THE ROLE OF THE GREEN QUOTA AND REVENUE RECYCLING SCHEMES IN THE CLIMATE CHANGE OPTIONS: A DYNAMIC GENERAL EQUILIBRIUM ANALYSIS FOR AUSTRIA

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ABSTRACT

By simulations with the dynamic equilibrium model TD-BU-E3 DGEM the long term impacts of two alternative policy instruments for responses to climate change were assessed: green quota and double dividend. Electricity demand growth was de-coupled from the economic growth. 3 economic sectors, 5 existing and three new vintage electricity production technologies were considered.

By 2050 the share of renewables in the electricity production could be reaching 0,289 and there are sufficient potential renewable resources. The economic burden is bearable and the welfare is growing.

Checking the double dividend hypothesis (trade-off b/n environmental benefits and gross economic costs): the reduction in the labor tax is increasing consumption; the reduction of consumption tax to a lesser extent so but the reduction in the lump-sum refund to the representative household is detrimental to consumption.

Hence, only for the case of labor tax recycling, we could assume the existence of a strong double dividend.

Keywords: climate change, CO₂ taxation, abatement strategies, general equilibrium models

1. INTRODUCTION

The aim of the paper is to quantitatively assess the macroeconomic and sectoral impacts of future responses to climate change by evaluating policies for adaptation and mitigation aiming at promoting increased market penetration of electricity produced from renewable energy sources in Austria.

The term **adaptation** is to be related to de-coupling of electricity demand from the economic growth by energy and resources conservation in the sense of sustainable development, by changing consumption pattern and habits, etc. – all that are long term measures related to socio economic changes.

For the long-term **mitigation** options for the electric power sector will focus on CO_2 reduction by the mean of a set of the technological options where strong potentials for CO_2 reduction exist.

To grasp synergies in climate policy the adaptation and mitigation options must be analyzed within a consistent, dynamic framework allowing for carrying out of integrated analyses of alternative scenarios for adaptation and mitigation strategies.

Mitigation and adaptation policies should be assessed on their full effects and their quantification calls for the use of the newly developed Top/Down -BU for Bottom-up E3 (energy, environment, economy) dynamic general equilibrium model (TD-BU-E3 DGEM) allowing for systematic trade-off analysis of environmental quality, economic performance and welfare (consumption).

As to policy measures related to mitigation by promotion of renewable energies there had been a shift - as more generally in environmental policy design from command-and-control policies to market-based instruments such as taxes, subsidies, and tradable quotas. A recent impact assessment by the European Commission, 2008, shows that feed-in tariffs in Austria are the preferred promotion measure. In addition, direct subsidies for renewable energy have been enacted – typically differentiated by the type of green energy, i.e., wind, biomass, solar cells, etc.

A relatively new strand of policy regulation is the use of tradable green quotas where energy supplies are required to produce a certain share of energy services from renewable energy but are flexible to trade these shares between each other in order to exploit potential difference in specific compliance costs.

In this paper, focus on two alternative policy instruments which may be quite relevant to the Austrian strategy for promotion of renewable energy sources: quota obligation systems and Carbon Taxation (double dividend) instruments.

Methodological the focus is set on novel CGE (Computational General Equilibrium) modeling approaches. The methodological objective is to consistently describe the role of specific energy related technologies within a total analytical economic modeling framework. CGE is used as an analytical Top-Down framework that is enhanced by representation of specific technology descriptions.

The paper is structured as follows: Section 2 provides a background to the TD-BU-E3 DGEM and its algebraic representation in the MCP framework, followed by its adjustment to the study's specifics and application to the particular case studies in Section 3 that is dealing with Scenario definition and policy analysis starting with benchmark assumptions, then the description and analysis of the Baseline Scenario followed by the Green quota scenario and respective analysis and ending with the Carbon Taxation (double dividend) Scenario. Section 4 concludes.

