Kypreos, Socrates

Working Paper
A MERGE Model with Endogenous Technological Change and the Cost of Carbon Stabilization

Nota di Lavoro, Fondazione Eni Enrico Mattei, No. 123.2005

Provided in Cooperation with:
Fondazione Eni Enrico Mattei (FEEM)

Suggested Citation: Kypreos, Socrates (2005) : A MERGE Model with Endogenous Technological Change and the Cost of Carbon Stabilization, Nota di Lavoro, Fondazione Eni Enrico Mattei, No. 123.2005

This Version is available at:
http://hdl.handle.net/10419/74169

Terms of use:
Documents in EconStor may be saved and copied for your personal and scholarly purposes.
You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.
If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.
A MERGE Model with Endogenous Technological Change and the Cost of Carbon Stabilization
Socrates Kypreos

NOTA DI LAVORO 123.2005

OCTOBER 2005
CCMP – Climate Change Modelling and Policy

Socrates Kypreos, Paul Scherrer Institute, Energy-Economics Group, Switzerland

This paper can be downloaded without charge at:
The Fondazione Eni Enrico Mattei Note di Lavoro Series Index: http://www.feem.it/Feem/Pub/Publications/WPapers/default.htm

The opinions expressed in this paper do not necessarily reflect the position of Fondazione Eni Enrico Mattei
Corso Magenta, 63, 20123 Milano (I), web site: www.feem.it, e-mail: working.papers@feem.it
This paper is one of a series published by FEEM on the theme of innovation modeling in the context of the challenge of stabilising atmospheric concentrations of greenhouse gases, as part of the Innovation Modeling Comparison Project. This is an international project launched and overseen by the Steering Committee of the informal International Programme on the Economics of Atmospheric Stabilisation. The broad aim of the collaboration is to advance understanding of the economic issues surrounding atmospheric stabilisation, and the specific aims of the IMCP are to provide insights into the "state of the art" and implications of endogenous modeling of technical change in global energy-environment models when applied to various levels of atmospheric stabilisation.

Members of the Steering Committee provided review comments on earlier drafts and the paper has been forwarded to external review, the final results will be published as a Special Issue of the Energy Journal. The papers have all been encouraged to draw on a common baseline (the "Common Poles-Image baseline") and to report results in comparable formats, so as to facilitate intercomparison of the different modeling results. All the results and judgements expressed here remain the responsibility of the authors.

The research presented in this paper has been conducted within the Swiss NCCR-Climate (grant from the Swiss National Science Foundation). FEEM fund the working papers series, and seed money for the coordination work of the Innovation Modeling Comparison Project was provided by UK Department of Environment, Food and Rural Affairs and the German Ministry of Environment.
A MERGE Model with Endogenous Technological Change and the Cost of Carbon Stabilization

Summary

Two stylized backstop systems with endogenous technological learning formulations (ETL) are introduced in MERGE: one for the electric and the other for the non-electric markets. Then the model is applied to analyze the impacts of ETL on carbon-mitigation policy, contrasting the resulting impacts with the situation without learning. As the model considers endogenous technological change in the energy sector only some exogenous key parameters defining the production function are varied together with the assumed learning rates to check the robustness of our results. Based on model estimations and the sensitivity analyses we conclude that increased commitments for the development of new technologies to advance along their learning curves has a potential for substantial reductions in the cost of climate mitigation helping to reach safe concentrations of carbon in the atmosphere.

Keywords: Climate change stabilization policies, Non-linear optimization, Induced technological change, Energy and macroeconomy

JEL Classification: C61, O30, Q42, Q43

Address for correspondence:
Socrates Kypreos
Paul Scherrer Institute
Energy-Economics Group
5232 Villigen
Switzerland
Phone: +4156 310 2675
E--mail:socrates.kypreos@psi.ch
1. Introduction

The Innovation Modelling Comparison Project (IMCP) is an effort to present the state of the art in modelling technological change. The project brings together a variety of different approaches to the inclusion of technological change in global macroeconomic, Integrated Assessment and energy system models. In particular, the project aims to compare and contrast the cost and investment time-paths that could lead to stabilization at 450, 500, 550 ppmv carbon dioxide by 2100, and to explore sensitivities to different modelling approaches and technical assumptions. The PSI group has developed for the Swiss NCCR-Climate Program on “Climate Variability and Risk” Integrated Assessment Models (IAMs) to simulate policies to aid in climate-change mitigation. We report herein model changes and results from a version of MERGE, Manne et al. (1995), Kypreos (2000), Manne and Richels (2002), Kypreos (2005) that supports endogenous and induced technological learning in the energy sector.

The study reported herein is an effort to evaluate the economic advantages of endogenous learning via RD&D spending in support of carbon-free energy technologies. The method presented investigates R&D support and learning investments in carbon-free systems to aid these technologies to follow their learning curves. This dedicated RD&D spending could influence developments during the demonstration and deployment phases and reduces the cost of new technologies. We assume that R&D spending together with learning investments creates path dependent knowledge that is diffused on the global level via market uptake of these fundamentally different technological systems. We also expect that the increased sales of these advanced systems introduced under a global carbon constraint will induce technological change and significantly reduce the cost of carbon mitigation.

As this special issue gives an overview concerning the state of the art on modeling technological change we focus herein on the problems realized when RD&D spending is introduced as decision variable in hybrid optimization models with perfect foresight. Some first studies applying optimization models introduced by Barreto and Kypreos (2004), Bahn and Kypreos (2002) produced a restricted level of R&D investments reported as needed to support new and advanced technologies. On the contrary, simulation models with adaptive expectations, Criqui et al. (2000) and Kouvaritakis et al. (2000) do not indicate such behaviour. This article presents this version of MERGE that overtakes the difficulty.

Section 2 discusses the new version of MERGE that defines RD&D as decision variable and the assumptions on which costs, emissions, and learning characteristics of technologies that compete in the energy markets are based; this section also explains the formulation of the two factor learning curve (TFLC) model, together with the introduction of subsidies in MERGE. We consider scenarios related to a stabilization of CO₂ concentrations in the atmosphere when including (or excluding) technological learning. Section 3 then reports on this numerical application, and describes impacts of modelling endogenous technological progress in the MERGE environment. Section 4 performs a sensitivity analyses on the most critical input parameters to test the robustness of results. Finally, section 5 concludes with an elaboration of the importance of policies that foster endogenous technological learning while the Appendix describes in some details the calibration and the sensitivity analyses with MERGE.
2. Modelling framework

2.1 MERGE

The model for evaluating regional and global effects (MERGE) is an integrated assessment model (IAM) that provides a framework for assessing climate-change management proposals. We apply the MERGE5 version described by Manne and Richels (2002), which already includes some generic technologies capable of learning-by-doing (LBD), but we model both learning-by-searching (LBS) and learning subsidies. The world modelled in MERGE is divided into nine geopolitical regions: Canada, Australia and New Zealand (CANZ); China; eastern Europe and the former Soviet Union (EEFSU); India; Japan; Mexico, and OPEC (MOPEC); western Europe (WEUR); the United States of America (USA); and the rest of the world (ROW).

An ETA-MACRO model describes each of these nine regions. The ETA component is a ‘bottom-up’ engineering model; it describes the energy-supply sector of a given region, including the production of non-electric energy (fossil fuels, synthetic fuels, and renewables) as well as the generation of electricity. The ETA model captures price-dependent substitutions of energy forms (e.g., switching to low-carbon fossil fuels) and energy technologies (e.g., the use of renewable-energy power plants instead of fossil-fuel systems) to achieve specified CO2 reduction targets.

MACRO is a ‘top-down’ macro-economic growth model that balances the non-energy part of the economy of a given region using a nested constant-elasticity-of-substitution (CES) production function. The MACRO model also captures autonomous (e.g., price-independent) effects and macro-economic feedbacks between the energy sector and the rest of the economy, such as the impacts of higher energy prices (e.g., resulting from CO2 control) on economic activities. The mathematical formulation of regional ETA-MACRO sub-models translates into a non-convex, non-linear, optimization problem, where the economic equilibrium is determined by a single optimization. Finally, inclusion of a simple climate and damage model makes MERGE an Integrated Assessment Model. MERGE considers market (through production losses), and non-market damages (through losses in global welfare).

The model maximizes a welfare function defined as the net present value of the logarithm of regional consumption adjusted for the non-market damages. Included in the wealth of each MERGE region are initial endowments in fossil fuels, renewables, and CO2 emission permits.

MERGE links the regional ETA-MACRO sub-models, and aggregates the regional welfare functions, adjusted for the non-market damages, into a global welfare function using appropriate Negishi weights (Negishi, 1972). Global trade constraints applied in each period ensure that international trade of commodities is balanced. Regional technological learning with global spillovers, climate-change impacts and the associated market and non-market damages further enhance the regional links and interactions.

2.2 Technology Description

Table 1. Technologies used in MERGE5 and naming conventions
The two technologies with LBD become available in 2010 once sufficient RD&D investments will be made, otherwise are not available at all. Also, their penetration rates increases and their production cost is assumed to reduced due to RD&D spending.

