EMISSION TRADING VS. RENEWABLE ENERGY TECHNOLOGY PROMOTION FOR GHG CONTROL IN THE EUROPEAN UNION – EFFECTIVENESS, ECONOMIC COSTS, AND SECURITY OF SUPPLY

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Abstract

Policy instruments for GHG abatement may follow different strategies. Two prominent distinct strategies that are also part of the EU climate protection approach are market oriented cap and trade regimes and support schemes for carbon free generation technologies. The two strategies differ in their impact on the energy system and thus in effectiveness of abatement, in economic impact, and in consequences for energy security. We contrast the EU-wide impacts of two policy instruments each representing a single control strategy by using the recursive-dynamic, technology rich CGE model NEWAGE-W. First, we consider a cap and trade regime where international emission allowance trade is implemented following the Kyoto-protocol. Second, we consider targets for the application of renewable energy sources in electricity generation. Our model results suggest that for reasons of effectiveness, economic efficiency, and security of supply a GHG control strategy should not merely rely on technology oriented policies. Combining a technology oriented strategy with a cap and trade strategy may only slightly further decrease emissions where this reduction is accompanied by negative growth impacts. Impacts differ between new and old member states and are highly sensitive to the allocation of the overall EU target.

Introduction

GHG control strategies

Anthropogenic climate change largely stems from the combustion of fossil fuels in the energy system. In Europe (EU-25) approx. 80 % of green house gas (GHG) emissions are energy related and approx. one third originates from electricity generation. In the case of CO_2 which by far is the most important GHG, the electricity sector contributes approx. 35 % to total emissions in the EU-25. Moreover, approx. 45 % of total primary energy demand is being directed towards the generation sector. Hence, the electricity system's technological design strongly affects the environmental outcome, the security of energy supply as well as any potential economic impact induced by GHG control. Consequently, this paper explicitly emphasizes the composition of the electricity sector and its role for climate protection strategies. Focus is put on CO_2 mitigation strategies.

Policy instruments for CO_2 abatement may follow different strategies. For this paper, we identify two distinct strategies. The first strategy draws upon national administrative emission caps coupled with an allowance trading scheme. This cap and trade approach is to be considered a market oriented approach. It is brought into affect by the Kyoto protocol. Cap and trade strategies aim at indirectly changing the comparative advantages of distinct energy carriers and energy conversion technologies based on their specific emissions. Consequently, they can be considered market pull strategies.

The second strategy is a direct technology oriented approach. It builds upon regulatory policy instruments to set incentives for the generally direct application of specific energy carriers as well as energy conversion and electricity generation technologies. Hence, this approach relies on technology promotion. It may include quotas, norms, and subsidies for emission free technologies such as nuclear energy, renewable energy sources (RES), carbon capture and storage (CCS), as well as efficiency improvements of conventional generation (e. g. CHP). Administrative technology oriented approaches can be considered technology push strategies.

The EU approach for GHG control

In the current debate on GHG control, in its Presidency Conclusion of March 2007 the EU commission (EU (2007)) propagates an *Energy Policy for Europe* that includes both of the strategies identified above. First, EU (2007) announces an absolute GHG emission cap that yields emission reductions of at least 20 % in 2020 compared to 1990. Second, it installs a binding target of a 20 % share of RES in overall EU energy consumption by 2020.[1]

The propositions in EU (2007) are problematic in at least two senses. First, the RES target is relevant for total primary energy consumption. However, GHG control strategies in general as well as this paper specifically emphasize the importance of the electricity sector which is why we specify RES targets for the electricity mix. For the EU-15 the *Directive on the promotion of electricity produced from renewable energy sources in the internal electricity market* EU (2001) defines national RES quotas for the electricity mix up to 2010. Although there is no directive which states binding targets for the new member states, data is given by Eurostat (2007). Figure 1 displays resulting quotas for 2010. The national targets combined yield a quota of 22 % for the entire EU-15 (cf. EU (2001)). From 2010 onward no sector detailed targets are defined. This is why we draw upon an exemplary proposal of the German Renewable Energy Federation which suggests a RES share in electricity generation of 35 % from 2020 onward (cf. BEE (2006)).

