

Gerlagh, Reyer

**Working Paper**

## A Climate-Change Policy Induced Shift from Innovations in Energy Production to Energy Savings

Nota di Lavoro, No. 128.2004

**Provided in Cooperation with:**

Fondazione Eni Enrico Mattei (FEEM)

*Suggested Citation:* Gerlagh, Reyer (2004) : A Climate-Change Policy Induced Shift from Innovations in Energy Production to Energy Savings, Nota di Lavoro, No. 128.2004, Fondazione Eni Enrico Mattei (FEEM), Milano

This Version is available at:

<https://hdl.handle.net/10419/118001>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**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 Climate-Change Policy Induced  
Shift from Innovations in Energy  
Production to Energy Savings**

Reyer Gerlagh

NOTA DI LAVORO 128.2004

**OCTOBER 2004**

CCMP – Climate Change Modelling and Policy
--

Reyer Gerlagh, *IVM, Institute for Environmental Studies, Vrije Universiteit*

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>

Social Science Research Network Electronic Paper Collection:  
<http://ssrn.com/abstract=609763>

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](http://www.feem.it), e-mail: [working.papers@feem.it](mailto:working.papers@feem.it)

# **A Climate-Change Policy Induced Shift from Innovations in Energy Production to Energy Savings**

## **Summary**

We develop an endogenous growth model with capital, labor and energy as production factors and three productivity variables that measure accumulated innovations for energy production, energy savings, and neutral growth. All markets are complete and perfect, except for research, for which we assume that the marginal social value exceeds marginal costs by factor four. The model constants are calibrated so that the model reproduces the relevant trends over the 1970-2000 period. The model contains a simple climate module, and is used to assess the impact of Induced Technological Change (ITC) for a policy that aims at a maximum level of atmospheric CO<sub>2</sub> concentration (450 ppmv). ITC is shown to reduce the required carbon tax by about a factor 2, and to reduce costs of such a policy by about factor 10. Numerical simulations show that knowledge accumulation shifts from energy production to energy saving technology.

**Keywords:** Induced technological change, Environmental taxes, Partial equilibrium

**JEL Classification:** H23, O31, O41, Q42, Q43

*The research has been funded by the Dutch National Science Foundation (NWO) under contract nr. 016.005.040.*

*Address for correspondence:*

Reyer Gerlagh  
Institute for Environmental Studies  
IVM/FALW/VU  
Vrije Universiteit  
De Boelelaan 1087  
1081HV Amsterdam  
The Netherlands  
E-mail: [reyer.gerlagh@ivm.vu.nl](mailto:reyer.gerlagh@ivm.vu.nl)

## 1. INTRODUCTION

Environmental taxes and regulation reduce pollution by shifting behavior away from polluting activities, but they also encourage the development of new technologies that make pollution control less costly in the long run (Newel *et al.* 1999; Popp 2002). Understanding of the response of technology to economic incentives – dubbed induced innovation or induced technological change (ITC) – will prove crucial for designing appropriate environmental policies (Jaffe *et al.* 2002). In the literature, the subject of ITC has explicitly been studied in various theoretic models (e.g. Verdier 1995, Beltratti 1997, Newell *et al.* 1999, Goulder and Matthai 2000). In a slightly different strand of literature, a more general approach is followed when adapted endogenous growth models are used to investigate the effect of reduced resource use on growth (Gradus and Smulders 1993; Bovenberg and Smulders 1995; den Butter and Hofkes 1995; Bovenberg and Smulders 1996; Smulders 1999, Smulders and de Nooij 2003). Many of these studies develop endogenous growth models with capital and/or labour, and a natural resource, most often energy, as factors of production, in which economic growth is generated through the accumulation of knowledge. Such models are advantageous when one aims to study the effect on growth of resource conservation rules. One conclusion emerging from these studies is that abatement measures can increase growth when they reduce pollution and pollution harms the production of knowledge. In most other cases, resource use reduction harms growth.

In this paper, we build an endogenous growth model, comparable with those used in the second strand of literature, with three sectors; the first sector produces the final good, the second a generic intermediate, and the third produces energy. The final good uses the generic intermediate and energy as production factors, and productivity of both inputs is endogenous through technology driven by research. Both the intermediate and energy sector use a capital-labor composite as production factor, and also for these sectors, productivity of the input depends on a technology variable that measures accumulated (and depreciated) research. A major difference with the average endogenous growth model that includes a resource, though, is that we model energy as an intermediate good. The energy production technology, and thus the energy production costs, is endogenous to the model. A second major difference is that our model is calibrated to reproduce the trends of the past decades in overall growth and energy efficiency improvement.

The model is used to carry out policy analyses that verify the role of ITC in climate change policy. It thereby contributes to the literature on induced technological change in the context of

climate change, which is a yet undecided debate (Carraro *et al.* 2003). Various studies try to estimate the impact of ITC relative to the factor substitution effects without technological change through scenario analyses (Carraro and Galeotti 1997, Grübler and Messner 1998, Goulder and Schneider 1999, Nordhaus 2002, van der Zwaan *et al.* 2002, Buonanno *et al.* 2003, Gerlagh and van der Zwaan 2003, Gerlagh and Lise, 2003). But the estimated contribution of ITC varies considerably between the studies. Carraro and Galeotti (1997) employ an econometric model for the EU and come to an optimistic conclusion. ITC can bring about a double dividend when proper R&D incentives will reduce emissions without the need for decreasing consumption. Grübler and Messner (1998) use an energy-system model and conclude that ITC substantially decrease costs and warrant early emission reduction efforts. Goulder and Schneider (1999) and Nordhaus (2002) are more pessimistic and conclude that, though ITC is not negligible, its contribution to greenhouse gas emission abatement is small when compared to the contribution of factor substitution for given technology. Gerlagh and Lise (2003) consider two competing energy sources (i.e. renewables and carbon-rich energy sources). They show that induced technology change accelerates the substitution of carbon-free energy for fossil fuels substantially, and that in this setting, induced technological change is a powerful contributor to emission reductions.

One specific issue that we address in this paper is the question whether endogenous technological change (ETC) is beneficial to climate change policies. From the outset, such is not obvious. While ETC increases flexibility and thereby reduces costs, it can also increase costs when lower output levels lead to lower investments in learning. It is not unreasonable to assume that economic output will decrease more with endogenous technology, compared to a situation with an exogenous technological path. In this paper, we will verify whether costs of energy reductions increase or decrease when we account for endogenous technological change, and by how much. The approach is as follows. As in many other studies, we define scenarios in which policy sets an environmental target (i.e. atmospheric carbon emission concentration) with endogenous carbon taxes to reach the target. ITC is beneficial when costs of reaching this target decrease when modeling endogenous technological change, compared to a scenario in which technology follows a benchmark path set by the benchmark (or ‘business as usual’) scenario without environmental target. Our finding is important since most costs estimates for climate change policies assume given technology, and their estimates may be realistic when the ITC impact factor is minor, but it may be too pessimistic or too optimistic when the ITC impact factor is large.

When carrying out numerical scenario analyses, caution is warranted. We are aware of the limitations of the modeling approach we follow. In a certain way, we develop a cartoon model in the tradition of the highly stylized models developed in endogenous growth theory. The model explores some specific mechanisms, while abstracting from other mechanisms. Just to mention one feature, we neglect all taxes and other market distortions apart from carbon taxes. Still we

think our analysis can provide valuable qualitative insights on technological innovation as induced by climate change policy. Also, we attempt to reduce the sensitivity of our results with respect to specific model features as we calibrate the model such that it reproduces the recent past and produces a benchmark scenario that is in line with other studies.

Section 2 describes the basic features of the model. It describes the accumulation of knowledge and the linkage from energy use to climate change. Section 3 describes the calibration of the model. Section 4 provides the results of the simulations. The final section discusses the implications of our analysis for climate change policies. Two Appendices are added to the paper. Appendix 1 presents the full list of model equations, including the first order conditions for the energy producers and innovators. The numerical parameter values, as found in the calibration procedure, are presented in Appendix 2.

## 2. MODEL SET UP

The model has 60 distinct time periods of five years, each denoted by  $t=1, \dots, 60$ , covering the period 2000-2300. The model distinguishes one representative consumer, a representative production technology, and a public agent that can set emission taxes to reduce carbon dioxide emissions. There is one final good, or consumer good, for which prices are normalized to unity. All other prices are measured relative to this good.

### *The representative consumer*

We assume there is one representative consumer who maximises welfare subject to a budget constraint:

$$W = \sum_{t=1}^{\infty} (1 + \rho)^{-t} P_t \ln(C_t / P_t), \quad (1)$$

where  $W$  is total welfare,  $\rho$  is the pure time preference, and  $C_t / P_t$  is consumption per capita.

### *Production*

Output of the final good is denoted by  $Y$ . The final good is made of a generic intermediate  $M$  and energy  $E$

$$Y_t = \{(A_{Y,M}^{\pi_{Y,M}} M)^{(\sigma-1)/\sigma} + (A_{Y,E}^{\pi_{Y,E}} E)^{(\sigma-1)/\sigma}\}^{\sigma/(\sigma-1)}, \quad (2)$$

where  $\sigma$  is the elasticity of substitution between  $M$  and  $E$ , and  $A_{Y,M}$  and  $A_{Y,E}$  are the technology variables that control the productivity of  $M$  and  $E$ , respectively. The parameters  $\pi_{Y,M}$  and  $\pi_{Y,E}$  describe the elasticity of productivity to knowledge accumulation.

Both the generic intermediate  $M$  and energy  $E$  are produced using a capital-labor composite  $Z$  as production factor,

$$M_t = \varsigma_M A_{M,Z}^{\pi_{M,Z}} Z_M \quad (\mu) \quad (3)$$

$$E_t = \varsigma_E A_{E,Z}^{\pi_{E,Z}} Z_E \quad (q) \quad (4)$$

$$Z_{M,t} + Z_{E,t} = (K_t)^\alpha (L_t)^{1-\alpha} \quad (\zeta) \quad (5)$$

where  $A_{Y,M}$  and  $A_{Y,E}$  are technology variables that control the productivity of the capital-labor composite in producing  $M$  and  $E$ , respectively. The parameters  $\pi_{M,Z}$  and  $\pi_{E,Z}$  describe the elasticity of productivity to knowledge accumulation. The variables between brackets,  $\mu$ ,  $q$ , and  $\zeta$ , denote the Lagrange dual variables of the welfare maximization program, or stated otherwise, denote the shadow price for  $M$ ,  $E$ , and  $Z$ , respectively.

Capital depreciates at rate  $\delta_K$ , and accumulates through investments  $I$ ,

$$K_{t+1} = (1-\delta_K)K_t + I_t. \quad (\psi) \quad (6)$$

Knowledge is produced on basis of research. All knowledge stocks,  $A_{Y,M}$ ,  $A_{Y,E}$ ,  $A_{M,Z}$ , and  $A_{E,Z}$  are treated equally, and we use subscript  $j=(Y,M)$ ,  $(Y,E)$ ,  $(M,Z)$ ,  $(E,Z)$  when convenient. The accumulation of knowledge depends on both the current stock of knowledge,  $A_j$ , and the level of research expenditures,  $R_j$ . The flow of new ideas has decreasing returns to scale in the research flow  $R_j$ , the so-called fishing-out effect (Caballero and Jaffe 1993; Kortum 1993).

$$A_{j,t+1} = (1-\delta_A)A_{j,t} + \zeta_j R_{j,t}^\eta A_{j,t}^{1-\eta} \quad (\theta_j, j=(Y,M), (Y,E), (M,Z), (E,Z)) \quad (7)$$

where  $\delta_A$  is the share of knowledge that becomes obsolete in each period.