2. THE TD-BU-E3 DGEM

Our modeling work was motivated by recent theoretical and practical developments in algorithms for nonlinear complementarity problems and variational inequalities based on the GAMS/MCP modeling format (Rutherford, 2002).

The TD-BU-E3 DGEM where TD stands for Top/Down, BU for Bottom-up, E3 for energy, environment, economy and DGEM for dynamic general equilibrium model.

The TD-BU-E3 DGEM provides a basis for evaluating economic impacts of the chosen energy policies both at macroeconomic and at the sectoral level – indicating the effects of the energy decisions on the economic environment. This approach permits an energy-economy model to combine technological details of an energy system (bottom-up) with a characterization of the market equilibrium (top-down).

TD-BU-E3 DGEM applications include the impacts of scenarios on country's economic variables, e.g., changes of the main real economic indicators, in the consumption of the households, in the sectoral employment levels, in the energy consumption, of the emission levels, the energy price indices, etc., but TD-BU-E3 DGEM is also used for applied energy and environmental policy analysis, e.g., the impacts of the Green Quotas and the Environmental Tax Reform

2.1. TD-BU-E3 DGEM: algebraic representation in MCP framework

In our formulation of an integrated top-down / bottomup model we consider a competitive (Arrow-Debreu) economy with n commodities (including economic goods, energy goods and primary factors) indexed by i, m production activities (sectors) indexed by j, and h households (including government) indexed by k. We making use of the MCP framework suggested by Boehringer (2007) formulation of market equilibrium problems as mixed complementarity problems (MCP) thus permitting integration of bottom-up programming models of the energy system into top-down general equilibrium models of the overall economy. The decision variables of the economy can be classified into the following categories:

p denotes a non-negative *n*-vector in prices for all goods and factors,

y is a non-negative *m*-vector for activity levels of constant-returns-to-scale (CRTS) production sectors, *M* is a *h*-vector of consumer income levels,

e represents a non-negative *n*-vector of net energy system outputs (including, for example, electricity, oil, coal, and natural gas supplies), and

x denotes a non-negative *n*-vector of energy system inputs (including labor, capital, and materials inputs).

Given the underlying functional forms, we observe that the complementarity conditions only will apply for the energy sector technologies and the shadow prices on the associated capacity constraints; all of the macroeconomic prices and quantities will be non-zero. By use of Shepard's Lemma we can then write the equilibrium as the following mixed complementarity problem:

Zero-profit conditions:

$$\overline{z}_{it} \geq z_{it} \perp \mu_{it} \geq 0 \tag{1}$$

$$- \prod_{it}^{E} \geq 0 \perp z_{it} \geq 0$$
 (2)

$$\prod_{j}^{N} s_{j} = 0 \tag{3}$$

□ Market clearance conditions:

$$s_{j} = \sum_{ii} a_{ii}^{j} z_{ii} + c \frac{\partial \Pi_{c}}{\partial p_{j}}$$

$$j = 1 - N$$

$$\overline{L} = \sum_{j=1}^{N} s_{j} \frac{\partial \Pi_{j}}{\partial w}$$

$$\overline{K}_{j} = s_{j} \frac{\partial \Pi_{j}}{\partial r_{j}}$$

$$\sum_{i} z_{ii} - \sum_{i'i} b_{ii'i} z_{i'i} = c \frac{\partial \Pi_{c}}{\partial p_{i}^{E}} + \sum_{j=1}^{N} s_{j} \frac{\partial \Pi_{j}}{\partial p_{i}^{E}}$$

$$c = \frac{M}{p_{c}}$$

(Equations 4 to 8)

□ Income balance:

$$M = \sum_{j=1}^{N} r_j \overline{K} j + w \overline{L} + \sum_{it} \mu_{it} z_{it}$$
⁽⁹⁾

Extending the above setting into an intertemporal model version only requires a few additions (most of the underlying economic relationships hold on a periodby-period basis), regarding capital stock formation and investment, an efficient allocation of capital, i.e. investment over time, implies two central intertemporal zero profit conditions which relate the cost of a unit of investment, the return to capital, and the purchase price of a unit of capital stock for each time period τ .