Second, EU (2007) explicitly stipulates that an EU member burden sharing scheme yet is necessary for a cost efficient achievement of the two targets emission reduction and RES share. However, the differentiated national targets of such a burden sharing agreement are yet to be negotiated for the time after 2010. Difficulty in defining a burden sharing for a RES target lies in the very different national power plant systems and technical potentials among the EU member states. Whereas especially the new member states (except Latvia, Slovakia, and Slovenia) historically have only fragmentarily implemented RES in their electricity mix, in the EU-15 RES play a more important role. This is possibly also due to targets having been established earlier by the EU directive.

By following the two strategies EU (2007) not only aims at improving environmental compatibility with respect to GHG control. Explicit complementary goals are those of the energy policy triangle, namely to enhance the economic efficiency of the energy system, and to increase energy security. Consequently, we assess the impact on the policy triangle imposed by the two policy instruments cap and trade and RES quota as well by the combination of the two. Using a CGE model, we compare their effectiveness in GHG mitigation, their economic efficiency, and

[1] The overall emission reduction will be increased to 30 % if other major industrialized countries impose significant reductions as well. Another important pillar is to increase energy efficiency by 20 % compared to baseline development in 2020. Notwithstanding the fact that this approach could also be analysed with our model NEWAGE-W, it cannot be discussed within the limited scope of this paper.

their impacts on security of supply. To highlight the impact of diverse starting points regarding RES application this paper differentiates between EU-15 RES policy and cohesive EU-25 RES policies. We start our analysis with policies for the EU-15 due to the fact that here, RES targets have long been established. Additional emphasis is then laid on the effect of a cohesive EU-25 approach in contrast to a single EU-15 RES policy.

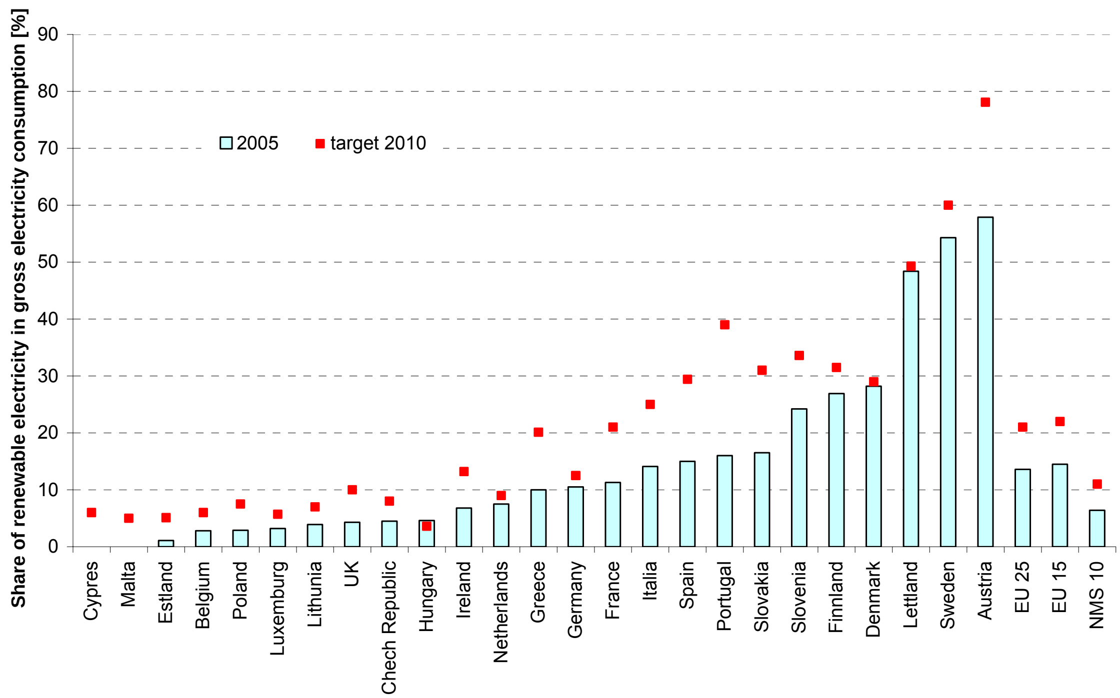

Figure 1. RES actual share and target share in electricity consumption in the EU-25 (Eurostat 2007)

Methodological Approach

The CGE Model NEWAGE-W

In applied economic research, Computational General Equilibrium (CGE) modeling has been shown to provide a well established instrument for the quantification of the direct and indirect economic impacts of climate and energy policy measures. A CGE analysis of the implications of policy induced changes in the electricity system needs to incorporate explicitly generation technology specifications. To meet this requirement the paper at hand modifies and uses the CGE model NEWAGE-W as developed in Küster et al. (2007) and Zürn et al. (2005). The NEWAGE-W version applied here is a recursive dynamic, technology rich, multi-sectoral world economy model with ten regions, including Germany, the EU-15, and the EU-25. In each region 13 industries produce output by applying four primary factors, namely capital, skilled labor, unskilled labor, and exhaustible energy resources. Households and government are represented by a single regional representative agent. The model base year is 2001. The model is calibrated towards the GTAP database Version 6 from 2005 (cf. GTAP (2005)) so that underlying data for production and trade consistently follow the economic input-output concept.