The model is closed by the commodity balance for the final good; output  $Y$  is used for consumption  $C$ , investments  $I$ , and research expenditures  $R$ .

$$C_t + I_t + R_t = Y_t, \quad (\lambda) \quad (8)$$

where  $R$  is the aggregate research level,

$$R = R_{Y,M} + R_{Y,E} + R_{M,Z} + R_{E,Z} \quad (9)$$

Labour  $L_t$  is supplied inelastically. We assume it is a fixed ratio of population, i.e.  $L_t = \gamma P_t$  with  $0 < \gamma < 1$  and  $P_t$  is the total population. In turn, population is assumed to grow logistically:

$$P_{t+1} = (1 + \chi(1 - P_t/P^{LT}))P_t, \quad (10)$$

where  $\gamma$  is the population growth rate for low population levels and  $P^{LT}$  is the population level in the long term to which  $P_t$  converges.

The model assumes complete and perfect markets for all goods, except for research. That is, the model imposes the first order conditions that follow from the welfare maximization program, presented in the appendix. For research, it is assumed that the marginal social value of research exceeds the marginal social costs by factor  $\omega$  (Baumol 2002, p135). For  $\omega=1$ , the model would calculate a first-best allocation. For  $\omega>1$ , the social benefits of research exceed the costs. Thus, there is a research externality in the model. This is important for climate change policies for the following reason. A policy measure that will increase the total research effort will tend to increase welfare, whereas a policy measure that decreases the overall research effort will tend to decrease welfare. It is not obvious, from the outset, whether climate change policy will increase or decrease total research.

### *Climate Change*

Carbon dioxide emissions,  $Em_t$ , are linked to the use of energy through an emission intensity parameter  $\varepsilon_t$  that describes the level of emissions per unit of energy use:

$$Em_t = \varepsilon_t E_t. \quad (11)$$

We assume that emission intensity of energy use and energy efficiency of production improves (so-called energy-efficiency improvement or EEI) autonomously over time. Carbon emissions are linked to the atmospheric carbon concentration, which in turn determines the global average surface temperature. The carbon cycle dynamics assumed in our model are simple and follow the approximations supposed in DICE (Nordhaus, 1994) and DEMETER (Gerlagh and Van der Zwaan, 2003). The link between carbon emissions, atmospheric carbon concentration  $ATM_t$  and the global surface temperature,  $TEMP_t$ , is a “1-box representation”:

$$ATM_{t+1} = (1 - \delta_M)(ATM_t - ATM_0) + (1 - \delta_E)(Em_t - \bar{Em}_t), \quad (12)$$

$$TEMP_{t+1} = (1 - \delta_T) TEMP_t + \delta_T TEMP_0 \ln(ATM_t/ATM_0)/\ln(2), \quad (13)$$



where  $\delta_M$  is the atmospheric CO<sub>2</sub> depreciation rate,  $ATM_0$  is the pre-industrial atmospheric CO<sub>2</sub> concentration,  $1-\delta_E$  is the retention rate,  $\bar{E}m_t$  are emissions not linked to energy production,  $\delta_T$  is the temperature adjustment rate resulting from the atmospheric warmth capacity, and  $TEMP_0$  is the long-run equilibrium temperature change associated with a doubling of the atmospheric CO<sub>2</sub> concentration. The model version used for this paper does not specify a damage function, though such an equation can simply be added. The reason is that damage estimates are subject to normative debates on the valuation of environmental losses, and we attempt to keep away from these discussions. Instead, we will run cost-effective analyses that assume a certain climate change target.

To reach climate change targets, the public agent may levy a tax  $\tau_t$  on emissions  $E m_t$  produced by the final good sector when using energy. The public agent may levy a tax on emissions produced by the final good producer when using energy in production. This carbon tax is a fee expressed in \$/tC,  $\tau_{E,t}$ , and it adds a constant markup value to the energy users costs,

$$q_t^\tau = q_t + \tau_{E,t} \varepsilon_t, \quad (14)$$

where  $q_t^\tau$  is the price of energy including the carbon tax,  $q_t$  is the production costs of energy, and  $\varepsilon_t$  the emission intensity as defined in equation (11). We assume that the public agent is budget neutral in the case of a tax policy, so that, on the other hand, if a carbon tax is levied, i.e.  $\tau_t > 0$ , the generic intermediate  $M$  is subsidized with a rate  $s_{M,t}$

$$\mu_t^\tau = (1 - s_{M,t}) \mu_t, \quad (15)$$

where  $\mu_t^\tau$  is the intermediate price of  $M$  including the subsidy. The carbon tax revenues and the total amount of subsidies are in balance:

$$\tau_{E,t} \varepsilon_t E_t = s_{M,t} \mu_t M_t. \quad (16)$$

Alternatively, we could assume that carbon tax revenues are recycled by research subsidies, but this would produce a bias in our results in favor of carbon taxes. Under our central assumption of research externality  $\omega > 1$ , even without carbon taxes, a subsidy on research would increase total welfare. Selling an innovation subsidy as a natural by-product of carbon taxes mixes up climate change policies and generic research policies.

### 3. CALIBRATION

We use the model outlined above to carry out a numerical simulation where model parameters are based on historical trends derived from the World Development Indicator (WDI) set for the period 1960 to 2000. Based on the WDI data, we estimate levels and growth rates for the main variables

for the period 2000-2005. In the second calibration stage, the model starts in 1900 and runs to 2300, and we calculate parameters such that simulated variable levels and growth rates in the period 2000-2005 match the empirical data. This scenario is the benchmark, and is also referred to as Business as Usual (BAU).

Variables that are used as an input in the calibration process are population ( $P$ ), labor ( $L$ ) population growth ( $g_L$ ), output or GDP ( $Y$ ), GDP growth rate ( $g_Y$ ), gross investments ( $I$ ), the capital stock ( $K$ ), total primary energy supply and total primary energy use measured in Exa Joules ( $E$ ), the energy price in \$/GJ ( $q$ ) and its growth rate ( $g_q$ ), the energy-efficiency improvement ( $EEI$ ), CO<sub>2</sub> emissions ( $Em$ ), the decline in the emission intensity of energy ( $g_e$ ), overall research expenditures ( $R$ ), and the real interest rate. These 15 data points are used to calibrate the 17 parameters  $P^{LT}$ ,  $\gamma$ ,  $\chi$ ,  $\zeta_{Y,E}$ ,  $\zeta_{M,Z}$ ,  $\zeta_{E,Z}$ ,  $\pi_{Y,E}$ ,  $\pi_{M,Z}$ ,  $\pi_{E,Z}$ ,  $\varsigma_M$ ,  $\varsigma_Z$ ,  $\delta_K$ ,  $\delta_A$ ,  $\rho$ ,  $\alpha$ ,  $\epsilon$ , and the growth rate of  $\epsilon$ . We notice that there is freedom for the choice of the unit of measurement for knowledge,  $A_{M,Z}$  and  $A_{E,Z}$ .<sup>1</sup> Thus, there are two degrees of freedom in the calibration process, which is used to compensate for the difference between the 15 data points and the 17 parameters calculated. Furthermore, there are some parameters chosen on basis of the literature. The elasticity of substitution between energy and the generic intermediate  $M$  is described by the parameter  $\sigma$ , for which we following Manne (1999),  $\sigma=0.4$ . The social returns on research are assumed to exceed the private returns by factor 4 (Baumol 2002, p135), thus,  $\omega=4$ . The elasticity of knowledge accumulation to research is set to half,  $\eta=0.5$ . Finally, we take  $\pi_{Y,M}=0$ , so that  $A_{Y,M}$  and  $\zeta_{Y,M}$ , drop out of the model. We can do so without loss of generality since all energy-neutral innovation is already captured through the variables  $R_{M,Z}$  and  $A_{M,Z}$ .

In 2000, the world population ( $P_{2007}$ ) is 6.1 billion people, and its growth rate is 1.2%. In the long run, the world population is assumed to stabilize at a level of 11.4 billion people (as in World Bank, 1999; and Nakicenovic et al. 1998; and Gerlagh and Van der Zwaan, 2003). We assume that labor force is a fixed rate of population, i.e.  $\gamma=0.48$ , as indicated by the most recent WDI data. We calculated per capita GWP in 2000 at 5.800 US\$(1995), and the trend of the per capita GWP growth rate at 1.7% per year. In 2000, total energy use is estimated at 326 EJ per year. The energy intensity (ratio of energy use over GDP) is approximately 10.5 GJ/\$, and on basis of the 1971–1991 WDI sample, we estimate the Energy Efficiency Improvement (EEI) at 1% per year. The initial average price of energy ( $q$ ) is assumed to be 2.7 US\$(1995)/GJ, and almost constant. The autonomous improvement of the emission intensity is 0.2% per year, and for the year 2000, the emission intensity is estimated at 0.0155 kgC/GJ. The CO<sub>2</sub> emissions ( $Em_{2000}$ ) amount to almost 6 Gigaton carbon (GtC) per year.

---

<sup>1</sup> We can increase  $A_{M,Z}$  by any factor and decrease  $\varsigma_M$  by the same factor (raised to the power  $\pi_{M,Z}$ ) and represent the same equilibrium with the same flows  $M$  and  $E$ . Thus, in the calibration, there is arbitrage between  $A_{M,Z}$ , and  $\varsigma_M$ , and between  $A_{E,Z}$  and  $\varsigma_E$ . Practically, we set  $A_{M,Z}$  to 100, and demand that  $\varsigma_M=\varsigma_E$ .

## 4. SIMULATION RESULTS

### *Policy Scenarios*

This section presents and discusses the results with the calibrated model. After the calibration stage, we use the model for simulations. The simulation model runs for 60 time steps of 5 years each, representing the period 2000-2300, though the presentation of data and figures will be restricted to the first two centuries 2000-2200. State variables (knowledge and capital stocks) are fixed at the beginning of this period. We have simulated four scenarios. First, the BAU scenario assumes the absence of carbon taxes.

In the second scenario, policy makers are supposed to employ the carbon tax instrument such that total research expenditures are maximized. That is, the carbon tax is not used to combat emissions, but to increase welfare derived from the consumption of final goods. The background to this policy is the understanding that a carbon tax supported by a subsidy on the intermediate  $M$  might increase the overall research effort, or decrease the overall research effort, and it is not known in advance which of the two possibilities holds. In case the overall research level is increased, this will increase welfare since the marginal social benefits of research exceed the marginal social costs by factor  $\omega > 1$ . Whether a carbon tax will increase or decrease the overall research levels cannot be concluded in advance, it depends on parameter values that follow from the calibration process. The second scenario is labeled MAXW.