Capital evolves through geometric investment and geometric depreciation

Output markets must also account for investment demand.

The consumer allocates lifetime income, i.e., the intertemporal budget, over time in order to maximize utility, solving:

$$\max \sum_{\tau} \left(\frac{1}{1+\rho}\right)^{\tau} u(C_{\tau}) \tag{10}$$

subject to

$$\sum_{\tau} p_{\tau}^{C} C_{\tau} = M \tag{11}$$

With isoelastic lifetime utility the instantaneous utility function is given as:

$$u(c) = \frac{c^{1-\frac{1}{\eta}}}{1-\frac{1}{\eta}}$$
(12)

Summary of equilibrium variables in the TD-BU-E3 DGEM:

Activity veriables

a. Activity variables		
с	Aggregate consumption	
S_j	Production of goods in the sectors $j = 1 - N$	
E_i	E_i Aggregated output of energy good <i>i</i>	
$Z_{i,t}$	Production by technology t for energy good i	
E_i^j	Demand for energy good i in the sectors S_j	
E_i^c	Final demand for energy good <i>i</i>	
L	Labor demand of goods in the sectors S _i	
b. Price variables		
p_c	Price index of final consumption	
P_{j}	Non energy goods from sectors S_i	
p_i^E	Energy prices for $i = \{OIL, GAS, COL, ELE\}$	
W	Wage rate	
R_{i}	Returns to non energy capital for S _i	
$\mu_{_{it}}$	Energy sector returns	
c. Income variable		
Μ	Income of the representative agent	
d. Additional variables and parameters for		
dynamic extension		
pK_{τ}	value (purchase price) of one unit of capital stock in period τ ,	
K_{τ}	associated dual variable which indicates the activity level of capital stock formation in period	

	τ
I_{τ}	is the associated dual variable which indicates the
	activity level of aggregate investment in period τ
u(.)	denotes the instantaneous utility function of the
	representative agent,
ρ	is the time preference rate
М	represents lifetime income (from endowments
	with capital, time, and resources).
η	constant intertemporal elasticity of substitution

For calibration of the TD-BU-E3 DGEM we use the social accounting matrix for 2005 and also the following data:

,-
%/year
.9 %/year
%/year

Price of electricity for $S_j = f AGR/FOR$, PRD/EIS, SRV, ENE (coal, gas, oil, electricity); j = 1 - Nwritten as Cobb-Douglass function (the same form is used for all other prices)

$$p_{j}^{E} = \left(\frac{P_{ELE}}{\theta_{j}^{ELE}}\right)^{\theta_{j}^{ELE}} \left\{ \delta_{j} \left(\frac{p_{COL}}{\delta_{j}}\right)^{(1-\sigma_{i}^{E})} + (1-\delta_{j}) \left[\sum_{ff} \left(\frac{p_{ff}}{(1-\delta_{j})\theta_{j}^{ff}}\right)^{\theta_{j}^{ff}}\right]^{(1-\sigma_{j}^{E})} \right\}^{H}$$
(13)

$oldsymbol{ heta}_{j}^{ELE}$	Cost share of electricity, or oil or gas coal in the composite output Y
$\delta_{_j}$	Cost share of non electricity energy composite in the output Y
σ_{j}^{E}	Elasticity of substitution
p_j^E	Price of electricity for sector j

<u>Unit profit functions for S_j .{AGR-FOR, PRD-EIS,</u> <u>SRV, ENE }, j = 1 - N are in turn given by:</u>

$$\Pi_{j} = p_{j} - \frac{1}{\phi_{j}} \left[\gamma_{j} \left(\frac{p_{j}^{E}}{\gamma_{j}} \right)^{(1-\sigma_{j})} + (1-\gamma_{j}) \left(\frac{r_{j}}{\theta_{j}(1-\gamma_{j})} \right)^{\theta_{j}(1-\sigma_{j})} \left(\frac{w}{(1-\theta_{j})(1-\gamma_{j})} \right)^{(1-\theta_{j})(1-\sigma_{j})} \right]^{l/(1-\sigma_{j})}$$
(14)