A specific aspect of NEWAGE-W is the integration of bottom-up detail into a top-down general equilibrium framework. Different to most existing CGE models, NEWAGE-W follows a hybrid approach where overall production of the sector electricity production is not modeled as a standard aggregated production function but as an aggregate of technological detailed single technology CES functions. Following Zürn et al. (2006) and Zürn et al. (2005), 13 distinct generation technologies are modeled. Every single generation technology is considered with technology specific cost shares and energy input and emission intensities. Regionally differentiated cost data is applied where available. The technologies are characterized by a strict Leontief nesting for all inputs. In the case of fossil fired generation technologies the input of energy is connected with CO_2 allowance input. Single technology outputs are aggregated in a production function which represents the national power plant system. Aggregation is structured by differentiating between base, middle, and peak load technology application. In order to account for the specific role of renewable energy technologies, the nesting in this version of NEWAGE-W moreover distinguishes between renewable and non-renewable energy carriers applied in generation. Amongst the renewable energy branch we differentiate between adjustable and stochastic production technologies. The resulting electricity portfolio which consists of 16 generation options is where substitution patterns may take place. Hence, substitutions in the electricity sector are not directly occurring with respect to primary factors in the technology production function but rather by the structure of the electricity mix. The electricity sector as a whole is displayed in Figure 2. Specific elasticities of substitutions are implemented in every nest and reflect different ease of substitution on inter- and intraload levels and for fluctuating and constant generation levels.

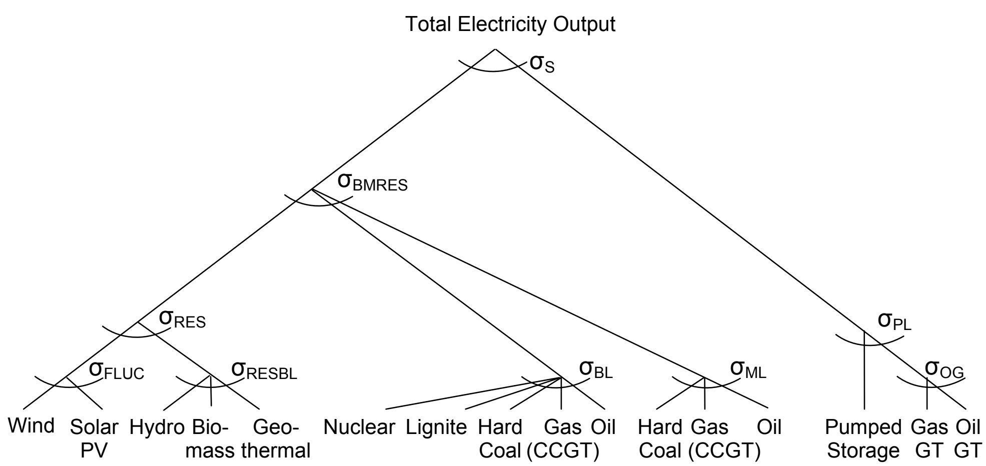

Figure 2. Electricity CES production function

The bottom-up integration enables us to model technology oriented policies in a comprehensive economic framework. For the paper at hand, it allows for the novel modeling of a quota of renewable energies applied in overall electricity generation. The quota modeling is in principle oriented at Böhringer and Rutherford (2005) who develop a stylized CGE model with renewable energy targets. In order to implement a RES quota in generation, we exogenously define a cumulative quantity constraint on the share of electricity originating from RES. The quantity constraint relates to a complementary endogenous subsidy on RES application. By using an endogenously computed subsidy for the integration of RES into the electricity mix, the model makes allowance for the additional electricity system costs through the application of the more cost intensive RES technologies that have to be borne by the economy.