Then, we consider two stabilization scenarios, labeled 450\_ITC and 450\_NOITC that target the atmospheric carbon concentration level at 450 ppmv. In the BAU scenario, this carbon concentration level will be reached around 2050. In both stabilization scenarios, there is a variable carbon tax (in \$/tC) levied on energy use to achieve the target. Figure 1 plots the emission levels and Figure 2 plots the associated carbon concentration levels. Figure 1 shows that, for our simple 1-box atmospheric model, the 450 ppmv target is consistent with long-term constant annual emissions of about 3.2 GtC. Comparison of the third and fourth scenario can show us the importance of induced technological change relative to factor substitution that happens with the benchmark technological change path.

### *Scenario Results*

From the comparison of the four scenarios, we will draw conclusions with respect to the relation between ETC and (i) the timing of emission reductions, (ii) the carbon tax levels required to reach climate stabilization targets, (iii) the costs of meeting the climate change constraints, and (iv) the direction of technological change.

From Figure 1, the first outstanding conclusion is that the endogenous growth model suggests a win-win policy exists. The second scenario, which maximizes welfare abstracting from climate change costs, results in lower emission levels compared to the benchmark. A modest carbon tax (Figure 3 and Figure 4) raises expenditures in energy savings R&D (Figure 7) and lowers expenditures for energy production R&D (Figure 9). The overall R&D expenditures are lifted by 0.04% of GDP. Given that the social benefits of R&D exceed the costs, consumption increases, by 0.19% in 2050 and by 0.26% in 2100 (Figure 6).

The second conclusion we draw from Figure 1 and Figure 2 is that ITC (the third scenario) implies a slight advancement of emission reductions, compared to the fourth scenario without ITC. In Figure 2, the two graphs for the two scenarios are almost on top of one another, but in Figure 1, a difference is visible. This finding is consistent with Grubler and Messner (1998) and van der Zwaan *et al.* (2002). The result, however, should be interpreted with care, given the findings for the second scenario. A substantial part of the advancement of emission reductions is due to the carbon-tax induced welfare gain that is independent of the climate change constraint, as presented in the second scenario.

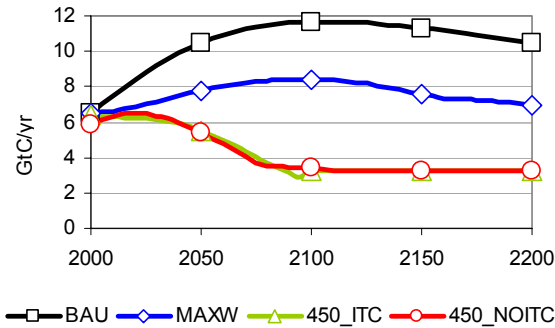


FIGURE 1. *Annual emission levels*

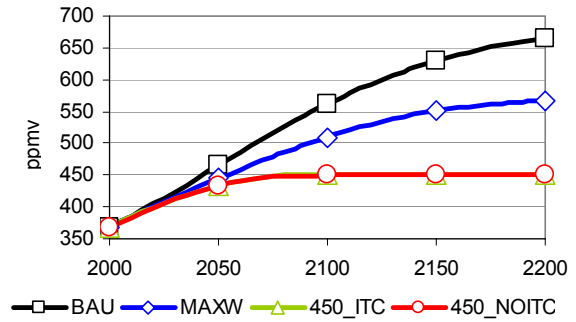


FIGURE 2. *Atmospheric CO2 concentration levels*

Next, we turn to the implications of ITC for the level of the carbon tax. It is obvious that an economy with endogenous technology is more flexible and in the long-term, technological change increases the elasticity of emissions. Figure 3 and Figure 4 present the tax on carbon dioxide emissions that supports the energy reductions. They show that ITC cuts the required carbon tax by approximately half. Stated the other way around, ITC doubles the elasticity of emissions with respect to a carbon tax. The tax levels shown for the end of the 21<sup>st</sup> and the whole 22<sup>nd</sup> century do not seem realistic from a political perspective. In the longer term, however, we can expect the substitution between carbon rich and carbon poor energy sources to contribute substantially to emission reductions (Gerlagh and van der Zwaan 2004) and long-term carbon taxes required to meet the climate change constraints will substantially be cut.

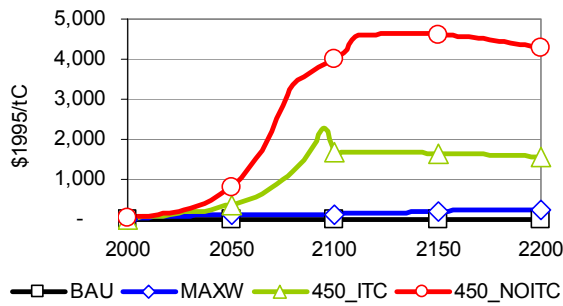


FIGURE 3. *Carbon tax*

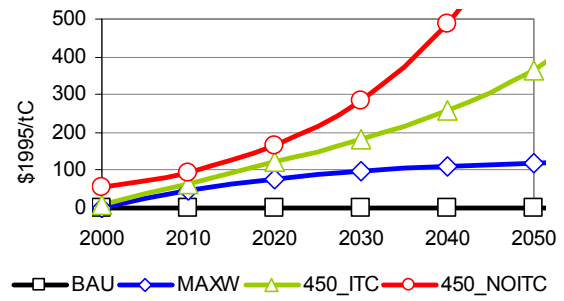


FIGURE 4. *Carbon tax for first five decades*

The effect of ITC on the costs of climate change targets is even stronger than its effect on the elasticity of emissions. Figure 5 shows the development of consumption per capita, and Figure 6 shows the same path, but now relative to the benchmark BAU scenario. The first figure shows that, on the scale of long-term income growth, costs of meeting climate change targets are almost negligible. Azar and Schneider (2003) and Gerlagh and Papyrakis (2003) discuss the relevance of this finding, which is a common feature found in many analyses with IAMs. Figure 6 shows that, notwithstanding the small size of the costs compared to the overall income growth, costs are still substantial and significantly different between the two scenarios with and without ITC. Abstracting from ITC, the emission reduction by about two-third, in the 22<sup>nd</sup> century, decreases output and consumption by about 5%. When technology adjusts, costs decrease to below 1% of GDP. When calculating the costs in terms of the welfare measure as defined in (1), we find that ITC decreases the costs by factor 11.8. Thus, studies based on inflexible technology may vastly overestimate long-term costs of energy savings.

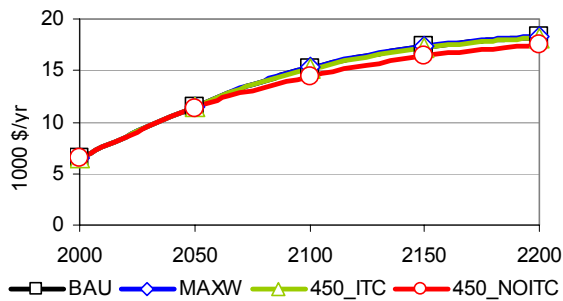


FIGURE 5. *Output per capita*

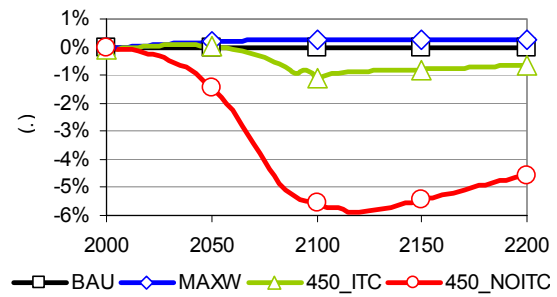


FIGURE 6. *Development of consumption relative to BAU scenario.*

The next figures present R&D expenditures and the paths of technology, that is, how technology accumulation adjusts to climate change policy. Figure 7 presents the share of R&D in GDP that is

used to increase the productivity of energy in the production of the final good. Comparing the third (450\_ITC) and the first (benchmark) scenario, we see that the climate change policy increases energy saving R&D by about factor 4/3 in the short-term, and by about factor 2 in the long term. The carbon tax peaks at the end of the 21<sup>st</sup> century, and so the energy savings R&D expenditures peak around the same period. Figure 8 presents the implications for the development of the stock of energy savings knowledge,  $A_{YE}$ . In the benchmark scenario, energy savings knowledge increases by almost factor 4 over the current century. The increased R&D expenditures induced by the carbon tax enhance the accumulation of energy savings knowledge by another factor 2.

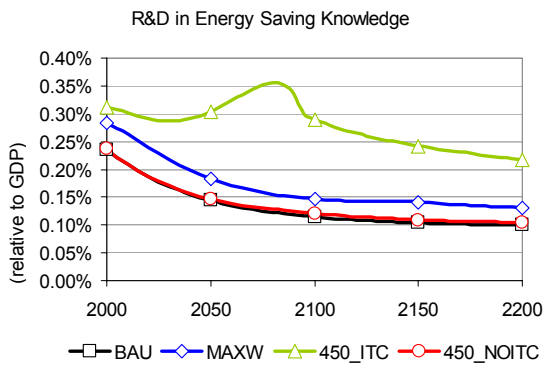


FIGURE 7. *R&D expenditures for Energy Savings as share of GDP*

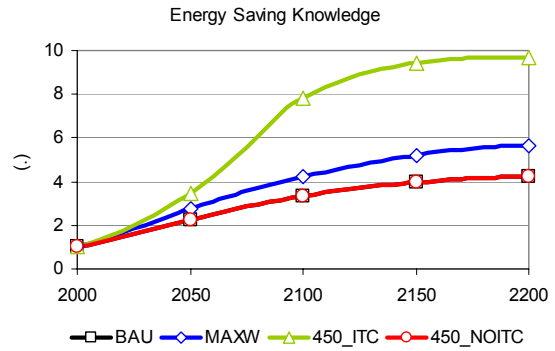


FIGURE 8. *Development of Energy Savings Knowledge,  $A_{YE}$ , relative to level in 2000*

Figure 9 presents the effect of the carbon-tax on the energy production technology. The effect is opposite to the energy savings technology. A carbon tax captures part of the value of energy supply, and thereby reduces the revenues that can be invested in research increasing the efficiency of energy production. The R&D expenditures are about halved, and consequently, the knowledge stock is halved, compared to the benchmark, as well, as shown in Figure 10.

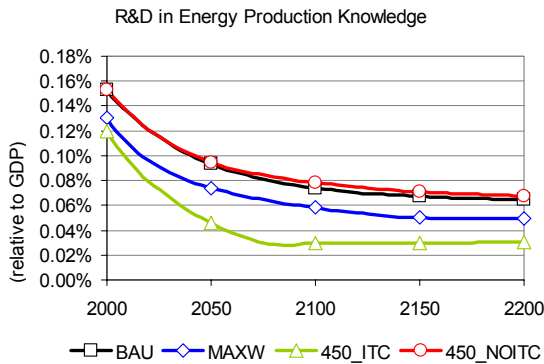


FIGURE 9. *R&D expenditures for Energy*

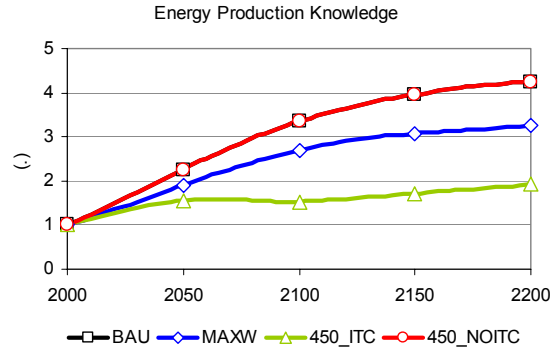


FIGURE 10. *Development of Energy Production*

Comparing the two knowledge stocks, we see that the carbon tax shifts knowledge from efficient energy production to efficient energy use. We also mention that the R&D levels for the generic productivity of  $M$  is almost unaffected (not shown in a graph). In the climate change constrained scenario, energy production is less efficient than in the benchmark scenario, but energy use is more efficient. Costs involved in this shift of knowledge are small, compared to costs involved in factor substitution.