<table>
<thead>
<tr>
<th>Electric technologies</th>
<th>Introduction date</th>
<th>Gen. Cost mills/kWh</th>
<th>Carbon Emissions kg C/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>HYDRO</td>
<td>Existing</td>
<td>40.0</td>
<td>0.0</td>
</tr>
<tr>
<td>NUC</td>
<td>Existing</td>
<td>50.0</td>
<td>0.0</td>
</tr>
<tr>
<td>GAS-R</td>
<td>Existing</td>
<td>35.7</td>
<td>0.1443</td>
</tr>
<tr>
<td>OIL-R</td>
<td>Existing</td>
<td>37.8</td>
<td>0.2094</td>
</tr>
<tr>
<td>COAL-R</td>
<td>Existing</td>
<td>20.3</td>
<td>0.2533</td>
</tr>
<tr>
<td>GAS-N</td>
<td>2000</td>
<td>30.3</td>
<td>0.0935</td>
</tr>
<tr>
<td>GAS-A</td>
<td>2020</td>
<td>47.7</td>
<td>0.0</td>
</tr>
<tr>
<td>COAL-NA</td>
<td>2000</td>
<td>40.6</td>
<td>0.1955</td>
</tr>
<tr>
<td>COAL-A</td>
<td>2020</td>
<td>55.9</td>
<td>0.0068</td>
</tr>
<tr>
<td>IGCC</td>
<td>2020</td>
<td>62.0</td>
<td>0.024</td>
</tr>
<tr>
<td>ADV-HC</td>
<td>Existing</td>
<td>95.0</td>
<td>0.0</td>
</tr>
<tr>
<td>LBDE*</td>
<td>2010</td>
<td>95.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Non-Electric technologies</th>
<th>US$/GJ</th>
<th>tons C/GJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLDU</td>
<td>2.5</td>
<td>0.0241</td>
</tr>
<tr>
<td>OIL1-OIL10</td>
<td>3-5.25</td>
<td>0.0199</td>
</tr>
<tr>
<td>GAS1-GAS10</td>
<td>2-4.25</td>
<td>0.0137</td>
</tr>
<tr>
<td>SYNF</td>
<td>8.33</td>
<td>0.04</td>
</tr>
<tr>
<td>RNEW</td>
<td>6.0</td>
<td>0.0</td>
</tr>
<tr>
<td>NEB-HC</td>
<td>14.0</td>
<td>0.0</td>
</tr>
<tr>
<td>LBDE*</td>
<td>14.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

*) The two technologies with LBD become available in 2010 once sufficient RD&D investments will be made, otherwise are not available at all. Also, their penetration rates increases and their production cost is assumed to reduced due to RD&D spending.

Technological learning describes how the specific cost of a given technology is reduced through the accumulation of knowledge. This learning process evolves either from manufacturing and operation of the technology (LBD) or research-and-development (LBS) expenditures allocated to that technology. A learning curve relates the specific cost incurred by a given technology to one or more factors describing the accumulation of knowledge in that technology.

Specific components of the energy technologies are treated as generic; for instance, high-cost (ADV-HC) and low-cost (ADV-LC) carbon-free power plants, or plants producing low-cost, non-electric energy from renewables (RNEW) are identified. Table 1 lists the technologies modelled in MERGE, with, the first generic learning technology corresponding to power generation and the second technology referring to a non-electric energy system.

We assume for LBD that a 20% cost reduction is incurred for each doubling in production, and a 15% cost reduction for each doubling in the knowledge stock. Also, a barrier is introduced to represent a maximum possible reduction of generating cost of (e.g., 40 mills per kWh for electric backstop systems and 6 US$/GJ for the non-electric backstop). Electric-generation backstop technologies consist of renewable sources, like wind, solar PV and biomass, new nuclear concepts and carbon capture and sequestration1. Non-electric energy-generation/carrier backstop technologies are identified with the

---

1 CCS systems are explicitly introduced in the technological options listed in Table 1 but as learning is not adopted for technologies other than the backstop systems, CCS systems are not explicitly introduced in the solution.
use of methanol or hydrogen fuels, while the primary-energy sources for these non-electric energy carriers are either biomass or renewable electricity or nuclear (i.e., a carbon-free non-exhaustible energy form). All technologies and the non-learning costs associated with these backstop systems are assumed to be encompassed in an autonomous cost reduction at a rate of 0.2% per annum.

2.3 The Two Factor Learning Curve

In the two-factor learning curve, the cumulative production (output) is used as a proxy for the accumulation of experience that affects the specific investment cost of a given technology. Similarly, the knowledge stock, defined as the accumulation of a depreciated R&D spending, is used to determine cost reductions attendant LBS processes. The learning curve for the generation cost $G_{C,k,t}$ (in US$ per MWh for electric or US$ per GJ for non-electric) of a technology $k$ is then defined as:

$$G_{C,k,t} = a \cdot CP_{k,t}^b \cdot KS_{k,t}^c$$  \hspace{1cm} (1)

with the knowledge stock $KS_{k,t}$ estimated as the depreciated sum of annual AR&D spending:

$$KS_{k,t} = KS_{k,t-1} \cdot (1-s) + AR&D_{k,t} \cdot ypp_t$$  \hspace{1cm} (2)

where $s$ is the depreciation factor (e.g., 3 percent per year) and $ypp$ the number of years per period.

The parameter $a$ can be calibrated by applying equation (1) for the initial point ($G_{C,k,0}$, $K_{S,k,0}$, $CP_{k,0}$) of the learning curve, and the parameters $b$ and $c$ are the learning indices. The latter define the speed of learning and are derived from the learning ratio. The learning ratio $lr$ is the rate at which the generating cost declines (e.g., 20%) each time the cumulative capacity doubles, while $lrs$ is the rate at which the cost declines each time the knowledge stock doubles. The relation between $b$, $c$, $lr$ and $lrs$ can be expressed as follows:

$$1 - lr = 2^b \text{ and } 1 - lrs = 2^c$$  \hspace{1cm} (3)

The model assumes that both "learning" and "knowledge" diffuse to the entire world and eventually create positive externalities. For the changes in the model, a few new variables and equations are defined. The new variables refer to the annual research and development (AR&D) spending, the knowledge stock ($KS$) and the amount of subsidized production ($SPE$). The cumulative production of electricity ($CP$) is based on the annual generation of unsubsidized $PE$, and subsidized electricity, $SPE$.

$$CP_{k,t} = CP_{k,t-1} + (PE_{k,t} + SPE_{k,t}) \cdot ypp_t$$  \hspace{1cm} (4)

The learning curve is coded directly as a non-linear and non-convex formulation according to equation (5), e.g., as function of the cumulative production and the knowledge stock relative to the starting year. The CONOPT3 optimizer defines directly

---

1 The initial annual energy R&D is 360 million US$ equally divided for electric and non-electric backstop technologies. The assumed initial knowledge stock is 8 times the annual spending with a maximum annual growth rate in R&D of 5 percent. The depreciation rate of knowledge is 3% per year.
the global optimal solution in the case that terminal conditions are defined such that local optima are excluded, as explained by Manne and Barreto, (2004).

\[
\frac{GC_{k,t}}{GC_{k,0}} = \left( \frac{CP_{k,t}}{CP_{k,0}} \right)^{-b} \left( \frac{KS_{k,t}}{KS_{k,0}} \right)^{c}
\]  

(5)

The budget equation of MERGE is re-formulated to take into account R&D spending and the subsidies in learning investments. We assume that knowledge creates positive externalities due to spillovers across different production firms and regions. We also assume public support via subsidies (e.g., learning investments) in the early stage of technology implementation. If the subsidized backstop systems become competitive in the markets their cost decreases with time based on LBD and LBS. Equation (6) describes the budget constraint; \( C_{rt} \) is for consumption; \( I_{rt} \) for investments; \( EC_{rt} \) for the energy cost; \( DC_{rt} \) for damages and \( NTX_{rt} \) for the net trade balance of a region.

\[
Y_{rt} = C_{rt} + I_{rt} + EC_{rt} + DC_{rt} + NTX_{rt} + AR & D_{rt}
\]  

(6)

We also assume that the two learning technologies could be made available in 2010 if competitive, while their penetration rates are increased (e.g., to 13.5 % per annum; i.e., above the standard value of 11.5% applied in MERGE). Annualized R&D spending is included in the budget Eq. (6) but they are introduced only when enough benefits are generated to compensate for the cost of research and development. In other words, the induced benefits of the cost reduction for energy production should be greater than the discounted and cumulative cost of R&D. The subsidies option was not active in this study.

3 Case studies

3.1 The BaU cases

Several scenarios related to CO₂ emission control are presented as illustrations of the results generated by this version of MERGE. Apart from the business-as-usual (BaU) cases, where CO₂ emissions are not limited, we have considered the implications of stabilizing atmospheric carbon concentrations to 550-450 ppmv. All scenarios are assessed with and without ETL options. The baseline case is designated by BaUS, where technological change is endogenous. The database for the baseline cases reflects the original technology data of MERGE5, while the growth data are downwards adjusted to reflect the assumptions of the Innovation Modelling Comparison Project (IMCP). Constraints are introduced only on the CO₂ concentration although MERGE considers all other greenhouse gases (GHGs), carbon sinks and aerosols.