Scenario definition

We apply the model for the comparative analysis of four scenarios. Even though the scenarios do not completely capture the recent policy approach of EU (2007), they reflect specific instruments of the two discussed EU GHG control strategies. Whereas RES targets are implemented in the model according to the EU policy, the emission budget for the cap and trade regime in our scenarios is based on the Kyoto protocol only. The result analyses focus on the impact on the EU, especially the EU-15. The scenario compositions are shown in Table 1.

Table 1. Scenario table

K	R	K+R	K+R-EU25
Kyoto forever emission trading system between all effective Annex-B countries with Kyoto EU target constant at -8 % from 2010 onward	RES target for EU-15 only yielding at least 35 % from 2020 onward	K plus additional RES target for EU-15 only yielding at least 35 % from 2020 onward	K+R plus additional RES targets for the new member states (NMS-10)

The fist scenario K considers an emission standard including allowance trade between countries involved in emission reduction, i.e. EU-25 and effective other Annex-B countries. The emission caps reflect national goals of the Kyoto protocol which are considered to be constant and effective even after the first commitment period. The second scenario R is technology oriented. It implements an endogenously specified subsidy on technologies using renewable energy sources in a way that a share of RES in the EU-15 electricity mix correspondent to EU targets as given in EU (2001) and in BEE (2006) is achieved.[2] The third scenario K+R combines both promotion of RES technologies for the EU-15 as well as emission caps and allowance trade of the Kyoto forever case K. The fourth scenario K+R-EU25 widens the scope of the technology strategy onto the EU-25 so that all EU countries are obliged to fulfill the RES target shares. This highlights the role of harmonization and unification in EU climate and energy policy.

For the model regions the targets relevant for 2010 are 12.5 % for Germany, 25 % for the aggregate of all other members of the EU-15, and 11 % for the ten new member states of the EU-25. This decomposition is consistent to the overall target of 22 % for the EU-15, and 21 % for the EU-25 in 2010. From 2020 onward, EU member countries unilaterally must achieve a 35 % RES share. Further restrictions concerning the energy system that hold true for all scenarios are a limited physical potential for the renewable energy carriers hydropower and biomass and the nuclear phase out accord for Germany.

[2] EU (2001) defines renewable electricity as the share of electricity produced from RES in total electricity consumption. The latter includes imports and exports of electricity. Electricity generated from pumped hydro storage by definition is not considered as a renewable source of energy. For reasons of methodology, this paper considers RES shares in electricity production.

Comparative analysis of impact on effectiveness, efficiency, and security of supply

Electricity production structure

The primary objective of cap and trade regimes as well as of increasing the share of RES is to decrease energy related CO_2 emissions. Whereas the ecological effectiveness of a cap and trade regime is given by definition of the overall emission budget, the emission impact of the promotion of RES is determined endogenously on the market by application of the technologies. For both policies, NEWAGE-W detects significant changes in the electricity mix based on changes in technologies' and energy carriers' comparative advantages. Figure 3 compares scenario specific electricity mixes for the EU-15.