## 5. CONCLUSION

In this paper, we have built an endogenous growth model with three sectors, and with endogenous technology for each of the sectors. The first sector produces the final good, the second a generic intermediate, and the third produces energy. Energy production and use lead to emissions of carbon dioxide, and the model contains a simple climate change module that links emissions to atmospheric carbon dioxide concentration levels and temperature change. This module can also be used inversely to define a window of emission paths that are consistent with an exogenous climate change target, such as an atmospheric 450 ppmv ceiling.

We have used numerical simulations to study the potential for a double dividend, that is, a reduction in emissions and increase in output, at the same time. Climate change policy can bring about a double dividend when an energy savings policy increases the R&D level in certain sectors more than it decreases the R&D level in other sectors, assuming that social returns to R&D are the same in both sectors. Indeed, when parameter values were calibrated to match the 1970-2000 growth levels for output and energy use, we found a double dividend for modest energy savings. Yet when energy savings were more stringent to be consistent with a 450 ppmv stabilization target economic growth fell.

The model is also used to carry out policy analyses that verify the specific role of ITC in climate change policy. We conclude from the results that ITC's contribution to greenhouse gas emission abatement can be substantial. In our calculations, the elasticity of emissions to a carbon tax doubles, and the costs of emission reductions drop by approximately factor 10. In this setting, induced technological change proves a powerful contributor to emission reductions.

Our finding is important since most cost estimates for climate change policies assume given technology, and their estimates may be too pessimistic. There are two apparent qualifications to be made. First, results crucially depend on parameter values, which do not only depend on growth rates over the period on which the model is calibrated for output and energy use, but which also depend on various assumptions such as on the relative value of research expenditures and the

social rate of return on research. For future work, it is essential to gather more data that allow us a more robust calibration procedure. Second, the model assumes a long-term planning and cooperation on a global scale. When climate change targets are set on a shorter horizon and cooperation is incomplete, such as under the Kyoto Protocol, technology will be less adaptive and climate change policy costs increase.

Having said this, we want to emphasize that not all results are sensitive. It seems intuitive that a carbon tax will shift innovations between sectors, from sectors that are responsible for fossil fuel energy production to sectors that are responsible for energy savings and carbon-free energy production. It is this shift in research that will drive most of the long-term cost reductions for climate change mitigation policies. This also points to an important caveat in the current study. Inclusion of carbon capturing and sequestration and carbon-free energy sources is an apparent subject for further work.

## APPENDIX 1. FIRST ORDER CONDITIONS FOR FIRMS' PROFIT MAXIMIZATION

We use  $\beta_t$  as the price deflator for the final good from period  $t$  to period  $t+1$ . So,  $\beta_t = 1/(1+r_t)$ , where  $r_t$  is the real interest rate. Welfare optimisation gives the Ramsey rule as a first-order-condition for consumption,

$$\beta_t = (C_t / P_t) / ((1+\rho)(C_{t+1} / P_{t+1})) \quad (17)$$

The first order conditions for  $M$ ,  $E$ ,  $Z_M$ ,  $Z_E$ ,  $K$ ,  $A_{Y,M}$ ,  $A_{Y,E}$ ,  $A_{M,Z}$ ,  $A_{E,Z}$ ,  $R_{Y,M}$ ,  $R_{Y,E}$ ,  $R_{M,Z}$ ,  $R_{E,Z}$ , and  $I$  are, respectively,

$$\mu M = (A_{Y,M}^{\pi_{Y,M}} M)^{(\sigma-1)/\sigma} Y^{1/\sigma}, \quad (18)$$

$$qE = (A_{Y,E}^{\pi_{Y,E}} E)^{(\sigma-1)/\sigma} Y^{1/\sigma}, \quad (19)$$

$$\xi Z_M = \mu M, \quad (20)$$

$$\xi Z_E = qE, \quad (21)$$

$$\alpha \xi (Z_M + Z_E) = (\delta_k + \psi - 1)K, \quad (22)$$

$$\begin{aligned} \theta_{Y,M} &= \lambda \pi_{Y,M} A_{Y,M}^{\pi_{Y,M}(\sigma-1)/\sigma-1} M^{(\sigma-1)/\sigma} Y^{1/\sigma} \\ &+ \beta \theta_{Y,M,+1} [(1-\delta_A) + (1-\eta_{Y,M}) \xi_{Y,M} (R_{Y,M}/A_{Y,M})^{\eta_{Y,M}}], \end{aligned} \quad (23)$$

$$\begin{aligned} \theta_{Y,E} &= \lambda \pi_{Y,E} A_{Y,E}^{\pi_{Y,E}(\sigma-1)/\sigma-1} E^{(\sigma-1)/\sigma} Y^{1/\sigma} \\ &+ \beta \theta_{Y,E,+1} [(1-\delta_A) + (1-\eta_{Y,E}) \xi_{Y,E} (R_{Y,E}/A_{Y,E})^{\eta_{Y,E}}], \end{aligned} \quad (24)$$



$$\theta_{M,Z} = \pi_{M,Z} \mu M / A_{M,Z} + \beta \theta_{M,Z,+1} [(1 - \delta_A) + (1 - \eta_{M,Z}) \zeta_{M,Z} (R_{M,Z} / A_{M,Z})^{\eta_{Y,Z}}], \quad (25)$$

$$\theta_{E,Z} = \pi_{E,Z} q E / A_{E,Z} + \beta \theta_{E,Z,+1} [(1 - \delta_A) + (1 - \eta_{E,Z}) \zeta_{E,Z} (R_{E,Z} / A_{E,Z})^{\eta_{E,Z}}], \quad (26)$$

$$\omega = \beta \theta_{j,+1} [\eta_j \zeta_j (A_j / R_j)^{1 - \eta_j}]. \quad j = (Y, M), (Y, E), (M, Z), (E, Z) \quad (27)$$

$$\psi_{+1} = 1/\beta, \quad (28)$$

In a first-best optimum, we would have  $\omega=1$ . As explained in the main text, however, it is assumed that in market equilibrium,  $\omega=4$ .

### *Carbon tax scenario*

In the case of a carbon tax scenario, equations (18) and (19) become

$$(1 - s_M) \mu M = (A_M M)^{(\sigma-1)/\sigma} Y^{1/\sigma}, \quad (29)$$

$$(q + \tau_c \varepsilon_t) E = (A_E E)^{(\sigma-1)/\sigma} Y^{1/\sigma}. \quad (30)$$

### *Complete model*

The complete model consists of the 21 endogenous variables: for  $W, Y, R, C, M, E, Z_M, Z_E, K, A_{Y,M}, A_{Y,E}, A_{M,Z}, A_{E,Z}, R_{Y,M}, R_{Y,E}, R_{M,Z}, R_{E,Z}, I, Em, Atm, Temp$ , 8 shadow prices  $\mu, q, \zeta, \psi, \theta_{Y,M}, \theta_{Y,E}, \theta_{M,Z}, \theta_{E,Z}$ , and 1 price deflator  $\beta$ . The model has and 30 equations: (1)-(6), 4x(7), (9)-(8), (11)-(13), (17), (18)-(26), 4x(27), (28). The model has 2 exogenous variables,  $P, L$ , and 16 economic parameters,  $\rho, \sigma, \zeta_M, \zeta_E, \alpha, \delta_K, \delta_A, 4x\zeta_j, 4x\eta_j, \omega$  and 5 climate change parameters,  $\varepsilon_t, \delta_M, \delta_E, \delta_T, TEMP_0$ . There are two policy instruments  $\tau_M$  and  $\tau_c$ , that are linked through (16)

## APPENDIX 2. CALIBRATION RESULTS

TABLE 1. *Variable and parameter values in first period (2000)*

<i>Parameters</i>	<i>Per period</i>	<i>Endogenous variables</i>	<i>Per period</i>	<i>per year</i>
$\rho$	0.186 <sup>#</sup>	$Y$	217.300*	44.025
$\alpha$	0.252 <sup>#</sup>	$C$	161.220	33.031
$\delta_K$	0.351 <sup>#</sup>	$I$	43.500*	8.819
$\delta_A$	0.229 <sup>#</sup>	$M$	224.120	44.824
$\sigma$	0.400	$E$	21.320*	4.284
$\zeta_M$	2.092 <sup>#</sup>	$K$	86.900*	
$\zeta_E$	2.092 <sup>#</sup>	$R$	10.856	2.186
$\omega$	4.000	$R_{Y,M}$	n.a.	
$\eta$	0.500	$R_{Y,E}$	0.520	0.104
$\zeta_{Y,M}$	n.a.	$R_{M,Z}$	10.000*	2.014
$\zeta_{Y,E}$	10.611 <sup>#</sup>	$R_{E,Z}$	0.336	0.067
$\zeta_{M,Z}$	1.278 <sup>#</sup>	$A_{Y,M}$	n.a.	
$\zeta_{E,Z}$	9.522 <sup>#</sup>	$A_{Y,E}$	503.004	
$\pi_{Y,M}$	0.000	$A_{M,Z}$	100.000*	
$\pi_{Y,E}$	0.765 <sup>#</sup>	$A_{E,Z}$	262.062	
$\pi_{M,Z}$	0.321 <sup>#</sup>	$Z_M$	24.129	4.826
$\pi_{E,Z}$	0.495 <sup>#</sup>	$Z_E$	0.651	0.130
		$\psi$	1.280	
		$q$	0.270*	
		$\mu$	0.957	
<i>Environmental variables</i>		$\zeta$	8.885	
		$\theta_{Y,M}$	n.a.	
		$\theta_{Y,E}$	0.032	
		$\theta_{M,Z}$	2.561	
<i>Exogenous Variables</i>		$\theta_{E,Z}$	0.039	
$P$ (billion)	6.730	$\chi_{Y,M}$	n.a.	
$L$ (manyr)	16.152	$\chi_{Y,E}$	0.941	
		$\chi_{M,Z}$	0.970	
$P_{max}$	11.360	$\chi_{E,Z}$	0.941	
<i>Exogenous variables growth rates</i>		<i>Variables growth rates</i>		
		$\beta$	0.784*	
$g_L$	0.061	$g_Y$	0.141*	0.027
$g_{Pop}$	0.061	$g_M$	0.087	0.027
		$g_E = g_Y - EEI$	0.087*	0.017
		$g_K$	0.150	0.028
		$g_q$	0.000*	0.002
		$g_\mu$	0.002	0.000
		$g_\zeta$	0.054	
		$g_{A,Y,M}$	n.a.	
		$g_{A,Y,E}$	0.112	
		$g_{A,M,Z}$	0.170	
		$g_{A,E,Z}$	0.112	
		$g_{Z,M}$	0.084	
		$g_{Z,E}$	0.031	

\* The variables with an \* have been based on empirical data, and are used as input in the calibration process.