All stabilization scenarios without ETL assume that the penetration of backstop technologies is on the same levels as in the baseline case with ETL. This is equivalent with the assumption that in these scenarios the same level of RD&D spending or investments into niche markets will take place.
In the BaUS case, the world GDP grows more than 9 times (i.e., to US$312.5 trillion in 2100); but primary-energy supply and carbon emissions are strongly decoupled from economic growth and increase to 1246 EJ of primary energy per annum (at 45% efficiency for the backstop electricity) and 17.91 GtC/yr carbon emissions in 2100. In the BaUS case, global CO₂ concentrations increase to 693 ppmv, while the average temperature rise between the year 2000 and the year 2100 is 2.36° Celsius. Most of the economic growth occurs in economies (currently) in transition and in developing countries. Regional differences in income, primary-energy intensity, and carbon intensity of GDP are decreasing over time. The currently less-developed countries assume a high economic growth such that they will produce most of the global GDP in the year 2100 while OECD countries will contribute by 38% to the total output. It should be noted that the potential socio-economic growth underlying this scenario is exogenous as well as the autonomous efficiency improvement.

Energy efficiency and decarbonisation continue to contribute to improved energy, economic, and environmental indices. Policies that support technological learning result in a strong contribution of renewables in meeting non-electric-sector demands. This shift enhances the use of non-electric backstop technologies. For the BaUS case, therefore, renewable-energy sources and nuclear contribute 38%, coal 46%, oil 7% and gas 9% of the energy mix. Figure 2 illustrates the impact of learning on the generating cost of electricity for the 450-ppmv cases. We assume a moderate exogenous rate of generation cost reduction that of 0.2% per year. The most significant mechanism in cost reduction is the contribution of the LBD while LBS is important during the first, introductory periods of the new technologies.
Fig. 2: A significant cost reduction over time is shown when LBD applies. RD&D policies are important in the early stage of introducing a new technology.

3.3 Stabilizing carbon concentrations

Economic considerations govern the transition to a low-carbon economy. Two of these considerations represent key options for the second half of this century: the exhaustion of oil and gas resources, and the significant cost reduction in carbon-free energy technologies. When R&D policies are appropriately applied, we attain a significant reduction of energy generation cost and carbon control costs, as shown in Figures 2 to 4. Obviously, the stronger the carbon constraint is, the faster the penetration of carbon-free technologies into the market mixes, and the stronger the relative cost reduction.

Fig. 3: Cumulative and undiscounted GWP losses for the Carbon stabilization cases, relative to BaUS. Global losses are significantly reduced in the case of LBD and LBS. For the 450-ppmv cases, the cumulative loss is reduced to 0.56%.
The scenarios where atmospheric CO₂ concentration is held to 450-ppmv assume that efficient strategies will be adopted worldwide and a full-scope transfer of “know-how” will take place. Under these circumstances, the following conclusions can be made: First, the induced cumulative GWP losses of the carbon-stabilization are low (e.g., in relation to the cumulative baseline-GWP): for example, below 1.26% in the case without learning, while with ETL policies the GWP losses are less than 0.55% (Figure 3). Secondly, the marginal costs related to carbon stabilization are also reduced to a fraction of the marginal cost without learning (Figure 5), but remain always significant for the case of the 450 ppmv atmospheric carbon limit (e.g., below 600 $/tC in the 450 ppmv case with ETL).

Fig. 4: The marginal costs of carbon control are reduced by almost 50% by the end of the century in the case of ETL and in relation with cases without learning. To avoid terminal conditions effects on the shadow prices by the end of time horizon the cases have been analyzed up to 2120 while results are reported up to 2100.

4. Calibration and Sensitivity Analyses

The mathematical formulation of the production function in MERGE is given by the set of equations (7):

\[ Y = \left[ a \left( K^{\alpha} \cdot L^{1-\alpha}\right) + b \left( E^\beta \cdot NE^{1-\beta}\right) \right]^{1/\rho} \]

with \( \rho = (\sigma - 1) / \sigma \quad \sigma \neq 0,1, \infty \)

The aggregate economic output \( Y \) is described by a nested constant elasticity of substitution function between the value added pairs of capital (K) and Labour (L) and the energy related pairs of electric (E) and non-electric (NE) energy. Details of the calibration procedure are explained in the Appendix together with the key input used for the specification of the reference development.

1 MERGE is neither an endogenous growth model nor considers explicitly R&D for the non-energy sector. A new model formulation that includes R&D in energy conservation and non-energy related R&D was beyond the scope of the IMCP study due to time and resource limitations.
The standard MERGE model is calibrated such that the primary energy use, the regional GDP, the installed capacities and electricity production by region are consistent with the statistics of the starting year. Also, emissions and energy flows for the first decades are consistent with EIA projections given in the IEO (2004) report. There is no effort to provide empirical estimates of the production function of the model. Instead, the authors describe in “Buying Greenhouse Gas Insurance” (Manne and Richels, 1992) the model’s ability to reproduce past statistics. This model verification work is not repeated here. Instead, we perform a sensitivity analysis with alternative assumptions on key model input parameters like the elasticity of substitution (ESUB), the autonomous efficiency improvement (AEEI) and the learning rates (LBD & LBS) to check the robustness of our conclusions reported herein and to explain the model behaviour. Details of the sensitivity analyses are explained in the Appendix.

As the model introduces R&D spending as a decision variable, it was not possible to perform any sensitivity analyses on R&D other than assuming different elasticity values for learning by searching. Thus, learning elasticity rates describing LBD and the LBS performance are reduced to 50% of their reference levels.

The AEEI factor is a modelling invention to describe the autonomous (i.e., price independent) decoupling between economic growth and primary energy use. MERGE assumes that the AEEI is a given fraction (e.g., 40% to 50%) of the regional economic growth rate. In most of the cases structural economic changes and not the efficiency improvement, explain the value of the factor, in spite of the name used. On the other hand, the elasticity of substitution (ESUB) describes the price-induced substitution for energy using capital and labour when the energy price changes. The higher the value of ESUB the easier it is to substitute capital and labour for energy when prices increase. Interesting is to emphasize that at low energy system costs ESUB is almost the same as the absolute value of the price elasticity of demand. In the sensitivity analyses ESUB is increased by 10% for Annex I and by 20% for non-Annex I regions. Key results are reported in Figures 5 and 6; e.g., the primary energy use change and the cumulative GWP in relation with the 450 ppmv case under endogenous technological change.

![Fig. 5: Cumulative Primary Energy (2000-2120) change relative to 450 ppmv Reference case in percent. The level of primary energy use per case is very sensitive to the AEEI factor.](image-url)
Results on primary energy use are very sensitive to the AEEI factor but less sensitive to ESUB. Assuming a reduction by 50% to the LBD and the LBS elasticity increases the economic cost of carbon control and the marginal cost of energy production and reduces primary energy demand as energy becomes more expensive.

Fig. 6: Cumulative GWP change (2000-2120) relative to the 450 ppmv reference case in percent
5. Conclusions

Technological progress has and will continue to play a fundamental role in the evolution of energy systems; as such progress favours the transition toward more-efficient, economic, and cleaner energy technologies, rather than being driven by resource depletion per se. It is important, therefore, to incorporate the dynamics of technological change into energy system models. The work reported herein quantifies the impacts of RD&D spending on the development and promotion of carbon-free energy technologies that mitigate global warming. To quantify these impacts, the TFLC formulation has been introduced together with learning investments in favour of the two clusters of backstop technologies in MERGE5. Impacts have been quantified with the help of top-level economy indicators and a sensitivity analyses on key input factors is performed. We also considered several scenarios related to CO2 emissions and technological learning.

Although our model shows that technological learning favours new advanced backstop systems, this model formulation does not significantly change the conclusions derived from the original MERGE model for the first half of this century; as fossil fuels (mainly coal and natural gas) will continue to retain a significant share of the global electricity and energy-supply markets in the next 50 years, while energy-related carbon emissions will continue to grow substantially. But, RD&D spending is significantly increased in the first half of the century paving the way to reach carbon mitigation targets.

In the case where atmospheric carbon is stabilized at 450-ppmv, a significant development and market penetration of low-carbon generation options is required. Technological learning in these circumstances favours new advanced systems, represented collectively in the model as electric and non-electric backstop systems. Finally, the importance of technological progress for carbon control has been shown, as such progress allows low-cost carbon-reduction options to enter the generation mix and, hence, reduces GWP losses and minimizes the marginal cost of carbon control.

With the help of the main results and the sensitivity analyses shown herein, we conclude that RD&D increased commitments (either private or public) towards the development of new technologies, is a key strategy against global warming as otherwise conventional technologies will be locked-in the system.