The unit cost of energy inputs to final demand are given by:

$$p_{c}^{E} = \left(\sum_{i} \beta_{i} \left(\frac{p_{i}^{E}}{\beta_{i}}\right)^{1-\sigma^{EC}}\right)^{1/(1-\sigma^{EC})}$$
(15)

And the resulting cost of a unit of final consumption for j=1-N e.g.{AGR, PRD, EIS, ENE, SRV}is: $\int (1-\sigma_{i}^{E})$

$$p^{c} = \left[\alpha \left(\frac{p_{c}^{E}}{\alpha} \right)^{1-\sigma^{c}} + (1-\alpha) \left(\prod_{j=1}^{4} \left(\frac{p_{j}}{\theta_{j}^{c} (1-\alpha)} \right)^{\theta_{j}^{c}} \right)^{1-\sigma^{c}} \right]^{\frac{1}{(1-\sigma^{c})}}$$
(16)

Where

$$\sum_{j=1}^{N} \boldsymbol{\theta}_{j}^{c} = 1 \tag{17}$$

Finally, the unit profit associated with technology tfor energy good $i = \{col, oil, gas, ele\}$ is:

$$\Pi_{it}^{E} = p_{i}^{E} - \sum_{j=1}^{N} p_{j} a_{it}^{j} - \sum_{i'} p_{i}^{E} b_{i'it} - \mu_{it}$$
(18)

The top-down nesting structure of the production functions is exemplified at the Annex 1.

3. SCENARIO DEFINITION AND POLICY ANALYSIS

3.1. Some technological considerations

In TD-BU-E3 DGEM we have eight different technologies for electricity production, divided into existing and new vintage technologies, and also categorized as renewable (or green) or not renewable.

The existing electricity production technologies are: Gas Power Plants, Oil Power Plants, Coal Power Plants, Hydro Power Plants, and Bio-Wind Power Plants, where the latter accounts for a composite of existing Biomass and Wind electricity production power units. At the Figure 1 the benchmark production shares of the existing technologies for the year 2005 are shown.



Figure 1: Benchmark electricity production shares

For the future power production we are envisaging the so called new vintage technologies, namely, new wind, new biomass and solar/photovoltaic.

Here the terms new wind and biomass should be understood to be tentative names more the end-of-the pipe technologies that are assumed to be more efficient than the existing but also more costly. We made assumption that the existing power plants will be functioning in the future and the new technologies will be entering the market after the old have exhausted the limit of their resource allocation. For the existing Bio-Wind technology we have imposed a limit at a level of 2.5 times the value of its benchmark electricity production. Similarly, based on the limiter resource availability, the Hydro Power production was limited to 1.4 times its benchmark production level. According to the trend analysis the production of the coal power plants does not change much and oil power plants are going out of market.

The new renewable technologies have an imposed potential of their maximal contribution to the total electricity production, namely, the new Wind - 7%, new biomass - 15%, and the new solar - 20%.

For the technologies the relative prices per unit of electricity produced have been ranked from the cheapest, hydro power, to the most expensive, new solar which is assumed to be 2.2 more expensive than the hydro. The other technologies are lying in between this range.

The advanced renewables are assumed to be not active at the beginning of the period mainly because they are supposed to be technologically available at a later stage and because they are relatively quite expensive.

3.2. Baseline Scenario

Scenario assumption related to the **adaptation** is the decoupling of electricity demand from the economic growth. This is assumed to be done by energy and resources conservation in the sense of sustainable development, by changing consumption pattern and habits, etc. – all that are long term measures related to socio economic changes. The growth of total electricity production, shown at Figure 3, is assumed to be 0.7% per year, hence decoupled from the assumed economic growth of 0.9%/year. Just for comparison – till 2008 electricity demand in Austria were growing with 1% per year.