# The parameters with an # have been calculated as part of the calibration process

## REFERENCES

- Azar, C., Schneider, H.S., 2002. Are the economic costs of stabilising the atmosphere prohibitive? *Ecological Economics* 42, 73-80
- Barro R.J. and X.X.Sala-i-Martin (1995) *Economic growth*. McGraw-Hill, Inc., New York.
- Basu S, Fernald JG (1997), Returns to scale in US production: Estimates and implications, *Journal Of Political Economy* 105 (2): 249-283.
- Beltratti, A. (1997) "Growth with Natural and Environmental Resources", in C. Carraro and D. Siniscalco, eds., *New Directions in the Economic Theory of the Environment*, Cambridge University Press, Cambridge.
- Bovenberg A.L. and S.A. Smulders (1995) "Environmental quality and pollution-augmenting technological change in a two-sector endogenous growth model" in *Journal of Public Economics* 57: 369-391.
- Bovenberg, A.L., and S.A. Smulders (1996) "Transitional Impacts of Environmental Policy in an Endogenous Growth Model", *International Economic Review* 37: 861-893.
- Buonanno, P., C. Carraro, and M. Galeotti (2003) "Endogenous induced technical change and the costs of Kyoto", forthcoming in *Resource and Energy Economics*.
- Caballero, RJ, and RK Lyons (1992), "External effects in US procyclical productivity", in *Journal of Monetary Economics* 29: 209-225.
- Carraro C. and M.Galeotti (1997) "Economic growth, international competitiveness and environmental protection: R&D innovation strategies with the WARM model", *Energy Economics* 19: 2-28.
- Chakravorty U., J.Roumasset, and K.Tse (1997) "Endogenous substitution among energy resources and global warming" in *Journal of Political Economy* 105: 1201-1234.
- Den Butter F.A.G. and M.W.Hofkes (1995) "Sustainable development with extractive and non-extractive use of the environment in production" in *Environmental and Resource Economics* 6: 341-358.
- Gerlagh, R., and W. Lise (2003), "Induced technological change under carbon taxes", *Nota di Lavoro* 84.2003, Fondazione Eni Enrico Mattei, Milan, Italy.
- Gerlagh R. and E. Papyrakis (2003) "Are the economic costs of (non-)stabilising the atmosphere prohibitive? A comment", *Ecological Economics* 46: 325-327.
- Gerlagh R., and B.C.C. van der Zwaan (2003), "Gross World Product and Consumption in a Global Warming Model with Endogenous Technological Change", *Resource and Energy Economics*, 25:35-57.
- Gerlagh R., and B.C.C. van der Zwaan (2004), "A sensitivity analysis on timing and costs of greenhouse gas abatement, calculations with DEMETER", *Climatic Change* 65:39-71.
- Goulder L.H. and K.Mathai (2000) "Optimal CO2 abatement in the presence of induced technological change" in *Journal of Environmental Economics and Management* 39: 1-38.

- Goulder L.H. and S.H.Schneider (1999) "Induced technological change and the attractiveness of CO2 abatement policies" in *Resource and Energy Economics* **21**: 211-253.
- Gradus R.H.J.M. and S.A.Smulders (1993) "The trade-off between environmental care and long-term growth; pollution in three prototype growth models" in *Journal of Economics* 58: 25-51.
- Grossman, G. M. and A.B. Krueger (1993). Environmental Impacts of a North American Free Trade Agreement, in P. Garber, ed., *The U.S.-Mexico Free Trade Agreement*, p13-56, MIT Press, Cambridge, MA.
- Harris R.I.D, and E. Lau (1998), "Verdoorn's law and increasing returns to scale in the UK regions, 1968-91: some new estimates based on the cointegration approach", *Oxford Economic Papers-New Series* 50: 201-219.
- Jaffe, A.B. (1986), "Technological opportunity and spillovers of R&D: evidence from firms' patents, profits and market value", *American Economic Review* 76:984-1001
- Jaffe A.B., R.G. Newell, and R.N. Stavins (2002), "Environmental Policy and Technological Change", in *Environmental and Resource Economics* 22:41-70.
- Jefferson G.H. (1988), "The Aggregate Production Function And Productivity Growth - Verdoorns Law Revisited", *Oxford Economic Papers-New Series* 40 (4): 671-691.
- Magill M.J.P. (1977) "Some new results on the local stability of the process of capital accumulation" in *Journal of Economic Theory* **15**: 174-210.
- Manne A.S., R.Mendelsohn, and R.Richels (1995) "MERGE, A model for evaluating regional and global effects of GHG reduction policies" in *Energy Policy* **23**: 17-34.
- Newell R.G., A.B. Jaffe and R.N. Stavins (1999), "The induced innovation hypothesis and energy-saving technological change", *Quarterly Journal of Economics* 114: 941-975.
- Nordhaus W.D. (2002), "Modeling induced innovation in climate change policy", Ch 9 in *Modeling induced innovation in climate change policy*, A. Grubler, N. Nakićenović, and W.D. Nordhaus (eds), Resources for the Future Press.
- Popp, D. (2000), "Induced innovation and energy prices", *American Economic Review* 92: 160-180.
- Smulders S.A. (1999) "Endogenous growth theory and the environment" in *Handbook of environmental and resource economics*, Ch. 42, edited by J.C.J.M.v.d.Bergh. Edward Elgar,
- Van der Zwaan B.C.C., R. Gerlagh, G. Klaassen, and L. Schrattenholzer (2002) "Endogenous technological change in climate change modelling", *Energy Economics* 24:1-19.
- Verdier, T. (1995) "Environmental Pollution and Endogenous Growth", in C. Carraro and J. Filar, eds., *Control and Game-Theoretic Models of the Environment*, Birckhauser, Boston.
- Weyant, J.P. and T. Olavson (1999), "Issues in modeling induced technological change in energy, environment, and climate policy", in *Environmental Modeling and Assessment* 4: 67-85.

# 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.ssrn.com/link/feem.html>

## NOTE DI LAVORO PUBLISHED IN 2003

PRIV	1.2003	<i>Gabriella CHIESA and Giovanna NICODANO: <u>Privatization and Financial Market Development: Theoretical Issues</u></i>
PRIV	2.2003	<i>Ibolya SCHINDELE: <u>Theory of Privatization in Eastern Europe: Literature Review</u></i>
PRIV	3.2003	<i>Wietze LISE, Claudia KEMFERT and Richard S.J. TOL: <u>Strategic Action in the Liberalised German Electricity Market</u></i>
CLIM	4.2003	<i>Laura MARSILIANI and Thomas I. RENSTRÖM: <u>Environmental Policy and Capital Movements: The Role of Government Commitment</u></i>
KNOW	5.2003	<i>Reyer GERLAGH: <u>Induced Technological Change under Technological Competition</u></i>
ETA	6.2003	<i>Efrem CASTELNUOVO: <u>Squeezing the Interest Rate Smoothing Weight with a Hybrid Expectations Model</u></i>
SIEV	7.2003	<i>Anna ALBERINI, Alberto LONGO, Stefania TONIN, Francesco TROMBETTA and Margherita TURVANI: <u>The Role of Liability, Regulation and Economic Incentives in Brownfield Remediation and Redevelopment: Evidence from Surveys of Developers</u></i>
NRM	8.2003	<i>Elissaios PAPYRAKIS and Reyner GERLAGH: <u>Natural Resources: A Blessing or a Curse?</u></i>
CLIM	9.2003	<i>A. CAPARRÓS, J.-C. PEREAU and T. TAZDAÏT: <u>North-South Climate Change Negotiations: a Sequential Game with Asymmetric Information</u></i>
KNOW	10.2003	<i>Giorgio BRUNELLO and Daniele CHECCHI: <u>School Quality and Family Background in Italy</u></i>
CLIM	11.2003	<i>Efrem CASTELNUOVO and Marzio GALEOTTI: <u>Learning By Doing vs Learning By Researching in a Model of Climate Change Policy Analysis</u></i>
KNOW	12.2003	<i>Carole MAIGNAN, Gianmarco OTTAVIANO and Dino PINELLI (eds.): <u>Economic Growth, Innovation, Cultural Diversity: What are we all talking about? A critical survey of the state-of-the-art</u></i>
KNOW	13.2003	<i>Carole MAIGNAN, Gianmarco OTTAVIANO, Dino PINELLI and Francesco RULLANI (lix): <u>Bio-Ecological Diversity vs. Socio-Economic Diversity. A Comparison of Existing Measures</u></i>
KNOW	14.2003	<i>Maddy JANSSENS and Chris STEYAERT (lix): <u>Theories of Diversity within Organisation Studies: Debates and Future Trajectories</u></i>
KNOW	15.2003	<i>Tuzin BAYCAN LEVENT, Enno MASUREL and Peter NIJKAMP (lix): <u>Diversity in Entrepreneurship: Ethnic and Female Roles in Urban Economic Life</u></i>
KNOW	16.2003	<i>Alexandra BITUSIKOVA (lix): <u>Post-Communist City on its Way from Grey to Colourful: The Case Study from Slovakia</u></i>
KNOW	17.2003	<i>Billy E. VAUGHN and Katarina MLEKOV (lix): <u>A Stage Model of Developing an Inclusive Community</u></i>
KNOW	18.2003	<i>Selma van LONDEN and Arie de RUIJTER (lix): <u>Managing Diversity in a Globalizing World</u></i>
Coalition	19.2003	<i>Sergio CURRARINI: <u>On the Stability of Hierarchies in Games with Externalities</u></i>
Theory	20.2003	<i>Giacomo CALZOLARI and Alessandro PAVAN (lx): <u>Monopoly with Resale</u></i>
Network	21.2003	<i>Claudio MEZZETTI (lx): <u>Auction Design with Interdependent Valuations: The Generalized Revelation Principle, Efficiency, Full Surplus Extraction and Information Acquisition</u></i>
PRIV	22.2003	<i>Marco LiCalzi and Alessandro PAVAN (lx): <u>Tilting the Supply Schedule to Enhance Competition in Uniform-Price Auctions</u></i>
PRIV	23.2003	<i>David ETTINGER (lx): <u>Bidding among Friends and Enemies</u></i>
PRIV	24.2003	<i>Hannu VARTIAINEN (lx): <u>Auction Design without Commitment</u></i>
PRIV	25.2003	<i>Matti KELOHARJU, Kjell G. NYBORG and Kristian RYDQVIST (lx): <u>Strategic Behavior and Underpricing in Uniform Price Auctions: Evidence from Finnish Treasury Auctions</u></i>
PRIV	26.2003	<i>Christine A. PARLOUR and Uday RAJAN (lx): <u>Rationing in IPOs</u></i>
PRIV	27.2003	<i>Kjell G. NYBORG and Ilya A. STREBULAIEV (lx): <u>Multiple Unit Auctions and Short Squeezes</u></i>
PRIV	28.2003	<i>Anders LUNANDER and Jan-Eric NILSSON (lx): <u>Taking the Lab to the Field: Experimental Tests of Alternative Mechanisms to Procure Multiple Contracts</u></i>
PRIV	29.2003	<i>TangaMcDANIEL and Karsten NEUHOFF (lx): <u>Use of Long-term Auctions for Network Investment</u></i>
PRIV	30.2003	<i>Emiel MAASLAND and Sander ONDERSTAL (lx): <u>Auctions with Financial Externalities</u></i>
ETA	31.2003	<i>Michael FINUS and Bianca RUNDSHAGEN: <u>A Non-cooperative Foundation of Core-Stability in Positive Externality NTU-Coalition Games</u></i>
KNOW	32.2003	<i>Michele MORETTO: <u>Competition and Irreversible Investments under Uncertainty</u></i>
PRIV	33.2003	<i>Philippe QUIRION: <u>Relative Quotas: Correct Answer to Uncertainty or Case of Regulatory Capture?</u></i>
KNOW	34.2003	<i>Giuseppe MEDA, Claudio PIGA and Donald SIEGEL: <u>On the Relationship between R&amp;D and Productivity: A Treatment Effect Analysis</u></i>
ETA	35.2003	<i>Alessandra DEL BOCA, Marzio GALEOTTI and Paola ROTA: <u>Non-convexities in the Adjustment of Different Capital Inputs: A Firm-level Investigation</u></i>