5. References


Appendix: MERGE calibration

The production function

The aggregate economic output $Y$ is described by a nested constant elasticity of substitution function between the value added pairs of capital ($K$) and Labour ($L$) and the energy related pairs of electric ($E$) and non-electric ($NE$) energy. $a$ and $b$ are scaling factors which are defined based on first-order optimality conditions taking into account the price of oil at the refinery at gate. The autonomous energy efficiency improvement factor (AEEI) is summarized by the growth of the scaling factor $b$. $\alpha$ denotes the optimal value share of capital in the value added pair and $\beta$ the optimal value share of electricity in the energy pair.

$$Y = \left[a(K^\alpha \cdot L^{1-\alpha})^\rho + b(E^\beta \cdot NE^{(1-\beta)})^\rho\right]^{1/\rho}$$

with $\rho = (\sigma - 1)/\sigma$, $\sigma \neq 0,1,\infty$

if $f \equiv a(K^\alpha \cdot L^{1-\alpha})^\rho + b(E^\beta \cdot NE^{(1-\beta)})^\rho$ then, $Y = f^{1/\rho}$

Calibration

We apply the first-order optimality condition for the starting period:

$$\partial Y / \partial NE = PN = \partial Y / \partial f \cdot \partial f / \partial NE$$

$$PN = 1/\rho \cdot f^{1/\rho-1} \cdot \rho \cdot b \cdot (1 - \beta) \cdot E^{\beta \rho} \cdot NE^{(1-\beta)\rho-1} \Rightarrow$$

$$b = PN \cdot Y^{\rho-1} / ((1 - \beta) \cdot E^{\beta \rho} \cdot NE^{(1-\beta)\rho-1})$$

with known $b$ we can define $a$ as:

$$a = Y^\rho - b(E^\beta \cdot NE^{(1-\beta)})^\rho / (K^\alpha \cdot L^{1-\alpha})^\rho$$

The autonomous energy efficiency improvement factors (aeei):

We assume that energy use per unit of output follows an autonomous (i.e., price independent) annual rate of efficiency improvement $aeei$. The factor is defined such that it varies around 0.5% of the GDP growth rate. The factors and the Labour productivity define the reference energy use time path assuming that energy prices remain constant.

$$E_{ref_t} = L_t \cdot E_0 \cdot \prod_{t=1,t} (1 - aeei_t)^{supp}$$

$$N_{ref_t} = L_t \cdot N_0 \cdot \prod_{t=1,t} (1 - aeei_t)^{supp}$$

$$Y_{ref_t} = L_t \cdot Y_0$$

$$K_{ref_t} = L_t \cdot K_0$$

Applying the first-order optimality conditions again we can define the reference development such that the scaling factors depend on time and to avoid the rebound effect i.e., artificial demand increase.
\[ b_t = P N_0 \cdot \text{Ref}_{t-1}^\rho \cdot \left(1 - \beta \right) \cdot \text{Ref}_{t}^{\beta \rho} \cdot N_{\text{ref}}^{(1-\beta)\rho-1} \]

\[ a_t = \text{Ref}_{t}^{\beta \rho} - b_t \cdot \left(\text{Ref}_{t}^{\beta \rho} \cdot N_{\text{ref}}^{(1-\beta)}\right)^{\rho} \cdot \left(K_{\text{ref}}^{\alpha} \cdot L_{t-1}^{1-\rho}\right)^{\rho} \]

Data used in the model and values applied in the sensitivity analyses:

Table 1: Regional population in billions

<table>
<thead>
<tr>
<th>Year</th>
<th>Usa</th>
<th>Weur</th>
<th>Japan</th>
<th>Canz</th>
<th>Eefsu</th>
<th>china</th>
<th>India</th>
<th>Mopec</th>
<th>Row</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>0.276</td>
<td>0.389</td>
<td>0.127</td>
<td>0.054</td>
<td>0.412</td>
<td>1.275</td>
<td>1.009</td>
<td>0.608</td>
<td>1.899</td>
</tr>
<tr>
<td>2005</td>
<td>0.30</td>
<td>0.30</td>
<td>0.13</td>
<td>0.06</td>
<td>0.40</td>
<td>1.37</td>
<td>1.16</td>
<td>0.73</td>
<td>2.28</td>
</tr>
<tr>
<td>2010</td>
<td>0.31</td>
<td>0.31</td>
<td>0.13</td>
<td>0.06</td>
<td>0.40</td>
<td>1.41</td>
<td>1.23</td>
<td>0.79</td>
<td>2.48</td>
</tr>
<tr>
<td>2015</td>
<td>0.33</td>
<td>0.33</td>
<td>0.13</td>
<td>0.06</td>
<td>0.39</td>
<td>1.45</td>
<td>1.29</td>
<td>0.86</td>
<td>2.68</td>
</tr>
<tr>
<td>2020</td>
<td>0.33</td>
<td>0.33</td>
<td>0.13</td>
<td>0.06</td>
<td>0.39</td>
<td>1.47</td>
<td>1.36</td>
<td>0.95</td>
<td>2.97</td>
</tr>
<tr>
<td>2025</td>
<td>0.35</td>
<td>0.35</td>
<td>0.13</td>
<td>0.06</td>
<td>0.39</td>
<td>1.49</td>
<td>1.41</td>
<td>1.03</td>
<td>3.21</td>
</tr>
<tr>
<td>2030</td>
<td>0.35</td>
<td>0.35</td>
<td>0.13</td>
<td>0.06</td>
<td>0.39</td>
<td>1.49</td>
<td>1.44</td>
<td>1.09</td>
<td>3.40</td>
</tr>
<tr>
<td>2035</td>
<td>0.35</td>
<td>0.35</td>
<td>0.13</td>
<td>0.06</td>
<td>0.39</td>
<td>1.49</td>
<td>1.47</td>
<td>1.19</td>
<td>3.69</td>
</tr>
<tr>
<td>2040</td>
<td>0.35</td>
<td>0.35</td>
<td>0.13</td>
<td>0.06</td>
<td>0.39</td>
<td>1.49</td>
<td>1.49</td>
<td>1.22</td>
<td>3.80</td>
</tr>
<tr>
<td>2045</td>
<td>0.35</td>
<td>0.35</td>
<td>0.13</td>
<td>0.06</td>
<td>0.39</td>
<td>1.49</td>
<td>1.50</td>
<td>1.26</td>
<td>3.94</td>
</tr>
<tr>
<td>2050</td>
<td>0.35</td>
<td>0.35</td>
<td>0.13</td>
<td>0.06</td>
<td>0.39</td>
<td>1.49</td>
<td>1.50</td>
<td>1.31</td>
<td>4.08</td>
</tr>
</tbody>
</table>

Table 2: Reference development expressed as GDP in trillion USA $\times1000$ per year that defines the labour productivity growth (L)

<table>
<thead>
<tr>
<th>Year</th>
<th>Usa</th>
<th>Weur</th>
<th>Japan</th>
<th>Canz</th>
<th>Eefsu</th>
<th>china</th>
<th>India</th>
<th>Mopec</th>
<th>Row</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>9.83</td>
<td>9.76</td>
<td>4.60</td>
<td>1.32</td>
<td>1.05</td>
<td>1.17</td>
<td>0.52</td>
<td>1.25</td>
<td>3.91</td>
</tr>
<tr>
<td>2005</td>
<td>11.08</td>
<td>10.88</td>
<td>4.88</td>
<td>1.54</td>
<td>1.29</td>
<td>1.68</td>
<td>0.67</td>
<td>1.46</td>
<td>4.55</td>
</tr>
<tr>
<td>2010</td>
<td>13.10</td>
<td>12.26</td>
<td>5.42</td>
<td>1.79</td>
<td>1.59</td>
<td>2.30</td>
<td>0.87</td>
<td>1.83</td>
<td>5.72</td>
</tr>
<tr>
<td>2015</td>
<td>15.27</td>
<td>13.76</td>
<td>5.937</td>
<td>2.057</td>
<td>1.93</td>
<td>3.092</td>
<td>1.129</td>
<td>2.266</td>
<td>7.08</td>
</tr>
<tr>
<td>2020</td>
<td>17.58</td>
<td>15.43</td>
<td>6.461</td>
<td>2.353</td>
<td>2.32</td>
<td>4.126</td>
<td>1.457</td>
<td>2.75</td>
<td>8.956</td>
</tr>
<tr>
<td>2030</td>
<td>19.73</td>
<td>17.86</td>
<td>7.185</td>
<td>2.752</td>
<td>2.994</td>
<td>5.967</td>
<td>2.227</td>
<td>3.861</td>
<td>12.055</td>
</tr>
<tr>
<td>2040</td>
<td>22.03</td>
<td>20.56</td>
<td>7.956</td>
<td>3.198</td>
<td>3.853</td>
<td>8.524</td>
<td>3.33</td>
<td>5.279</td>
<td>16.461</td>
</tr>
<tr>
<td>2050</td>
<td>24.44</td>
<td>23.48</td>
<td>8.769</td>
<td>3.689</td>
<td>4.942</td>
<td>12.077</td>
<td>4.909</td>
<td>7.08</td>
<td>22.047</td>
</tr>
<tr>
<td>2070</td>
<td>29.53</td>
<td>29.97</td>
<td>10.498</td>
<td>4.789</td>
<td>8.023</td>
<td>23.704</td>
<td>10.37</td>
<td>12.211</td>
<td>37.933</td>
</tr>
<tr>
<td>2080</td>
<td>32.15</td>
<td>33.46</td>
<td>11.4</td>
<td>5.384</td>
<td>10.132</td>
<td>32.754</td>
<td>14.891</td>
<td>15.777</td>
<td>48.954</td>
</tr>
<tr>
<td>2090</td>
<td>34.78</td>
<td>37.03</td>
<td>12.313</td>
<td>5.997</td>
<td>12.696</td>
<td>44.69</td>
<td>21.199</td>
<td>20.196</td>
<td>62.595</td>
</tr>
<tr>
<td>2100</td>
<td>37.38</td>
<td>40.63</td>
<td>13.23</td>
<td>6.615</td>
<td>15.76</td>
<td>59.993</td>
<td>29.863</td>
<td>25.622</td>
<td>79.337</td>
</tr>
<tr>
<td>2110</td>
<td>39.91</td>
<td>44.20</td>
<td>14.14</td>
<td>7.227</td>
<td>19.347</td>
<td>78.912</td>
<td>41.51</td>
<td>32.221</td>
<td>99.679</td>
</tr>
<tr>
<td>2120</td>
<td>42.35</td>
<td>47.67</td>
<td>15.034</td>
<td>7.822</td>
<td>23.446</td>
<td>101.277</td>
<td>56.72</td>
<td>40.148</td>
<td>124.101</td>
</tr>
</tbody>
</table>
Table 3: Macroeconomic parameters used for the calibration of the production function