The Scenario assumptions for the main fuel inputs in the power production till the year 2050 are based on energy supply analysis by Kratena and Wrüger (2005) (Figure 2).

The main features of this scenario are:

- doubling the natural gas input for power production,
- hard coal use almost constant,
- quadrupling the wind and biomass use and
- gradual extinction on fuel oil use in the power plants.

The quadrupling of fuel wood and wind electricity seem to be realizable because the available wind energy potential has been evaluated at 14 - 50 PJ and the fuel wood availability at 30 Mio m3 or 232 PJ (Hantsch and Moidl 2007; Balabanov 2008).



Figure 2: Assumptions for the main fuel inputs till the year 2050 (in PJ)

As said the growth of total electricity production, at Figure 3, is assumed to be decoupled from the economic growth of 0.9%/year so that we are coming to a growth index of 1.64 for electricity production over the 50 year period. In the baseline scenario renewables will increasing their part of the production but at the historical growth rate – reaching approximately 9% by 2050.



Figure 3: Structure of the power production

3.3. Green quota scenario

A part of the integrated energy and climate change policy guidelines, as adopted by the EU in December 2008 (DG for Energy and Transport 2008), is the obligation by the member states for covering an average of 20% of their total energy needs from renewable sources. Therefore each country agreed to fulfill a different renewable energy quota by 2020.

The target for Austria by 2020 is 34% whilst for the year 2005 it was 23.3% of the total energy use. In so far as this target is recognizing the hydro power as green energy and the *Hydro share for 2020 is projected to be 14.73%* in fulfilling the quota obligation an accelerated growth rate of other renewables would be need in order

to reach around 20% by 2020 which is seen by WKOE (2008) as difficult.

In this paper the green quota scenario is attempting to simulate the impacts on the technology mix of the Austrian electricity sector of increasing the share of renewables in the electricity production up to 30% by 2050.

By running the TD-BU-E3 DGEM under the above assumption we have as an output the changes in the main indicators as shown at Figure 4. The growth of the power production indexed with 1.66 is following quite closely the scenario assumption and around 2030 there is a small bump. This is result of the exhaustion of the conventional hydro and bio-wind resources and the slum is due to the significant subsidies needed for the start up of the new wind and biomass technologies.



The accelerated development of the agricultural sector (X1) is a result of the demands of agricultural inputs by the biomass technologies while heavy industry's production (X2) is slightly declining due the general trend in exporting/downsizing the energy intensive industries.

The growth of investment is following closely the growth of the electricity output and this is due to the

high capital intensity of the power sector. It is quite indicative that the consumption is growing, albeit at a lower rate, despite the significant investment demand.

Here is to be said that by 2030 the share of renewables (without hydro) is reaching 0,184 and by 2050 - 0,289.

To summarize: achieving the quota of close to 30% by 2050 is feasible and there are sufficient quantities of potential renewable resources for that purpose. It also

seems that the economic burden is bearable and the welfare is growing.

The next figure shows the electricity production structure by the different technologies in TWh for graphical reasons the dominating Hydro power production is not shown at Figure 5, since it would be depressing the view. The scenario run resulted in steady increase of hydro power production of up to 50 TWh by 2020 when in it reaches its imposed production limit.



Figure 5: Production (in TWh) of the conventional and renewable energy technologies

Few years later – by 2025 - the bio-wind is also reaching its production limit which results in the output rise by the conventional bio-wind technologies and that is opening the way to entering the market for the new wind and new biomass – the so called backstop technologies.

This start up of the new and expensive technologies result in a jump of the subsidy rate for green technologies, see Figure 6, first in 2025 at the level of 8% from the electricity production cost. When new Vintage reaches its potential, in 2030 there is another jump in subsidy rates reaching to 14%, so that new biomass technologies could start producing electricity.