GG	36.2003	<i>Matthieu GLACHANT</i> : <u>Voluntary Agreements under Endogenous Legislative Threats</u>
PRIV	37.2003	<i>Narjess BOUBAKRI, Jean-Claude COSSET and Omrane GUEDHAMI</i> : <u>Postprivatization Corporate Governance: the Role of Ownership Structure and Investor Protection</u>
CLIM	38.2003	<i>Rolf GOLOMBEK and Michael HOEL</i> : <u>Climate Policy under Technology Spillovers</u>
KNOW	39.2003	<i>Slim BEN YOUSSEF</i> : <u>Transboundary Pollution, R&amp;D Spillovers and International Trade</u>
CTN	40.2003	<i>Carlo CARRARO and Carmen MARCHIORI</i> : <u>Endogenous Strategic Issue Linkage in International Negotiations</u>
KNOW	41.2003	<i>Sonia OREFFICE</i> : <u>Abortion and Female Power in the Household: Evidence from Labor Supply</u>
KNOW	42.2003	<i>Timo GOESCHL and Timothy SWANSON</i> : <u>On Biology and Technology: The Economics of Managing Biotechnologies</u>
ETA	43.2003	<i>Giorgio Busetti and Matteo MANERA</i> : <u>STAR-GARCH Models for Stock Market Interactions in the Pacific Basin Region, Japan and US</u>
CLIM	44.2003	<i>Katrin MILLOCK and Céline NAUGES</i> : <u>The French Tax on Air Pollution: Some Preliminary Results on its Effectiveness</u>
PRIV	45.2003	<i>Bernardo BORTOLOTTI and Paolo PINOTTI</i> : <u>The Political Economy of Privatization</u>
SIEV	46.2003	<i>Elbert DIJKGRAAF and Herman R.J. VOLLEBERGH</i> : <u>Burn or Bury? A Social Cost Comparison of Final Waste Disposal Methods</u>
ETA	47.2003	<i>Jens HORBACH</i> : <u>Employment and Innovations in the Environmental Sector: Determinants and Econometrical Results for Germany</u>
CLIM	48.2003	<i>Lori SNYDER, Nolan MILLER and Robert STAVINS</i> : <u>The Effects of Environmental Regulation on Technology Diffusion: The Case of Chlorine Manufacturing</u>
CLIM	49.2003	<i>Lori SNYDER, Robert STAVINS and Alexander F. WAGNER</i> : <u>Private Options to Use Public Goods. Exploiting Revealed Preferences to Estimate Environmental Benefits</u>
CTN	50.2003	<i>László Á. KÓCZY and Luc LAUWERS (Ixi)</i> : <u>The Minimal Dominant Set is a Non-Empty Core-Extension</u>
CTN	51.2003	<i>Matthew O. JACKSON (Ixi)</i> : <u>Allocation Rules for Network Games</u>
CTN	52.2003	<i>Ana MAULEON and Vincent VANNETELBOSCH (Ixi)</i> : <u>Farsightedness and Cautiousness in Coalition Formation</u>
CTN	53.2003	<i>Fernando VEGA-REDONDO (Ixi)</i> : <u>Building Up Social Capital in a Changing World: a network approach</u>
CTN	54.2003	<i>Matthew HAAG and Roger LAGUNOFF (Ixi)</i> : <u>On the Size and Structure of Group Cooperation</u>
CTN	55.2003	<i>Taiji FURUSAWA and Hideo KONISHI (Ixi)</i> : <u>Free Trade Networks</u>
CTN	56.2003	<i>Halis Murat YILDIZ (Ixi)</i> : <u>National Versus International Mergers and Trade Liberalization</u>
CTN	57.2003	<i>Santiago RUBIO and Alistair ULPH (Ixi)</i> : <u>An Infinite-Horizon Model of Dynamic Membership of International Environmental Agreements</u>
KNOW	58.2003	<i>Carole MAIGNAN, Dino PINELLI and Gianmarco I.P. OTTAVIANO</i> : <u>ICT, Clusters and Regional Cohesion: A Summary of Theoretical and Empirical Research</u>
KNOW	59.2003	<i>Giorgio BELLETTINI and Gianmarco I.P. OTTAVIANO</i> : <u>Special Interests and Technological Change</u>
ETA	60.2003	<i>Ronnie SCHÖB</i> : <u>The Double Dividend Hypothesis of Environmental Taxes: A Survey</u>
CLIM	61.2003	<i>Michael FINUS, Ekko van IERLAND and Robert DELLINK</i> : <u>Stability of Climate Coalitions in a Cartel Formation Game</u>
GG	62.2003	<i>Michael FINUS and Bianca RUNDSHAGEN</i> : <u>How the Rules of Coalition Formation Affect Stability of International Environmental Agreements</u>
SIEV	63.2003	<i>Alberto PETRUCCI</i> : <u>Taxing Land Rent in an Open Economy</u>
CLIM	64.2003	<i>Joseph E. ALDY, Scott BARRETT and Robert N. STAVINS</i> : <u>Thirteen Plus One: A Comparison of Global Climate Policy Architectures</u>
SIEV	65.2003	<i>Edi DEFRANCESCO</i> : <u>The Beginning of Organic Fish Farming in Italy</u>
SIEV	66.2003	<i>Klaus CONRAD</i> : <u>Price Competition and Product Differentiation when Consumers Care for the Environment</u>
SIEV	67.2003	<i>Paulo A.L.D. NUNES, Luca ROSSETTO, Arianne DE BLAEIJ</i> : <u>Monetary Value Assessment of Clam Fishing Management Practices in the Venice Lagoon: Results from a Stated Choice Exercise</u>
CLIM	68.2003	<i>ZhongXiang ZHANG</i> : <u>Open Trade with the U.S. Without Compromising Canada's Ability to Comply with its Kyoto Target</u>
KNOW	69.2003	<i>David FRANTZ (Ixi)</i> : <u>Lorenzo Market between Diversity and Mutation</u>
KNOW	70.2003	<i>Ercole SORI (Ixi)</i> : <u>Mapping Diversity in Social History</u>
KNOW	71.2003	<i>Ljiljana DERU SIMIC (Ixi)</i> : <u>What is Specific about Art/Cultural Projects?</u>
KNOW	72.2003	<i>Natalya V. TARANOVA (Ixi)</i> : <u>The Role of the City in Fostering Intergroup Communication in a Multicultural Environment: Saint-Petersburg's Case</u>
KNOW	73.2003	<i>Kristine CRANE (Ixi)</i> : <u>The City as an Arena for the Expression of Multiple Identities in the Age of Globalisation and Migration</u>
KNOW	74.2003	<i>Kazuma MATOBA (Ixi)</i> : <u>Glocal Dialogue- Transformation through Transcultural Communication</u>
KNOW	75.2003	<i>Catarina REIS OLIVEIRA (Ixi)</i> : <u>Immigrants' Entrepreneurial Opportunities: The Case of the Chinese in Portugal</u>
KNOW	76.2003	<i>Sandra WALLMAN (Ixi)</i> : <u>The Diversity of Diversity - towards a typology of urban systems</u>
KNOW	77.2003	<i>Richard PEARCE (Ixi)</i> : <u>A Biologist's View of Individual Cultural Identity for the Study of Cities</u>
KNOW	78.2003	<i>Vincent MERK (Ixi)</i> : <u>Communication Across Cultures: from Cultural Awareness to Reconciliation of the Dilemmas</u>
KNOW	79.2003	<i>Giorgio BELLETTINI, Carlotta BERTI CERONI and Gianmarco I.P. OTTAVIANO</i> : <u>Child Labor and Resistance to Change</u>
ETA	80.2003	<i>Michele MORETTO, Paolo M. PANTEGHINI and Carlo SCARPA</i> : <u>Investment Size and Firm's Value under Profit Sharing Regulation</u>