<table>
<thead>
<tr>
<th></th>
<th>Usa</th>
<th>Weur</th>
<th>Japan</th>
<th>Canz</th>
<th>Eefsu</th>
<th>china</th>
<th>India</th>
<th>Mopec</th>
<th>Row</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital to GDP</td>
<td>2.4</td>
<td>2.8</td>
<td>2.8</td>
<td>2.8</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>ESUB</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Capital Value-share</td>
<td>0.24</td>
<td>0.28</td>
<td>0.28</td>
<td>0.28</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Electricity Value-share</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>Price of oil $/GJ</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3.7</td>
<td>4</td>
<td>4</td>
<td>3.7</td>
<td>4</td>
</tr>
<tr>
<td>Non-Electric $/GJ</td>
<td>2.75</td>
<td>5</td>
<td>6</td>
<td>4</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Sensitivity study on the elasticity of substitution (ESUB) by region

<table>
<thead>
<tr>
<th></th>
<th>Usa</th>
<th>Weur</th>
<th>Japan</th>
<th>Canz</th>
<th>Eefsu</th>
<th>china</th>
<th>India</th>
<th>Mopec</th>
<th>Row</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESUB-Sensitivity</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>ESUB-Reference</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Sensitivity study on AEEI:

The model defines AEEI by multiplying the annual GDP growth rate (minus of the annual population growth) by a factor of 0.5. This factor was increased by 20%, i.e. from 0.5 to 0.6.

Sensitivity study on learning by doing (LBD) and learning by searching (LBS):

The LBD elasticity was reduced from 20% to 10% per doubling of experience while the LBS factor was reduced from 15% to 7.5% per doubling of knowledge stock.

Results obtained for the sensitivity analyses not shown in the main report:

Two extra figures are given herein; the first refers to cumulative primary energy use and the second to the marginal cost estimates. The primary energy use is quite sensitive to the AEEI factor as it varies almost proportional to the factor modifying the AEEI coefficients. The fact that the relative reduction of the primary energy is not exactly proportional to the change is due to the model specification for the first decades that is kept constant to the results to the International Energy Outlook.

The shadow prices for the 450 ppmv cases indicate the existence of two peaks, one in the year 2070 and a second in the year 2110 with a valley around 2090. It also shows that shadow prices after 2090 are independent of the parameters varied in the sensitivity analyses. The first peak appears only in the 450 ppmv case that forces early and strong penetration of low carbon emitting technologies. The second peak is due to terminal conditions in MERGE.
Fig. 7: Cumulative Primary Energy (2000-2120) for the 450 ppmv reference and sensitivity cases. The primary energy use is very sensitive to the AEEI factor.

Fig. 8: Shadow prices for the 450 ppmv reference and sensitivity cases. Model results are sensitive to the reduction of LBD and LBS factors (which are changed by 50%) only around 2070 but back-stop systems do not dictate the shadow prices after 2080.
NOTE DI LAVORO DELLA FONDAZIONE ENI ENRICO MATTEI

Fondazione Eni Enrico Mattei Working Paper Series

Our Note di Lavoro are available on the Internet at the following addresses:
http://www.feem.it/Feem/Pub/Publications/WPapers/default.html
http://www.repec.org

NOTE DI LAVORO PUBLISHED IN 2004

IEM 1.2004 Anil MARKANDYA, Suzette PEDROSO and Alexander GOLUB: Empirical Analysis of National Income and So2 Emissions in Selected European Countries

ETA 2.2004 Masahika FUJITA and Shlomo WEBER: Strategic Immigration Policies and Welfare in Heterogeneous Countries

PRA 3.2004 Adolfo DI CARLUCCIO, Giovanni FERRI, Cecilia FRALE and Ottavio RICCHI: Do Privatizations Boost Household Shareholding? Evidence from Italy

ETA 4.2004 Victor GINSBURGH and Shlomo WEBER: Languages Disenfranchisement in the European Union


PRA 7.2004 Sandro BRUSCO, Giuseppe LOPOMO and S. VISWANATHAN (lvx): Merger Mechanisms

PRA 8.2004 Wolfgang AUSSENEGG, Pegaret PICHLER and Alex STOMPER (lvx): IPO Pricing with Bookbuilding, and a When-Issued Market

PRA 9.2004 Pegaret PICHLER and Alex STOMPER (lvx): Primary Market Design: Direct Mechanisms and Markets


PRA 11.2004 Bjarne BRENDSTRUP and Harry J. PAARSCH (lvx): Nonparametric Identification and Estimation of Multi-Unit, Sequential, Oral, Ascending-Price Auctions With Asymmetric Bidders

PRA 12.2004 Ohad KADAN (lvx): Equilibrium in the Two Player, k-Double Auction with Affiliated Private Values

PRA 13.2004 Maarten C.W. JANSEN (lvx): Auctions as Coordination Devices

PRA 14.2004 Gadi FIBICH, Arieh GAVIOUS and Aner SELA (lvx): All-Pay Auctions with Weakly Risk-Averse Buyers

PRA 15.2004 Orly SADE, Charles SCHNITZLEIN and Jaime P. ZENDER (lvx): Competition and Cooperation in Divisible Good Auctions: An Experimental Examination

CCMP 16.2004 Marta STRYSZOWSKA (lvx): Late and Multiple Bidding in Competing Second Price Internet Auctions


SIEV 18.2004 Marta STRYSZOWSKA (lvx): Profile Tourists for Balanced Utilization of Tourism-Based Resources in Kenya

NRM 19.2004 Anna ALBERINI, Paolo ROSATO, Alberto LONGO and Valentina ZANATTA: Information and Willingness to Pay in a Contingent Valuation Study: The Value of S. Erasmo in the Lagoon of Venice


NRM 21.2004 Jacqueline M. HAMILTON (lvxii): Climate and the Destination Choice of German Tourists


NRM 23.2004 Pius ODUNGA and Henk FOLMER (lvxii): Profiling Tourists for Balanced Utilization of Tourism-Based Resources in Kenya


NRM 26.2004 Juan Luis EUGENIO-MARTIN, Noelia MARTIN MORALES and Riccardo SCARPA (lvxii): Tourism and Economic Growth in Latin American Countries: A Panel Data Approach

NRM 27.2004 Raúl Hernández MARTÍN (lvxii): Impact of Tourism Consumption on GDP: The Role of Imports


NRM 29.2004 Marian WEBER (lvxii): Assessing the Effectiveness of Tradable Landuse Rights for Biodiversity Conservation: an Application to Canada’s Boreal Mixedwood Forest

NRM 30.2004 Trond BJORNDAL, Phoebe KOUNDOURI and Sean PASCOE (lvxii): Output Substitution in Multi-Species Trawl Fisheries: Implications for Quota Setting


CTN 33.2004 Wilson PEREZ: Divide and Conquer: Noisy Communication in Networks, Power, and Wealth Distribution


Rob DELLINK and Ekko van IERLAND: Pollution Abatement in the Netherlands: A Dynamic Applied General Equilibrium Assessment

Rosella LEVAGGI and Michele MORETTO: Investment in Hospital Care Technology under Different Purchasing Rules: A Real Option Approach

Salvador BARBERA and Matthew O. JACKSON (lxx): On the Weights of Nations: Assigning Voting Weights in a Heterogeneous Union

Alex ARENAS, Antonio CABRALES, Albert DÍAZ-GUILERA, Roger GUIMERÀ and Fernando VEGA-REDONDO (lxx): Optimal Information Transmission in Organizations: Search and Congestion

Francis BLOCH and Armando GOMES (lxx): Contracting with Externalities and Outside Options

Rabah AMIR, Efrosyni DIAMANTOUDI and Licun XUE (lxx): Merger Performance under Uncertain Efficiency Gains

Francis BLOCH and Matthew O. JACKSON (lxx): The Formation of Networks with Transfers among Players

Daniel DIERMEIER, Hulya ERASLAN and Antonio MERLO (lxx): Bicameralism and Government Formation

Rod GARRATT, James E. PARCO, Cheng-ZHONG QIN and Amnon RAPOPORT (lxx): Potential Maximization and Coalition Government Formation

Kfir ELIAZ, Debraj RAY and Ronny RAZIN (lxx): Group Decision-Making in the Shadow of Disagreement

Sanjeev GOTAL, Marco van der LEIJ and José Luis MORAGA-GONZÁLEZ (lxx): Economics: An Emerging Small World?