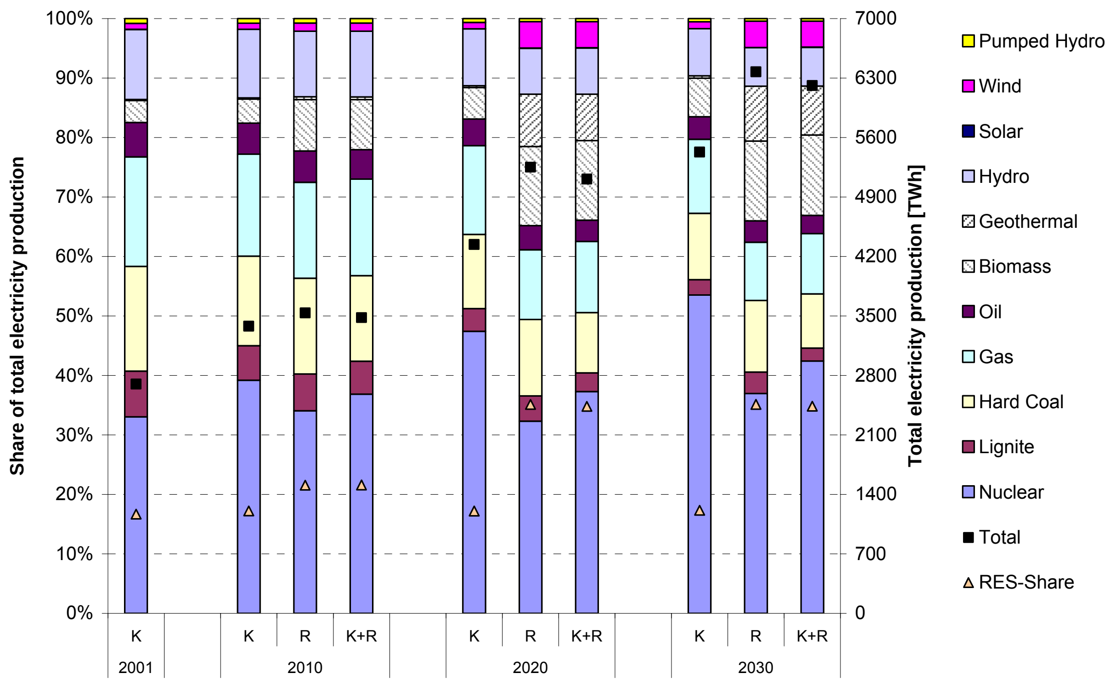

Figure 3. Electricity generation mix in the EU-15

The RES quota is mainly fulfilled by using biomass and geothermal power where the application of the latter is unrestricted in this model version. Nuclear power is less used, when RES quotas are applied. It is striking that inducing a quota strongly increases overall electricity production, namely by 17 % in 2030 in EU-15 compared to the case K. When quotas are implemented in the new member states as well, production increases by 33 % in the EU-25. This effect is to be interpreted with caution. It shows that under a quota regime our model tends to increase overall electricity production in order to fulfill the cumulative quantity constraint on the share of electricity originating from RES.

Effectiveness

The displayed changes in the electricity sector in addition with substitutions in the consumption of fossil fuels in the rest of the economy induce changes in the emission balance. Our model results show that without applying a cap, CO_2 emissions will increase by approx. 11.5 % in the

EU-15 in 2030 (Case R compared to case K).[3] Installing a share of RES in electricity generation cannot offset the increase of emissions that occurs in the lack of binding caps as shown in Figure 4. It is important to understand that the increase in emissions in scenario R compared to the scenario K is not principally due to the RES subsidy but to the lack of a binding cap. In combination with a cap, RES quotas may only slightly decrease emissions, as indicated by the small deviation K+R to K and K+R-EU25 to K in Figure 4. Thus, ecological effectiveness is remote.