Figure 6: The subsidy rates for the green technologies

As a result of these developments by 2030 the share of renewables in the electricity production (including hydro) is reaching **0,825** or without hydro **0,184** and by 2050 the same share without hydro is **0,289**, while the share (including hydro) remains at 0,825.

3.4. Carbon Taxation (double dividend) Scenario

The **greenhouse gases** are measured in megatons of Carbon dioxide equivalency (MCO_2eq) and there are a number of alternative tax instruments for reducing its emissions.

Carbon dioxide equivalency is a quantity that describes, for a given mixture and amount of greenhouse gas, the amount of CO_2 that would have the same global warming potential (**GWP**), when measured over a specified timescale (generally, 100 years). Carbon dioxide equivalency thus reflects the time-integrated radioactive forcing, rather than the instantaneous value described by **CO₂e**.

For example, the GWP for methane over 100 years is 25 and for nitrous oxide 298. This means that emissions of 1 million metric tons of methane and nitrous oxide respectively are equivalent to emissions of 25 and 298 million metric tons of carbon dioxide.

Over the last decade, several EU Member States have levied some type of carbon tax in order to reduce greenhouse gas emissions from fossil fuel combustion contributing to anthropogenic global warming (OECD 2001).

In this context, the debate on the **double dividend** hypothesis has addressed the question of whether the usual trade-off between environmental benefits and gross economic costs (i.e. the costs disregarding environmental benefits) of emission taxes prevails in economies where distortionary taxes finance public spending.

Emission taxes raise public revenues which can be used to reduce existing tax distortions. Revenue

recycling may then provide prospects for a double dividend from emission taxation (Goulder 1995):

Apart from an improvement in environmental quality (the first dividend), the overall excess burden of the tax system may be reduced by using additional tax revenues for a revenue-neutral cut of existing distortionary taxes (the second dividend).

If – at the margin – the excess burden of the environmental tax is smaller than that of the replaced (decreased) existing tax, public financing becomes more efficient and welfare gains will occur.

The setting of TD-BU-E3 DGEM for simulating Carbon Taxation Scenario differs slightly from the original setting for the Baseline Scenario, e.g., final consumption is being split into public (governmental) and private (household) consumption, where public consumption is estimated at a level of 25% of total consumption.

Therefore a new production activity is defined, indicating a public good (e.g. infrastructure, healthcare, etc.), which is then consumed by the Private households or firms in the economy.

In our dynamic policy simulations, we investigate the economic effects of carbon taxes that are set sufficiently high to reduce carbon emissions by 20% compared to the base year emission level. The figure bellow is showing the rate of decarburization of the produced electricity, namely the reduction of CO2 emissions per TWh of produced electricity.

While keeping public good consumption at the base-year level, the additional carbon tax revenues can be recycled in three different ways:

- (i) a reduction in the distortionary labor tax (labeled as "TL")
- (ii) a cut in the distortionary consumption tax (labeled as "TC")
- (iii) a lump-sum refund to the representative household (labeled in the Figure as "LS")



Figure 7: Trajectory of CO2 emissions per unit electricity produced

As seen at the Figure 8 – in line with the undisputed weak double dividend hypothesis (Goulder 1995) - the reduction of the distortionary consumption or labor taxes (TL) is superior in efficiency terms as compared to a lump-sum recycling of carbon tax revenues. In our dynamic simulation, we even obtain a

strong double dividend from revenue-neutral cuts in distortonary taxes (TL): Reflecting the larger marginal excess burden of the initial labor tax vis a vis the initial consumption tax, labor tax recycling is distinctly more beneficial than consumption tax recycling. The Figure 8 provides the consumption trajectories for the three different recycling options. In the case of reduction in the distortionary labor tax (TL) the consumption levels are increasing over a long period of time. To a lesser extend the same applies to the case of a cut in the distortionary consumption tax (labeled as "TC"): The reduction in the distortionary lump-sum refund to the representative household (labeled as "LS") tends to reducing consumption and respectively the welfare.