Edward CARTWRIGHT (lxx): Learning to Play Approximate Nash Equilibria in Games with Many Players

Finn R. FØRUND and Michael HOEL: Properties of a Non-Competitive Electricity Market Dominated by Hydroelectric Power

Elissaios PAPYRakis and Reyer GERLAGH: Natural Resources, Investment and Long-Term Income

Marzio GALEOTTI and Claudia KEMPFERT: Interactions between Climate and Trade Policies: A Survey

A. MARKANDYA, S. PEDROS0 and D. STREMIKIE: Energy Efficiency in Transition Economies: Is There Convergence Towards the EU Average?

Rolf GOLOMBEK and Michael HOEL: Climate Agreements and Technology Policy

Sergei IZMALKOV (lxx): Multi-Unit Open Ascending Price Efficient Auction

Gianmarco I. P. OTTAVIANO and Giovanni PERI: Cities and Cultures

Massimo DEL GAITO: Agglomeration, Integration, and Territorial Authority Scale in a System of Trading Cities, Centralisation versus devolution

Pierre-André JOUVE, Philippe MICHEL and Gilles ROTILLON: Equilibrium with a Market of Permits

Bob van der ZWAAN and Reyer GERLAGH: Climate Uncertainty and the Necessity to Transform Global Energy Supply

Francesco BOSELLO, Marco LAZZARIN, Roberto ROSON and Richard S.J. TOL: Economy-Wide Estimates of the Implications of Climate Change: Sea Level Rise

Gustavo BERGANTINOS and Juan J. VIDAL-PUGA: Defining Rules in Cost Spanning Tree Problems Through the Canonical Form

Siddhartha BANDYOPADHYAY and Mandar OAK: Party Formation and Coalitional Bargaining in a Model of Proportional Representation

Hans-Peter WEIKARD, Michael FINUS and Juan-Carlos ALTAMIRANO-CABRERA: The Impact of Surplus Sharing on the Stability of International Climate Agreements

Chiara M. TRAVISI and Peter NIJKAMP: Willingness to Pay for Agricultural Environmental Safety: Evidence from a Survey of Milan, Italy, Residents

Chiara M. TRAVISI, Raymond J. G. M. FLORAX and Peter NIJKAMP: A Meta-Analysis of the Willingness to Pay for Reductions in Pesticide Risk Exposure

Valentina BOSETTI and David TOMBERLIN: Real Options Analysis of Fishing Fleet Dynamics: A Test

Alessandra GORIA e Gretel GAMBARELLI: Economic Evaluation of Climate Change Impacts and Adaptability in Italy

Massimo FLORIO and Mara GRASSEN: The Missing Shock: The Macroeconomic Impact of British Privatisation

John BENNETT, Saul ESTRIN, James MAW and Giovanni URG: Privatisation Methods and Economic Growth in Transition Economies

Kira BÖRNER: The Political Economy of Privatization: Why Do Governments Want Reforms?

Pehr-Johan NORBACK and Lars PERSSON: Privatization and Restructuring in Concentrated Markets

Angela GRANZOTTO, Fabio PRANOVI, Simone LIBRALATO, Patrizia TORRICELLI and Danilo MAINARDI: Comparison between Artisanal Fishery and Manila Clam Harvesting in the Venice Lagoon by Using Ecosystem Indicators: An Ecological Economics Perspective

Somdeb LAHIRI: The Cooperative Theory of Two Sided Matching Problems: A Re-examination of Some Results

Giuseppe DI VITA: Natural Resources Dynamics: Another Look

Anna ALBERINI, Alistair HUNT and Anil MARKANDYA: Willingness to Pay to Reduce Mortality Risks: Evidence from a Three-Country Contingent Valuation Study

Valeria PAPPONETTI and Dino PINELLI: Scientific Advice to Public Policy-Making

Paulo A.L.D. NUNES and Laura ONOFRI: The Economics of Warm Glow: A Note on Consumer’s Behavior and Public Policy Implications

Patrick CAYrade: Investments in Gas Pipelines and liquefied Natural Gas Infrastructure What is the Impact on the Security of Supply?

Valeria COSTANTINI and Francesco GRACCEVA: Oil Security, Short- and Long-Term Policies
IEM 116.2004 Valeria COSTANTINI and Francesco GRACCEVA: Social Costs of Energy Disruptions
Christian EGENHOFER, Kyrilas GIALLOGLIOU, Giacomo LUCIANI, Maroeka BOOTS, Martin SCHEEPERS,
IEM 117.2004 Valeria COSTANTINI, Francesco GRACCEVA, Anil MARKANDYA and Giorgio VICINI: Market-Based Options
for Security of Energy Supply
IEM 119.2004 Giacomo LUCIANI: Security of Supply for Natural Gas Markets. What is it and What is it not?
IEM 120.2004 L.J. de VRIES and R.A. HAKVOORT: The Question of Generation Adequacy in Liberalised Electricity Markets
KTHC 121.2004 Alberto PETRUCCI: Asset Accumulation, Fertility Choice and Nondegenerate Dynamics in a Small Open
Economy
NRM 122.2004 Carlo GIUPPONI, Jaroslav MYSIAK and Anita FASSIO: An Integrated Assessment Framework for Water
Resources Management: A DSS Tool and a Pilot Study Application
NRM 123.2004 Margarethia BREIL, Anita FASSIO, Carlo GIUPPONI and Paolo ROSATO: Evaluation of Urban Improvement on
the Islands of the Venice Lagoon: A Spatially-Distributed Hedonic-Hierarchical Approach
ETA 124.2004 Paul MENSINK: Instant Efficient Pollution Abatement Under Non-Linear Taxation and Asymmetric
Information: The Differential Tax Revisited
NRM 125.2004 Mauro FABIANO, Gabriella CAMARSA, Rosanna DURSI, Roberta VALDI, Valentina MARIN and Francesca
PALMISANI: Integrated Environmental Study for Beach Management:A Methodological Approach
PRA 126.2004 Irena GROSFELD and Iraj HASHI: The Emergence of Large Shareholders in Mass Privatized Firms: Evidence
from Poland and the Czech Republic
CCMP 127.2004 Maria BERRITTELLA, Andrea BIGANO, Roberto ROSON and Richard S.J. TOL: A General Equilibrium
Analysis of Climate Change Impacts on Tourism
CCMP 128.2004 Reyer GERLAGH: A Climate-Change Policy Induced Shift from Innovations in Energy Production to Energy
Savings
NRM 129.2004 Elissas PAPYRAKIS and Reyer GERLAGH: Natural Resources, Innovation, and Growth
PRA 130.2004 Bernardo BORTOLOTTI and Mara FACCIO: Reluctant Privatization
SIEV 131.2004 Riccardo SCARPA and Mara THIENE: Destination Choice Models for Rock Climbing in the Northeast Alps: A
Latent-Class Approach Based on Intensity of Participation
for Public Goods: Finite Versus Continuous Mixing in Logit Models
IEM 133.2004 Santiago J. RUBIO: On Capturing Oil Rents with a National Excise Tax Revisited
ETA 134.2004 Ascensión ANDINA DÍAZ: Political Competition when Media Create Candidates’ Charisma
SIEV 135.2004 Anna ALBERINI: Robustness of VSL Values from Contingent Valuation Surveys
CCMP 136.2004 Gernot KLEPPER and Sonja PETERSON: Marginal Abatement Cost Curves in General Equilibrium: The
Influence of World Energy Prices
CCMP 137.2004 Herbert DAWID, Christophe DEISSENBERG and Pavel ŠEVČIK: Cheap Talk, Gullibility, and Welfare in an
Environmental Taxation Game
CCMP 139.2004 Reyer GERLAGH and Marjan W. HOFKES: Time Profile of Climate Change Stabilization Policy
NRM 140.2004 Chiara D’ALPAOS and Michele MORETTO: The Value of Flexibility in the Italian Water Service Sector: A
Real Option Analysis
PRA 141.2004 Patrick BAJARI, Stephanie HOUTHOUT and Steven TADELIS: (lxxi): Bidding for Incompete Contracts
PRA 142.2004 Susan ATHEY, Jonathan LEVIN and Enrique SEIRA: (lxxi): Comparing Open and Sealed Bid Auctions: Theory
and Evidence from Timber Auctions
PRA 143.2004 David GOLDRICH: (lxxi): Behavioral Biases of Dealers in U.S. Treasury Auctions
PRA 144.2004 Roberto BURGUE: (lxxi): Optimal Procurement Auction for a Buyer with Downward Sloping Demand: More
Simple Economics
Information and Strategic Behavior in the Government of Canada Securities Auctions
PRA 146.2004 Victor GINSBURGH, Patrick LEGROS and Nicolas SAHUQUET: (lxxi): How to Win Twice at an Auction. On
the Incidence of Commissions in Auction Markets
PRA 147.2004 Claudio MEZZETTI, Aleksandar PEKE and Ilia TSETLIN: (lxxi): Sequential vs. Single-Round Uniform-Price
Auctions
PRA 148.2004 John ASKER and Estelle CANTILLON: (lxxi): Equilibrium of Scoring Auctions
PRA 149.2004 Philip A. HAILE, Han HONG and Matthew SHUM: (lxxi): Nonparametric Tests for Common Values in First-
Price Sealed-Bid Auctions
PRA 150.2004 François DEGEORGE, François DERRIEN and Kent L. WOMACK: (lxxi): Quid Pro Quo in IPOs: Why
Bookbuilding is Dominating Auctions
CCMP 151.2004 Barbara BUCHNER and Silvia DALL’OLIO: Russia: The Long Road to Ratification. Internal Institution and
Pressure Groups in the Kyoto Protocol’s Adoption Process
CCMP 152.2004 Carlo CARRARO and Marzio GALEOTTI: Does Endogenous Technical Change Make a Difference in Climate
Policy Analysis? A Robustness Exercise with the FEEM-RICE Model
PRA 153.2004 Alejandro M. MANELLI and Daniel R. VINCENT: Multidimensional Mechanism Design: Revenue
Maximization and the Multiple-Good Monopoly
ETA 154.2004 Nicola ACOCELLA, Giovanni Di BARTOLOMEO and Winfried PAUWELS: Is there any Scope for Corporatism
in Stabilization Policies?
CTN 155.2004 Johan EYCKMANS and Michael FINUS: An Almost Ideal Sharing Scheme for Coalition Games with
Externalities
CCMP 156.2004 Cesare DOSI and Michele MORETTO: Environmental Innovation, War of Attrition and Investment Grants


