0.03	2.31
Hungary	-0.45	-0.01	0.46
Latvia	1.14	0.76	2.73
Lithuania	-0.14	0.23	1.77
Poland	-0.25	-0.06	0.72
Romania	-1.51	0.50	10.19
Sweden	-0.27	-0.02	0.75
United Kingdom	0.03	0.16	0.99

Source: own calculations

Table 11 confirms the results which we just described for the sectoral level: There would have been positive effects for Germany and Spain only for the electricity sectors and the deliverers of their inputs. All other sectors – and especially the machinery sector – would have been negatively affected. In the Czech Republic with its relatively low investment in renewables the impact on the machinery sector would have been induced by international trade of finished and intermediate machinery products.

Table 11: Scenario No expansion of investment in renewable energies. Full net investment demand. Deviations from the baseline in per cent for sectoral gross production in selected countries.

Industry	Czech Republic	Germany	Spain
Agriculture, Hunting, Forestry and Fishing	-0.50	0.15	-0.50
Mining and Quarrying	-0.52	3.25	-1.89
Food, Beverages and Tobacco	-0.38	-0.37	-0.34
Textiles and Textile Products	0.03	-0.17	0.31
Leather, Leather and	0.23	-0.18	-0.37

Footwear			
Wood and Products of Wood and Cork	-0.66	-0.03	-0.67
Pulp, Paper, Paper , Printing and Publishing	-0.40	-0.28	-0.61
Coke, Refined Petroleum and Nuclear Fuel	-0.41	-0.48	1.53
Chemicals and Chemical Products	-0.47	-0.33	-0.66
Rubber and Plastics	-0.87	-0.98	-1.43
Other Non-Metallic Mineral	-0.36	-0.10	-0.60
Basic Metals and Fabricated Metal	-1.94	-1.85	-2.39
Machinery, Nec	-7.37	-8.91	-16.39
Electrical and Optical Equipment	-1.04	-1.16	-1.49
Transport Equipment	-0.59	-0.30	-0.27
Manufacturing, Nec; Recycling	-0.43	0.09	-0.97
Electricity, Gas and Water Supply	-0.71	8.40	4.13
Construction	-0.17	-0.22	-0.46
Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	-0.48	-0.56	-0.94
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	-0.56	-0.57	-0.84
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	-0.55	-0.56	-0.20
Hotels and Restaurants	-0.39	-0.33	-0.56
Inland Transport	-0.48	-0.48	-0.84
Water Transport	-7.22	0.36	-0.32
Air Transport	-0.27	-0.77	-0.46
Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	-0.37	-0.52	-1.06

Post and Telecommunications	-0.45	-0.35	-0.49
Financial Intermediation	-0.46	-0.20	-0.39
Real Estate Activities	-0.51	-0.79	-0.76
Renting of M&Eq and Other Business Activities	-0.58	-0.51	-0.74
Public Admin and Defence; Compulsory Social Security	0.08	0.86	-0.20
Education	0.22	0.14	-0.45
Health and Social Work	0.15	0.16	-0.52
Other Community, Social and Personal Services	-0.33	-0.28	-0.68
Private Households with Employed Persons	0.42	0.64	NA

Source: own calculations

5 Conclusions

If the European countries would not have had introduced in the late 1990 and early 2000 years ETR's, the EU ETS and subsidies for renewables, the CO2 emissions of the member states would have been in the year 2008 up to 12% - 13% higher than historically observed. The concrete numbers differ between the countries due to their specific structures of production and the country specific part of climate policy concerning the intensity of taxation of energy goods and the intensity of their promotion of investment in renewable energies. If these climate policy innovations would not have been installed in Europe, we would have had probably lower but certainly not higher figures for GDP and employment in most European countries. Exemptions may have been some smaller transition countries.

The effects on competitiveness are different for the instruments: Environmental tax reforms sometimes pay a double dividend in terms of lower CO2 emissions and higher GDP and employment figures. Higher taxes on energy certainly reduce competitiveness, but the recycling of the tax revenues by the reduction of social security contributions or income taxes over compensates the negative effects on GDP. Our study shows that for most analysed countries this compensation is given to a large extent, but not totally. The results are slight reductions of GDP combined with either slightly reduced or even rising employment. The latter effect is expectable, if the reduction of social security contributions is part of the tax recycling.

Our simulations further show that the ETS reduces CO2 emissions, but there is a tendency to rising production costs for the firms being part of the ETS, because these firms calculate the opportunity costs of holding pollution rights. These costs spread over to others, which use

their products as inputs. The effects on competitiveness have been very small, because the instrument has been used in the past only in a restricted way.
Subsidies for renewables have had the strongest effect on CO2 emissions. It could be shown that the negative effect on competitiveness induced by the rising price of electricity is over compensated by the positive effect of rising investment demand. GDP and employment in most countries rise. The losers of this policy are only the conventional electricity producers and their deliverers of fossil energy carriers. All other sectors are winners.

Out of the scope of our study because being outside of our observation period two problems concerning the interaction of instruments occurred: The first was a collapse of the ETS market. The second was the dramatic rise of end user electricity prices in some countries.

For the collapse of the ETS one reason next to others was the dramatic rise of renewable energies in some countries, which substituted fossil fuels in electricity production. This problem could be solved in the future, if the supply of pollution rights would not be inelastic for a period of several years as it was in the past.
The second problem arose in some countries with absolutely fixed feed–in-tariffs for renewables. The success of renewables raises electricity supply and insofar reduces spot market prices for electricity. So two effects raise the burden for electricity demanders in the end user price: The amount of installations rises and the discrepancy between the feed-in-tariff and the spot market price rises. If additionally industries have exemptions from the burden, the rise of the end user price for electricity might have negative impacts on the welfare of low income households. To strengthen the societal acceptance of the feed in tariff concept it could be useful to reduce the taxes for electricity demand. Further the feed in tariff could be changed into a constant premium to be paid on the spot market price for electricity.

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