ITEM	81.2003	<i>Alessandro LANZA, Matteo MANERA and Massimo GIOVANNINI: <u>Oil and Product Dynamics in International Petroleum Markets</u></i>
CLIM	82.2003	<i>Y. Hossein FARZIN and Jinhua ZHAO: <u>Pollution Abatement Investment When Firms Lobby Against Environmental Regulation</u></i>
CLIM	83.2003	<i>Giuseppe DI VITA: <u>Is the Discount Rate Relevant in Explaining the Environmental Kuznets Curve?</u></i>
CLIM	84.2003	<i>Reyer GERLAGH and Wietze LISE: <u>Induced Technological Change Under Carbon Taxes</u></i>
NRM	85.2003	<i>Rinaldo BRAU, Alessandro LANZA and Francesco PIGLIARU: <u>How Fast are the Tourism Countries Growing? The cross-country evidence</u></i>
KNOW	86.2003	<i>Elena BELLINI, Gianmarco I.P. OTTAVIANO and Dino PINELLI: <u>The ICT Revolution: opportunities and risks for the Mezzogiorno</u></i>
SIEV	87.2003	<i>Lucas BRETSCGHER and Sjak SMULDERS: <u>Sustainability and Substitution of Exhaustible Natural Resources. How resource prices affect long-term R&amp;D investments</u></i>
CLIM	88.2003	<i>Johan EYCKMANS and Michael FINUS: <u>New Roads to International Environmental Agreements: The Case of Global Warming</u></i>
CLIM	89.2003	<i>Marzio GALEOTTI: <u>Economic Development and Environmental Protection</u></i>
CLIM	90.2003	<i>Marzio GALEOTTI: <u>Environment and Economic Growth: Is Technical Change the Key to Decoupling?</u></i>
CLIM	91.2003	<i>Marzio GALEOTTI and Barbara BUCHNER: <u>Climate Policy and Economic Growth in Developing Countries</u></i>
ITEM	92.2003	<i>A. MARKANDYA, A. GOLUB and E. STRUKOVA: <u>The Influence of Climate Change Considerations on Energy Policy: The Case of Russia</u></i>
ETA	93.2003	<i>Andrea BELTRATTI: <u>Socially Responsible Investment in General Equilibrium</u></i>
CTN	94.2003	<i>Parkash CHANDER: <u>The <math>\gamma</math>-Core and Coalition Formation</u></i>
ITEM	95.2003	<i>Matteo MANERA and Angelo MARZULLO: <u>Modelling the Load Curve of Aggregate Electricity Consumption Using Principal Components</u></i>
ITEM	96.2003	<i>Alessandro LANZA, Matteo MANERA, Margherita GRASSO and Massimo GIOVANNINI: <u>Long-run Models of Oil Stock Prices</u></i>
CTN	97.2003	<i>Steven J. BRAMS, Michael A. JONES, and D. Marc KILGOUR: <u>Forming Stable Coalitions: The Process Matters</u></i>
KNOW	98.2003	<i>John CROWLEY, Marie-Cecile NAVES (Ixi): <u>Anti-Racist Policies in France. From Ideological and Historical Schemes to Socio-Political Realities</u></i>
KNOW	99.2003	<i>Richard THOMPSON FORD (Ixi): <u>Cultural Rights and Civic Virtue</u></i>
KNOW	100.2003	<i>Alaknanda PATEL (Ixi): <u>Cultural Diversity and Conflict in Multicultural Cities</u></i>
KNOW	101.2003	<i>David MAY (Ixi): <u>The Struggle of Becoming Established in a Deprived Inner-City Neighbourhood</u></i>
KNOW	102.2003	<i>Sébastien ARCAD, Danielle JUTEAU, Sirma BILGE, and Francine LEMIRE (Ixi) : <u>Municipal Reform on the Island of Montreal: Tensions Between Two Majority Groups in a Multicultural City</u></i>
CLIM	103.2003	<i>Barbara BUCHNER and Carlo CARRARO: <u>China and the Evolution of the Present Climate Regime</u></i>
CLIM	104.2003	<i>Barbara BUCHNER and Carlo CARRARO: <u>Emissions Trading Regimes and Incentives to Participate in International Climate Agreements</u></i>
CLIM	105.2003	<i>Anil MARKANDYA and Dirk T.G. RÜBBELKE: <u>Ancillary Benefits of Climate Policy</u></i>
NRM	106.2003	<i>Anne Sophie CRÉPIN (Ix): <u>Management Challenges for Multiple-Species Boreal Forests</u></i>
NRM	107.2003	<i>Anne Sophie CRÉPIN (Ix): <u>Threshold Effects in Coral Reef Fisheries</u></i>
SIEV	108.2003	<i>Sara ANIYAR ( Ix): <u>Estimating the Value of Oil Capital in a Small Open Economy: The Venezuela's Example</u></i>
SIEV	109.2003	<i>Kenneth ARROW, Partha DASGUPTA and Karl-Göran MÄLER(Ix): <u>Evaluating Projects and Assessing Sustainable Development in Imperfect Economies</u></i>
NRM	110.2003	<i>Anastasios XEPAPADEAS and Catarina ROSETA-PALMA(Ix): <u>Instabilities and Robust Control in Fisheries</u></i>
NRM	111.2003	<i>Charles PERRINGS and Brian WALKER (Ix): <u>Conservation and Optimal Use of Rangelands</u></i>
ETA	112.2003	<i>Jack GOODY (Ix): <u>Globalisation, Population and Ecology</u></i>
CTN	113.2003	<i>Carlo CARRARO, Carmen MARCHIORI and Sonia OREFFICE: <u>Endogenous Minimum Participation in International Environmental Treaties</u></i>
CTN	114.2003	<i>Guillaume HAERINGER and Myrna WOODERS: <u>Decentralized Job Matching</u></i>
CTN	115.2003	<i>Hideo KONISHI and M. Utku UNVER: <u>Credible Group Stability in Multi-Partner Matching Problems</u></i>
CTN	116.2003	<i>Somdeb LAHIRI: <u>Stable Matchings for the Room-Mates Problem</u></i>
CTN	117.2003	<i>Somdeb LAHIRI: <u>Stable Matchings for a Generalized Marriage Problem</u></i>
CTN	118.2003	<i>Marita LAUKKANEN: <u>Transboundary Fisheries Management under Implementation Uncertainty</u></i>
CTN	119.2003	<i>Edward CARTWRIGHT and Myrna WOODERS: <u>Social Conformity and Bounded Rationality in Arbitrary Games with Incomplete Information: Some First Results</u></i>
CTN	120.2003	<i>Gianluigi VERNASCA: <u>Dynamic Price Competition with Price Adjustment Costs and Product Differentiation</u></i>
CTN	121.2003	<i>Myrna WOODERS, Edward CARTWRIGHT and Reinhard SELTEN: <u>Social Conformity in Games with Many Players</u></i>
CTN	122.2003	<i>Edward CARTWRIGHT and Myrna WOODERS: <u>On Equilibrium in Pure Strategies in Games with Many Players</u></i>
CTN	123.2003	<i>Edward CARTWRIGHT and Myrna WOODERS: <u>Conformity and Bounded Rationality in Games with Many Players</u></i>
1000		<b>Carlo CARRARO, Alessandro LANZA and Valeria PAPPONETTI: <u>One Thousand Working Papers</u></b>

## NOTE DI LAVORO PUBLISHED IN 2004

IEM	1.2004	Anil MARKANDYA, Suzette PEDROSO and Alexander GOLUB: <u>Empirical Analysis of National Income and So2 Emissions in Selected European Countries</u>
ETA	2.2004	Masahisa FUJITA and Shlomo WEBER: <u>Strategic Immigration Policies and Welfare in Heterogeneous Countries</u>
PRA	3.2004	Adolfo DI CARLUCCIO, Giovanni FERRI, Cecilia FRALE and Ottavio RICCHI: <u>Do Privatizations Boost Household Shareholding? Evidence from Italy</u>
ETA	4.2004	Victor GINSBURGH and Shlomo WEBER: <u>Languages Disenfranchisement in the European Union</u>
ETA	5.2004	Romano PIRAS: <u>Growth, Congestion of Public Goods, and Second-Best Optimal Policy</u>
CCMP	6.2004	Herman R.J. VOLLEBERGH: <u>Lessons from the Polder: Is Dutch CO2-Taxation Optimal</u>
PRA	7.2004	Sandro BRUSCO, Giuseppe LOPOMO and S. VISWANATHAN (lxv): <u>Merger Mechanisms</u>
PRA	8.2004	Wolfgang AUSSENEGG, Pegaret PICHLER and Alex STOMPER (lxv): <u>IPO Pricing with Bookbuilding, and a When-Issued Market</u>
PRA	9.2004	Pegaret PICHLER and Alex STOMPER (lxv): <u>Primary Market Design: Direct Mechanisms and Markets</u>
PRA	10.2004	Florian ENGLMAIER, Pablo GUILLEN, Loreto LLORENTE, Sander ONDERSTAL and Rupert SAUSGRUBER (lxv): <u>The Chopstick Auction: A Study of the Exposure Problem in Multi-Unit Auctions</u>
PRA	11.2004	Bjarne BRENDSTRUP and Harry J. PAARSCH (lxv): <u>Nonparametric Identification and Estimation of Multi-Unit, Sequential, Oral, Ascending-Price Auctions With Asymmetric Bidders</u>
PRA	12.2004	Ohad KADAN (lxv): <u>Equilibrium in the Two Player, k-Double Auction with Affiliated Private Values</u>
PRA	13.2004	Maarten C.W. JANSSEN (lxv): <u>Auctions as Coordination Devices</u>
PRA	14.2004	Gadi FIBICH, Arie GAVIOUS and Aner SELA (lxv): <u>All-Pay Auctions with Weakly Risk-Averse Buyers</u>
PRA	15.2004	Orly SADE, Charles SCHNITZLEIN and Jaime F. ZENDER (lxv): <u>Competition and Cooperation in Divisible Good Auctions: An Experimental Examination</u>
PRA	16.2004	Marta STRYSZOWSKA (lxv): <u>Late and Multiple Bidding in Competing Second Price Internet Auctions</u>
CCMP	17.2004	Slim Ben YOUSSEF: <u>R&amp;D in Cleaner Technology and International Trade</u>
NRM	18.2004	Angelo ANTOCI, Simone BORGHESI and Paolo RUSSU (lxvi): <u>Biodiversity and Economic Growth: Stabilization Versus Preservation of the Ecological Dynamics</u>
SIEV	19.2004	Anna ALBERINI, Paolo ROSATO, Alberto LONGO and Valentina ZANATTA: <u>Information and Willingness to Pay in a Contingent Valuation Study: The Value of S. Erasmo in the Lagoon of Venice</u>
NRM	20.2004	Guido CANDELA and Roberto CELLINI (lxvii): <u>Investment in Tourism Market: A Dynamic Model of Differentiated Oligopoly</u>
NRM	21.2004	Jacqueline M. HAMILTON (lxvii): <u>Climate and the Destination Choice of German Tourists</u>
NRM	22.2004	Javier Rey-MAQUIEIRA PALMER, Javier LOZANO IBÁÑEZ and Carlos Mario GÓMEZ GÓMEZ (lxvii): <u>Land, Environmental Externalities and Tourism Development</u>
NRM	23.2004	Pius ODUNGA and Henk FOLMER (lxvii): <u>Profiling Tourists for Balanced Utilization of Tourism-Based Resources in Kenya</u>
NRM	24.2004	Jean-Jacques NOWAK, Mondher SAHLI and Pasquale M. SGRO (lxvii): <u>Tourism, Trade and Domestic Welfare</u>
NRM	25.2004	Riaz SHAREEF (lxvii): <u>Country Risk Ratings of Small Island Tourism Economies</u>
NRM	26.2004	Juan Luis EUGENIO-MARTÍN, Noelia MARTÍN MORALES and Riccardo SCARPA (lxvii): <u>Tourism and Economic Growth in Latin American Countries: A Panel Data Approach</u>
NRM	27.2004	Raúl Hernández MARTÍN (lxvii): <u>Impact of Tourism Consumption on GDP. The Role of Imports</u>
CSRM	28.2004	Nicoletta FERRO: <u>Cross-Country Ethical Dilemmas in Business: A Descriptive Framework</u>
NRM	29.2004	Marian WEBER (lxvi): <u>Assessing the Effectiveness of Tradable Landuse Rights for Biodiversity Conservation: an Application to Canada's Boreal Mixedwood Forest</u>
NRM	30.2004	Trond BJORN DAL, Phoebe KOUNDOURI and Sean PASCOE (lxvi): <u>Output Substitution in Multi-Species Trawl Fisheries: Implications for Quota Setting</u>
CCMP	31.2004	Marzio GALEOTTI, Alessandra GORIA, Paolo MOMBRINI and Evi SPANTIDAKI: <u>Weather Impacts on Natural, Social and Economic Systems (WISE) Part I: Sectoral Analysis of Climate Impacts in Italy</u>
CCMP	32.2004	Marzio GALEOTTI, Alessandra GORIA, Paolo MOMBRINI and Evi SPANTIDAKI: <u>Weather Impacts on Natural, Social and Economic Systems (WISE) Part II: Individual Perception of Climate Extremes in Italy</u>
CTN	33.2004	Wilson PEREZ: <u>Divide and Conquer: Noisy Communication in Networks, Power, and Wealth Distribution</u>
KTHC	34.2004	Gianmarco I.P. OTTAVIANO and Giovanni PERI (lxviii): <u>The Economic Value of Cultural Diversity: Evidence from US Cities</u>
KTHC	35.2004	Linda CHAIB (lxviii): <u>Immigration and Local Urban Participatory Democracy: A Boston-Paris Comparison</u>
KTHC	36.2004	Franca ECKERT COEN and Claudio ROSSI (lxviii): <u>Foreigners, Immigrants, Host Cities: The Policies of Multi-Ethnicity in Rome. Reading Governance in a Local Context</u>
KTHC	37.2004	Kristine CRANE (lxviii): <u>Governing Migration: Immigrant Groups' Strategies in Three Italian Cities – Rome, Naples and Bari</u>
KTHC	38.2004	Kiflemariam HAMDE (lxviii): <u>Mind in Africa, Body in Europe: The Struggle for Maintaining and Transforming Cultural Identity - A Note from the Experience of Eritrean Immigrants in Stockholm</u>
ETA	39.2004	Alberto CAVALIERE: <u>Price Competition with Information Disparities in a Vertically Differentiated Duopoly</u>
PRA	40.2004	Andrea BIGANO and Stef PROOST: <u>The Opening of the European Electricity Market and Environmental Policy: Does the Degree of Competition Matter?</u>
CCMP	41.2004	Micheal FINUS (lxix): <u>International Cooperation to Resolve International Pollution Problems</u>
KTHC	42.2004	Francesco CRESPI: <u>Notes on the Determinants of Innovation: A Multi-Perspective Analysis</u>