Valentina BOSETTI, Marzio GALEOTTI and Alessandro LANZA: How Consistent are Alternative Short-Term Climate Policies with Long-Term Goals?


William BROCK and Anastasios XEPAPADEAS: Spatial Analysis: Development of Descriptive and Normative Methods with Applications to Economic-Ecological Modelling

Alberto PETRUCCI: On the Incidence of a Tax on PureRent with Infinite Horizons

Xavier LABANDEIRA, José M. LABEAGA and Miguel RODRÍGUEZ: Microsimulating the Effects of Household Energy Price Changes in Spain

NOTE DI LAVORO PUBLISHED IN 2005

Valentina BOSETTI, Carlo CARRARO and Marzio GALEOTTI: The Dynamics of Carbon and Energy Intensity in a Model of Endogenous Technical Change


Frédéric DEROIAN: Protection Motivation Theory and Contingent Valuation: Perceived Realism, Threat and WTP Estimates for Biodiversity Protection

Chiara D’ALPAOS, Cesare DOSI and Michele MORETTO: Is Inequality Harmful for the Environment in a Growing Economy?

Valentina BOSETTI, Jacqueline M. HAMILTON, Maren LAU, Richard S.J. TOL and Yuan ZHOU: A Global Database of Domestic and International Tourist Numbers at National and Subnational Level

Andrea BIGANO, Jacqueline M. HAMILTON and Richard S.J. TOL: The Impact of Climate on Holiday Destination Choice

Hubert KEMPF: Is Inequality Harmful for the Environment in a Growing Economy?

Andrea BIGANO, Jacqueline M. HAMILTON and Richard S.J. TOL: The Impact of Climate on Holiday Destination Choice

Carla MASSIDDA: How to Measure the Unobservable: A Panel Technique for the Analysis of TFP Convergence

Massimiliano MAZZANTI: The Dynamics of Carbon and Energy Intensity in a Model of Endogenous Technical Change