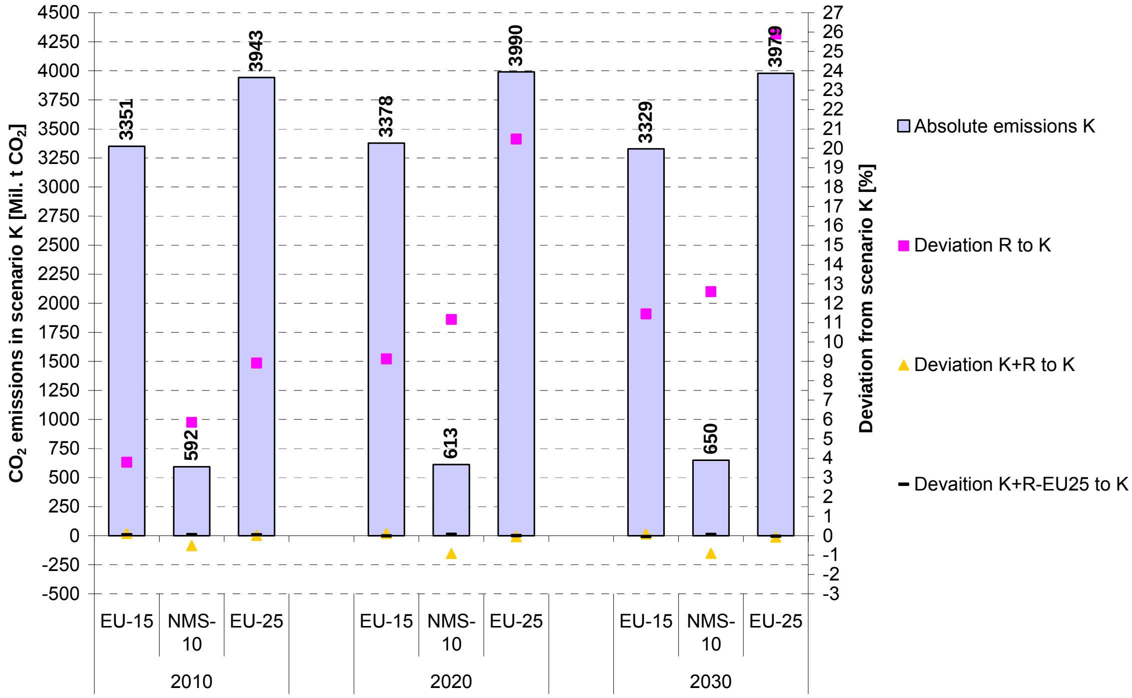

Figure 4. CO_2 emissions

Efficiency

Efficiency of the policy instruments can be tested by various model variables. Here, we consider GDP impacts, and changes in the Hicks equivalent welfare index (HEV). Figure 5 displays GDP and welfare impact of the scenarios R, K+R, and K+R-EU25 compared to the scenario K. GDP is given for the EU-25, the EU-15 and the ten new member states (NMS-10). The welfare index HEV cannot be aggregated to these regions due to methodological constraints and is rather given for the model regions Germany, the EU-15 without Germany, and the NMS-10. The results indicate that implementation of RES targets depress GDP in the EU-15 by approx. 0.75 % in 2030 compared to the mere cap and trade case K. When targets are imposed in the new member states as well, the GDP contraction is 0.87 % for the EU-25 in 2030. In this case, it is especially the new member states that suffer growth losses, namely 3 % in 2030. If new member states do not embark on RES target policy, they tend to experience positive macro-effects. Figure 5 also

[3] When comparing the case R to a reference case without neither caps nor RES targets, emissions in the case R would be lower by 12.4 % in EU-15 in 2030 than such a no policy reference case. This case cannot be presented in this limited paper.

shows that in early periods macroeconomic effects are slightly positive. This suggest that there may be a threshold when moving from rather moderate and differentiated RES targets imposed in 2010 to an overall target of 35 % from 2020 onward.