Hence, only for the case of labor tax recycling, we could assume the existence of a strong double dividend.



Figure 8: Carbon Taxation Scenarios

Figure 9 shows the associated carbon tax rates, or the marginal abatement cost (MAC), to achieve the target emission reductions. The computed maximum MAC of bellow EUR 100 that correlates very well with other multi country studies for the EU region, e.g. the Marginal Abatement Costs (MAC) levels have been estimated by the EU's "Impact Assessment of the EU's objectives on climate change and renewable energy for 2020" (EC 2008) to be around \in 90/t CO2.



Figure 9: Dynamics of the carbon tax rates/MAC

MAC – as the direct incentive for emission mitigation in production and consumption – increase with the stringency of the emission constraint but hardly differ across recycling variants.

In the dynamic analysis of environmental tax reforms, we impose a linear reduction of carbon emissions compared to baseline emission levels by 20% between 2005 and 2040, holding the percentage reduction vis--vis the Baseline and keeping it constant thereafter.

4. CONCLUSIONS

By adapting and extensively validating the newly developed Top/Down -BU for Bottom-up E3 (energy, environment, economy) dynamic general equilibrium model (TD-BU-E3 DGEM) we assessed the long term impacts on the macroeconomic and sectoral structural components of two alternative policy instruments for responses to climate change and for promotion of renewable energy sources:

Green quota, and

Carbon Taxation (double dividend)

In our baseline Scenario, as a part of the adaptation strategy, we assumed de-coupling of electricity demand growth from the economic growth.

In the model we have introduced 5 existing electricity production technologies, namely: Gas Power Plants, Oil Power Plants, Coal Power Plants, Hydro Power Plants, and Bio-Wind Power Plants (a composite of existing Biomass and Wind electricity production power units).

The new vintage technologies, namely, new wind, new biomass and solar/photovoltaic – are tentative names and should be better seen as the end-of-the pipe technologies that are assumed to be more efficient than the existing but also more costly.

The model runs for the Green quota scenario have shown that as a result of the inversing demands of agricultural inputs by the biomass technologies there is accelerated development of the agricultural sector while heavy industry's production is slightly declining due the general trend in exporting/downsizing the energy intensive industries.

The growth of investment is following closely the growth of the electricity output and this is due to the high capital intensity of the power sector. It is quite indicative that the consumption is growing, albeit at a lower rate, despite the significant investment demand.

Here is to be said that by 2030 the share of renewables in the electricity production (without hydro) is reaching 0,184 and **by 2050** - **0,289** and the renewables share (including hydro) is 0,825.

To summarize: achieving the quota of close to 30% by 2050 is feasible and there are sufficient quantities of potential renewable resources available for electricity production. It also seems that the economic burden is bearable and the welfare is growing.

The **double dividend** hypothesis has addressed the question of whether the usual trade-off between environmental benefits and gross economic costs (i.e. the costs disregarding environmental benefits) of emission taxes prevails in economies where distortionary taxes finance public spending.

Emission taxes raise public revenues which can be used to reduce existing tax distortions. Revenue recycling may then provide prospects for a double dividend from emission taxation.

While keeping public good consumption at the base-year level, the additional carbon tax revenues can be recycled in three different ways:

- (i) a reduction in the distortionary labor tax
- (ii) a cut in the distortionary consumption tax
- (iii) a lump-sum refund to the representative household

The results of the simulations are showing that the reduction in the distortionary labor tax is leading to increases over a long period of time of the consumption levels. To a lesser extend the consumption increases in the case of a cut in the distortionary consumption tax. From the other side the reduction in the distortionary lump-sum refund to the representative household tends to reducing consumption and respectively the welfare.

Hence, only for the case of labor tax recycling, we could assume the existence of a strong double dividend.

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ANNEX.1: TD-BU-E3 DGEM: NESTING STRUCTURE OF THE PRODUCTION FUNCTIONS