Valentina BOSETTI, Carlo CARRARO and Marzio GALEOTTI: The Dynamics of Carbon and Energy Intensity in a Model of Endogenous Technical Change
Alessandra CASELLA and Nobuyuki HANAKI (lxxii): Information Channels in Labor Markets, On the Resilience of Referral Hiring
Matthew O. JACKSON and Alison WATTS (lxxii): Social Games: Matching and the Play of Finitely Repeated Games
Anna BOGOMOLNAIA, Michel LE BRETON, Alexei SAVVATEEV and Shlomo WEBER (lxxii): The Egalitarian Sharing Rule in Provision of Public Projects
Francesco FERF: Stochastic Stability in Network with Decay
Aart de ZEEUW (lxxii): Dynamic Effects on the Stability of International Environmental Agreements
C. Martin van der HEIDE, Jeroen C.J.M. van den BERGH, Ekko C. van IERLAND and Paulo A.L.D. NUNES: NRM
Measuring the Economic Value of Two Habitat Defragmentation Policy Scenarios for the Veluwe, The Netherlands
Carla VIEIRA and Ana Paula SERRA: Abnormal Returns in Privatization Public Offerings: The Case of Portuguese Firms
Anna ALBERINI, Valentina ZANATTA and Paolo ROSATO: Combining Actual and Contingent Behavior to Estimate the Value of Sports Fishing in the Lagoon of Venice
Michael FINUS and Bianca RUNDSHAGEN: Participation in International Environmental Agreements: The Role of Timing and Regulation
Lorenzo PELLEGRINI and Reyer GERLACH: Are EU Environmental Policies Too Demanding for New Members States?
Matteo MANERA: Modeling Factor Demands with SEM and VAR: An Empirical Comparison
Ana MÁULEON, José SEMPERE-MONERRIS and Vincent J. VANNETELBOSCH (lxxii): A Characterization of Stochastically Stable Networks
Carlo CARRARO, Johan EYCKMANS and Michael FINUS: Optimal Transfers and Participation Decisions in Among Unionized Firms
Carlo CARRARO, Johan EYCKMANS and Michael FINUS: R&D Networks
Alireza NAGHAVI: Multilateral Environmental Agreements and Trade Obligations: A Theoretical Analysis of the Doha Proposal
Margaretha BREIL, Greetel GAMBARELLI and Paulo A.L.D. NUNES: Economic Valuation of On Site Material Damages of High Water on Economic Activities based in the City of Venice: Results from a Dose-Response-Expert-Based Valuation Approach
Alessandra del BOCA, Marzio GALEOTTI, Charles P. HIMMELBERG and Paola ROTA: Investment and Time to Plan: A Comparison of Structures vs. Equipment in a Panel of Italian Firms
Gernot KLEPPER and Sonja PETERSON: Emissions Trading, CDM, Ji, and More – The Climate Strategy of the EU
Maia DAVID and Bernard SINCLAIR-DESGAGNÉ: Environmental Regulation and the Eco-Industry
Alireza NAGHAVI: Multilateral Environmental Agreements and Trade Obligations: A Theoretical Analysis of the Doha Proposal
Margaretha BREIL, Greetel GAMBARELLI and Paulo A.L.D. NUNES: Economic Valuation of On Site Material Damages of High Water on Economic Activities based in the City of Venice: Results from a Dose-Response-Expert-Based Valuation Approach
Anna ALBERINI, Valentina ZANATTA and Paolo ROSATO: Combining Actual and Contingent Behavior to Estimate the Value of Sports Fishing in the Lagoon of Venice
Michael FINUS and Bianca RUNDSHAGEN: Participation in International Environmental Agreements: The Role of Timing and Regulation
Lorenzo PELLEGRINI and Reyer GERLACH: Are EU Environmental Policies Too Demanding for New Members States?
Matteo MANERA: Modeling Factor Demands with SEM and VAR: An Empirical Comparison
Ana MÁULEON, José SEMPERE-MONERRIS and Vincent J. VANNETELBOSCH (lxxii): A Characterization of Stochastically Stable Networks
Carlo CARRARO, Johan EYCKMANS and Michael FINUS: Optimal Transfers and Participation Decisions in Among Unionized Firms
Carlo CARRARO, Johan EYCKMANS and Michael FINUS: R&D Networks
Alireza NAGHAVI: Multilateral Environmental Agreements and Trade Obligations: A Theoretical Analysis of the Doha Proposal
IEM 75.2005  Margherita GRASSO and Matteo MANERA: Asymmetric Error Correction Models for the Oil-Gasoline Price Relationship
ETA 76.2005  Umberto CHERUBINI and Matteo MANERA: Hunting the Living Dead A “Peso Problem” in Corporate Liabilities Data
CTN 77.2005  Hans-Peter WEIKARD: Cartel Stability under an Optimal Sharing Rule
ETA 78.2005  Joëlle NOAILLY, Jeroen C.J.M. van den BERGH and Cees A. WITTHAGEN (lxxvi): Local and Global Interactions in an Evolutionary Resource Game
CCMP 80.2005  Massimiliano MAZZANTI and Roberto ZOBOLI: Economic Instruments and Induced Innovation: The Case of End-of-Life Vehicles European Policies
NRM 81.2005  Anna LASUT: Creative Thinking and Modelling for the Decision Support in Water Management
CCMP 82.2005  Valentina BOSETTI and Barbara BUCHNER: Using Data Envelopment Analysis to Assess the Relative Efficiency of Different Climate Policy Portfolios
KTHC 84.2005  Giulio CAINELLI, Susanna MANCINELLI and Massimiliano MAZZANTI: Social Capital, R&D and Industrial Districts
ETA 85.2005  Rosella LEVAGGI, Michele MORETTO and Vincenzo REBBA: Quality and Investment Decisions in Hospital Care when Physicians are Devoted Workers
CCMP 86.2005  Valentina BOSETTI and Laurent GILOTTE: Carbon Capture and Sequestration: How Much Does this Uncertain Option Affect Near-Term Policy Choices?
CSR 87.2005  Nicoletta FERRO: Value Through Diversity: Microfinance and Islamic Finance and Global Banking
ETA 88.2005  A. MARKANDYA and S. PEDROSO: How Substitutable is Natural Capital?
IEM 89.2005  Anil MARKANDYA, Valeria COSTANTINI, Francesco GRACCEVA and Giorgio VICINI: Security of Supply: Comparing Scenarios From a European Perspective
CCMP 90.2005  Vincent M. OTTO, Andreas LÖSCHEL and Rob DELLINK: Energy Biased Technical Change: A CGE Analysis
PRCG 91.2005  Carlo CAPUANO: Abuse of Competitive Fringe
CCMP 93.2005  Sabrina AUCI and Leonardo BECCHETTI: The Stability of the Adjusted and Unadjusted Environmental Kuznets Curve
CCMP 94.2005  Francesco BOSELLO and Jian ZHANG: Assessing Climate Change Impacts: Agriculture
CTN 95.2005  Alejandro CAPARROS, Jean-Christophe PEREAU and Tarik TAZDAIT: Bargaining with Non-Monolithic Players
CCMP 98.2005  Likelihood of an International Climate Agreement
CTN 99.2005  Valeria COSTANTINI, Riccardo CRESCENZI, Fabrizio De FILIPPIS, and Luca SALVATI: Bargaining in the Agricultural Negotiations of the Doha Round: Similarity of Interests or Strategic Choices?
IEM 100.2005  Giiliola FREY and Matteo MANERA: Econometric Models of Asymmetric Price Transmission
IEM 101.2005  Alessandro COLOGNI and Matteo MANERA: Oil Prices, Inflation and Interest Rates in a Structural Cointegrated VAR Model for the G-7 Countries
KTHC 102.2005  Chiara M. TRAVISI and Roberto CAMAGNI: Sustainability of Urban Sprawl: Environmental-Economic Indicators for the Analysis of Mobility Impact in Italy
SIEV 104.2005  Anna ALBERINI, Erik LICHTENBERG, Dominic MANCINI, and Gregmar I. GALINATO: Was It Something I Ate? Implementation of the FDA Seafood HACCP Program
SIEV 105.2005  Anna ALBERINI and Aline CHIABAI: Urban Environmental Health and Sensitive Populations: How Much are the Italians Willing to Pay to Reduce Their Risks?
CTN 107.2005  Michele BERNASCONI and Matteo GALIZZI: Coordination in Networks Formation: Experimental Evidence on Learning and Salience
KTHC 108.2005  Michele MORETTO and Sergio VERGALLI: Migration Dynamics
NRM 109.2005  Antonio MUSOLESI and Mario NOSVELLI: Water Consumption and Long-Run Urban Development: The Case of Milan
SIEV 110.2005  Benno TORGLER and Maria A. GARCIA-VALLINAS: Attitudes Towards Preventing Environmental Damage
SIEV 111.2005  Alberto LONGO and Anna ALBERINI: What are the Effects of Contamination Risks on Commercial and Industrial Properties? Evidence from Baltimore, Maryland
SIEV 112.2005  Anna ALBERINI and Alberto LONGO: The Value of Cultural Heritage Sites in Armenia: Evidence from a Travel Cost Method Study
CCMP 113.2005  Mikel GONZÁLEZ and Rob DELLINK: Impact of Climate Policy on the Basque Economy
NRM 114.2005  Gilles LAFFORGUE and Walid OUESLATI: Optimal Soil Management and Environmental Policy
<table>
<thead>
<tr>
<th>Journal</th>
<th>Date</th>
<th>Authors</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRM</td>
<td>115.2005</td>
<td>Martin D. Smith and Larry B. Crowder</td>
<td>Valuing Ecosystem Services with Fishery Rents: A Lumped-Parameter Approach to Hypoxia in the Neuse River Estuary</td>
</tr>
<tr>
<td>NRM</td>
<td>116.2005</td>
<td>Dan Holland and Kurt Schnier</td>
<td>Protecting Marine Biodiversity: A Comparison of Individual Habitat Quotas (IHQs) and Marine Protected Areas</td>
</tr>
<tr>
<td>PRCG</td>
<td>117.2005</td>
<td>John Nellis</td>
<td>The Evolution of Enterprise Reform in Africa: From State-owned Enterprises to Private Participation in Infrastructure — and Back?</td>
</tr>
<tr>
<td>PRCG</td>
<td>118.2005</td>
<td>Bernardo Bortolotti</td>
<td>Protecting Marine Biodiversity: A Comparison of Individual Habitat Quotas (IHQs) and Marine Protected Areas</td>
</tr>
<tr>
<td>SIEV</td>
<td>119.2005</td>
<td>Anna Alberini, Marcella Veronesi and Joseph C. Cooper</td>
<td>Detecting Starting Point Bias in Dichotomous-Choice Contingent Valuation Surveys</td>
</tr>
<tr>
<td>CTN</td>
<td>120.2005</td>
<td>Federico Echenique and Mehmet B. Yenmez</td>
<td>A Solution to Matching with Preferences over Colleagues</td>
</tr>
<tr>
<td>KTHC</td>
<td>121.2005</td>
<td>Valeria Gatta and Corrado Molteni</td>
<td>Dissipation of Knowledge and the Boundaries of the Multinational Enterprise</td>
</tr>
<tr>
<td>KTHC</td>
<td>122.05</td>
<td>Valeria Gatta</td>
<td>Firm’s Intangible Assets and Multinational Activity: Joint-Venture Versus FDI</td>
</tr>
<tr>
<td>CCMP</td>
<td>123.2005</td>
<td>Socrates Kypreos</td>
<td>A MERGE Model with Endogenous Technological Change and the Cost of Carbon Stabilization</td>
</tr>
</tbody>
</table>
### 2004 SERIES

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Editor</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCMP</td>
<td><em>Climate Change Modelling and Policy</em></td>
<td>Marzio Galeotti</td>
</tr>
<tr>
<td>GG</td>
<td><em>Global Governance</em></td>
<td>Carlo Carraro</td>
</tr>
<tr>
<td>SIEV</td>
<td><em>Sustainability Indicators and Environmental Valuation</em></td>
<td>Anna Alberini</td>
</tr>
<tr>
<td>NRM</td>
<td><em>Natural Resources Management</em></td>
<td>Carlo Giupponi</td>
</tr>
<tr>
<td>KTHC</td>
<td><em>Knowledge, Technology, Human Capital</em></td>
<td>Gianmarco Ottaviano</td>
</tr>
<tr>
<td>IEM</td>
<td><em>International Energy Markets</em></td>
<td>Anil Markandya</td>
</tr>
<tr>
<td>CSRM</td>
<td><em>Corporate Social Responsibility and Sustainable Management</em></td>
<td>Sabina Ratti</td>
</tr>
<tr>
<td>PRA</td>
<td><em>Privatisation, Regulation, Antitrust</em></td>
<td>Bernardo Bortolotti</td>
</tr>
<tr>
<td>ETA</td>
<td><em>Economic Theory and Applications</em></td>
<td>Carlo Carraro</td>
</tr>
<tr>
<td>CTN</td>
<td><em>Coalition Theory Network</em></td>
<td></td>
</tr>
</tbody>
</table>

### 2005 SERIES

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Editor</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCMP</td>
<td><em>Climate Change Modelling and Policy</em></td>
<td>Marzio Galeotti</td>
</tr>
<tr>
<td>SIEV</td>
<td><em>Sustainability Indicators and Environmental Valuation</em></td>
<td>Anna Alberini</td>
</tr>
<tr>
<td>NRM</td>
<td><em>Natural Resources Management</em></td>
<td>Carlo Giupponi</td>
</tr>
<tr>
<td>KTHC</td>
<td><em>Knowledge, Technology, Human Capital</em></td>
<td>Gianmarco Ottaviano</td>
</tr>
<tr>
<td>IEM</td>
<td><em>International Energy Markets</em></td>
<td>Anil Markandya</td>
</tr>
<tr>
<td>CSRM</td>
<td><em>Corporate Social Responsibility and Sustainable Management</em></td>
<td>Sabina Ratti</td>
</tr>
<tr>
<td>PRA</td>
<td><em>Privatisation, Regulation, Antitrust</em></td>
<td>Bernardo Bortolotti</td>
</tr>
<tr>
<td>ETA</td>
<td><em>Economic Theory and Applications</em></td>
<td>Carlo Carraro</td>
</tr>
<tr>
<td>CTN</td>
<td><em>Coalition Theory Network</em></td>
<td></td>
</tr>
</tbody>
</table>