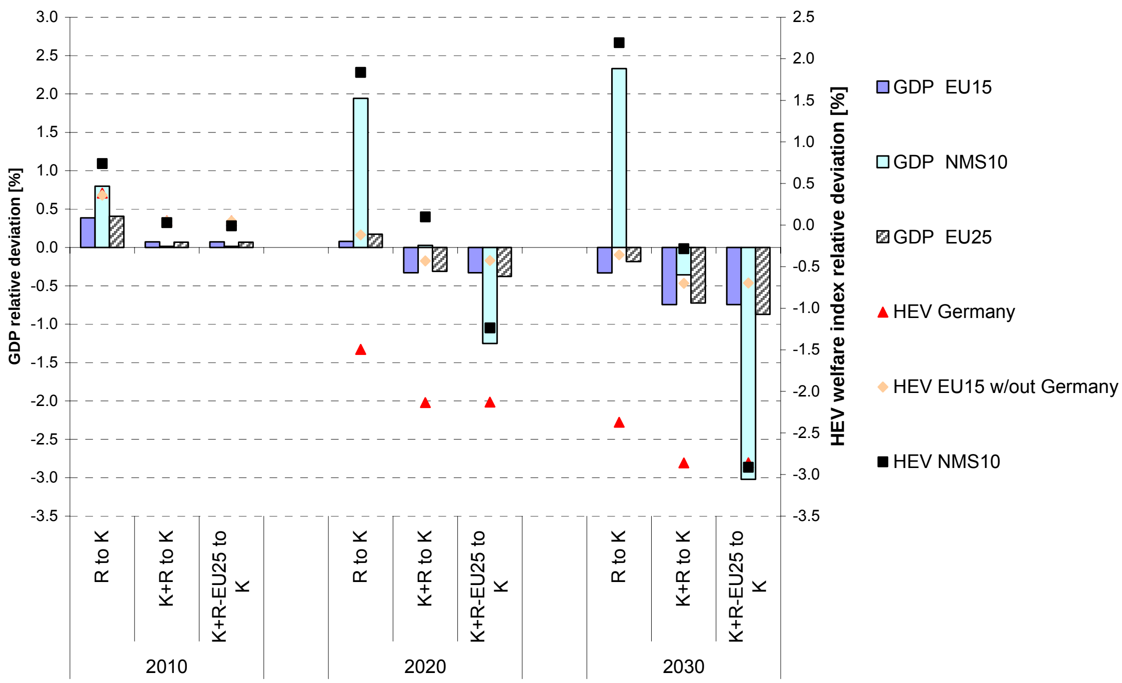

Figure 5. GDP and welfare impacts

The HEV welfare index which founds on changes in the economic agent's income highlights the economic transmission channel of subsidy supported RES targets. It captures budget effects and related changes in the income constraints imposed by the endogenous subsidy. Our results show that HEV welfare effects are analogous to the production effects reflected by the GDP. The HEV effect clearly shows the tightening of the income constraint through the subsidy in the scenarios R, K+R, and K+R-EU25 compared to K. In the long run, the effect is stronger for the single country Germany than it is for the rest of the European economy. One reason for this is the undifferentiated target from 2020 onward which leaves Germany with an obligation for a high increase in RES application (from 12.5 % in 2010) compared to the rest of the EU-15 (from 22 % in 2010).

Security of Supply

The energy security impact imposed by the two GHG control policies is exemplarily presented by the development of energy carrier imports into the EU-15 and the EU-25 respectively. Table 2 shows that coal imports are significantly reduced over time when a cap and trade regime is applied (scenarios K, K+R, and K+R-EU25). Gas imports increase which reflects the switch from coal to gas under emission caps. In all scenarios, the most important exporter to Europe is Russia with a share of total imports of approx. 46 % in EU-15 and around approx. 54 % in EU-25 in 2030. Crude oil imports increase in all scenarios with OPEC decreasing and Russia increasing their market shares in all scenarios. Contrasting the fuel type specific effects under cap and trade regimes, in general coal import experiences the by far strongest effects. Analogous, the case R imposes large changes in the coal import situation but only moderate changes in gas and crude oil imports compared to the other three scenarios. Comparing the scenarios that combine RES quotas with cap and trade regimes, it becomes obvious that the technology oriented policy cannot reduce European import dependency.

Table 2. Energy carrier imports into EU

Energy Carrier	Scenario	Region considered	2001	2010	2020	2030
Coal	K	EU-15	100	88	70	61
	R	EU-15	100	105	108	106
	K+R	EU-15	100	88	71	62
	K+R-EU25	EU-25	100	82	58	45
Gas	K	EU-15	100	106	109	106
	R	EU-15	100	109	114	112
	K+R	EU-15	100	106	109	107
	K+R-EU25	EU-25	100	107	111	112
Crude Oil	K	EU-15	100	104	106	106
	R	EU-15	100	111	118	118
	K+R	EU-15	100	104	106	106
	K+R-EU25	EU-25	100	105	108	109

Conclusions

Our model results suggest that for reasons of effectiveness, economic efficiency, and security of supply a GHG control strategy should not merely rely on technology oriented policies. Combining a technology oriented strategy with a cap and trade strategy may only slightly further decrease emissions. However, this reduction is accompanied by negative growth impacts. The fact that electricity production significantly increases when technology quotas are installed while at the same time GDP contracts is a strong indicator for inefficiencies in the energy system. Whereas moderate RES targets basically do not affect macro-economic growth, an increase up to 35 % has significant negative impacts. EU import dependency is decreased when emission standards cap fossil fuel consumption whereas renewable energy quotas do not decrease import dependency. An important result is that harmonization of RES technology oriented EU policy has negative economic implications especially for the new member states but also for the entire EU-25. This suggests that a cohesive strategy should provide differentiated goals for all member states and beyond what is regulated by the EU directive for the year 2010. Alternative to administrative individual targets, a corporate RES strategy could also found on tradable RES certificates with market mechanism inducing optimal burden sharing.

Hence, considering the preliminary goal of GHG abatement as well as the complementary goals of economic efficiency and energy security, we conclude that the changes in generation technology application necessary for climate protection are best achieved through the implementation of emission permits tradable on perfect allowance markets. Our concrete scenario examples suggest that market pull strategies excel over technology push strategies for GHG control. If an EU wide RES target is to be applied, the design of the related EU burden sharing will strongly affect its economic impact.

In addition to what is discussed in this paper, regarding the emission cap and trade strategy, further options for the design of a Post-Kyoto protocol as well as concrete 20 % reduction target of EU (2007) need to be considered. Regarding the electricity technology oriented strategy a further step would be to also assess and compare the impacts of other technology options for GHG control such as nuclear energy, CO_2 capture and storage, and energy saving through efficiency in production and consumption.

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