CTN	43.2004	<i>Sergio CURRARINI and Marco MARINI: <u>Coalition Formation in Games without Synergies</u></i>
CTN	44.2004	<i>Marc ESCRIHUELA-VILLAR: <u>Cartel Sustainability and Cartel Stability</u></i>
NRM	45.2004	<i>Sebastian BERVOETS and Nicolas GRAVEL (lxvi): <u>Appraising Diversity with an Ordinal Notion of Similarity: An Axiomatic Approach</u></i>
NRM	46.2004	<i>Signe ANTHON and Bo JELLES MARK THORSEN (lxvi): <u>Optimal Afforestation Contracts with Asymmetric Information on Private Environmental Benefits</u></i>
NRM	47.2004	<i>John MBURU (lxvi): <u>Wildlife Conservation and Management in Kenya: Towards a Co-management Approach</u></i>
NRM	48.2004	<i>Ekin BIROL, Ágnes GYOVAI and Melinda SMALE (lxvi): <u>Using a Choice Experiment to Value Agricultural Biodiversity on Hungarian Small Farms: Agri-Environmental Policies in a Transitional Economy</u></i>
CCMP	49.2004	<i>Gernot KLEPPER and Sonja PETERSON: <u>The EU Emissions Trading Scheme. Allowance Prices, Trade Flows, Competitiveness Effects</u></i>
GG	50.2004	<i>Scott BARRETT and Michael HOEL: <u>Optimal Disease Eradication</u></i>
CTN	51.2004	<i>Dinko DIMITROV, Peter BORM, Ruud HENDRICKX and Shao CHIN SUNG: <u>Simple Priorities and Core Stability in Hedonic Games</u></i>
SIEV	52.2004	<i>Francesco RICCI: <u>Channels of Transmission of Environmental Policy to Economic Growth: A Survey of the Theory</u></i>
SIEV	53.2004	<i>Anna ALBERINI, Maureen CROPPER, Alan KRUPNICK and Nathalie B. SIMON: <u>Willingness to Pay for Mortality Risk Reductions: Does Latency Matter?</u></i>
NRM	54.2004	<i>Ingo BRÄUER and Rainer MARGGRAF (lxvi): <u>Valuation of Ecosystem Services Provided by Biodiversity Conservation: An Integrated Hydrological and Economic Model to Value the Enhanced Nitrogen Retention in Renaturated Streams</u></i>
NRM	55.2004	<i>Timo GOESCHL and Tun LIN (lxvi): <u>Biodiversity Conservation on Private Lands: Information Problems and Regulatory Choices</u></i>
NRM	56.2004	<i>Tom DEDEURWAERDERE (lxvi): <u>Bioprospection: From the Economics of Contracts to Reflexive Governance</u></i>
CCMP	57.2004	<i>Katrin REHDANZ and David MADDISON: <u>The Amenity Value of Climate to German Households</u></i>
CCMP	58.2004	<i>Koen SMEKENS and Bob VAN DER ZWAAN: <u>Environmental Externalities of Geological Carbon Sequestration Effects on Energy Scenarios</u></i>
NRM	59.2004	<i>Valentina BOSETTI, Mariaester CASSINELLI and Alessandro LANZA (lxvii): <u>Using Data Envelopment Analysis to Evaluate Environmentally Conscious Tourism Management</u></i>
NRM	60.2004	<i>Timo GOESCHL and Danilo CAMARGO IGLIORI (lxvi): <u>Property Rights Conservation and Development: An Analysis of Extractive Reserves in the Brazilian Amazon</u></i>
CCMP	61.2004	<i>Barbara BUCHNER and Carlo CARRARO: <u>Economic and Environmental Effectiveness of a Technology-based Climate Protocol</u></i>
NRM	62.2004	<i>Elissaios PAPYRAKIS and Reyer GERLAGH: <u>Resource-Abundance and Economic Growth in the U.S.</u></i>
NRM	63.2004	<i>Györgyi BELA, György PATAKI, Melinda SMALE and Mariann HAJDÚ (lxvi): <u>Conserving Crop Genetic Resources on Smallholder Farms in Hungary: Institutional Analysis</u></i>
NRM	64.2004	<i>E.C.M. RUIJGROK and E.E.M. NILLESEN (lxvi): <u>The Socio-Economic Value of Natural Riverbanks in the Netherlands</u></i>
NRM	65.2004	<i>E.C.M. RUIJGROK (lxvi): <u>Reducing Acidification: The Benefits of Increased Nature Quality. Investigating the Possibilities of the Contingent Valuation Method</u></i>
ETA	66.2004	<i>Giannis VARDAS and Anastasios XEPAPADEAS: <u>Uncertainty Aversion, Robust Control and Asset Holdings</u></i>
GG	67.2004	<i>Anastasios XEPAPADEAS and Constadina PASSA: <u>Participation in and Compliance with Public Voluntary Environmental Programs: An Evolutionary Approach</u></i>
GG	68.2004	<i>Michael FINUS: <u>Modesty Pays: Sometimes!</u></i>
NRM	69.2004	<i>Trond BJØRNDAL and Ana BRASÃO: <u>The Northern Atlantic Bluefin Tuna Fisheries: Management and Policy Implications</u></i>
CTN	70.2004	<i>Alejandro CAPARRÓS, Abdelhakim HAMMOUDI and Tarik TAZDAÏT: <u>On Coalition Formation with Heterogeneous Agents</u></i>
IEM	71.2004	<i>Massimo GIOVANNINI, Margherita GRASSO, Alessandro LANZA and Matteo MANERA: <u>Conditional Correlations in the Returns on Oil Companies Stock Prices and Their Determinants</u></i>
IEM	72.2004	<i>Alessandro LANZA, Matteo MANERA and Michael MCALEER: <u>Modelling Dynamic Conditional Correlations in WTI Oil Forward and Futures Returns</u></i>
SIEV	73.2004	<i>Margarita GENIUS and Elisabetta STRAZZERA: <u>The Copula Approach to Sample Selection Modelling: An Application to the Recreational Value of Forests</u></i>
CCMP	74.2004	<i>Rob DELLINK and Ekko van IERLAND: <u>Pollution Abatement in the Netherlands: A Dynamic Applied General Equilibrium Assessment</u></i>
ETA	75.2004	<i>Rosella LEVAGGI and Michele MORETTO: <u>Investment in Hospital Care Technology under Different Purchasing Rules: A Real Option Approach</u></i>
CTN	76.2004	<i>Salvador BARBERÀ and Matthew O. JACKSON (lxx): <u>On the Weights of Nations: Assigning Voting Weights in a Heterogeneous Union</u></i>
CTN	77.2004	<i>Àlex ARENAS, Antonio CABRALES, Albert DÍAZ-GUILERA, Roger GUIMERA and Fernando VEGA-REDONDO (lxx): <u>Optimal Information Transmission in Organizations: Search and Congestion</u></i>
CTN	78.2004	<i>Francis BLOCH and Armando GOMES (lxx): <u>Contracting with Externalities and Outside Options</u></i>
CTN	79.2004	<i>Rabah AMIR, Effrosyni DIAMANTOUDI and Licun XUE (lxx): <u>Merger Performance under Uncertain Efficiency Gains</u></i>
CTN	80.2004	<i>Francis BLOCH and Matthew O. JACKSON (lxx): <u>The Formation of Networks with Transfers among Players</u></i>
CTN	81.2004	<i>Daniel DIERMEIER, Hülya ERASLAN and Antonio MERLO (lxx): <u>Bicameralism and Government Formation</u></i>

CTN	82.2004	<i>Rod GARRATT, James E. PARCO, Cheng-ZHONG QIN and Amnon RAPOPORT (lxx): <u>Potential Maximization and Coalition Government Formation</u></i>
CTN	83.2004	<i>Kfir ELIAZ, Debraj RAY and Ronny RAZIN (lxx): <u>Group Decision-Making in the Shadow of Disagreement</u></i>
CTN	84.2004	<i>Sanjeev GOYAL, Marco van der LEIJ and José Luis MORAGA-GONZÁLEZ (lxx): <u>Economics: An Emerging Small World?</u></i>
CTN	85.2004	<i>Edward CARTWRIGHT (lxx): <u>Learning to Play Approximate Nash Equilibria in Games with Many Players</u></i>
IEM	86.2004	<i>Finn R. FØRSUND and Michael HOEL: <u>Properties of a Non-Competitive Electricity Market Dominated by Hydroelectric Power</u></i>
KTHC	87.2004	<i>Elissaios PAPYRAKIS and Reyer GERLAGH: <u>Natural Resources, Investment and Long-Term Income</u></i>
CCMP	88.2004	<i>Marzio GALEOTTI and Claudia KEMFERT: <u>Interactions between Climate and Trade Policies: A Survey</u></i>
IEM	89.2004	<i>A. MARKANDYA, S. PEDROSO and D. STREIMIKIENE: <u>Energy Efficiency in Transition Economies: Is There Convergence Towards the EU Average?</u></i>
GG	90.2004	<i>Rolf GOLOMBEK and Michael HOEL: <u>Climate Agreements and Technology Policy</u></i>
PRA	91.2004	<i>Sergei IZMALKOV (lxy): <u>Multi-Unit Open Ascending Price Efficient Auction</u></i>
KTHC	92.2004	<i>Gianmarco I.P. OTTAVIANO and Giovanni PERI: <u>Cities and Cultures</u></i>
KTHC	93.2004	<i>Massimo DEL GATTO: <u>Agglomeration, Integration, and Territorial Authority Scale in a System of Trading Cities. Centralisation versus devolution</u></i>
CCMP	94.2004	<i>Pierre-André JOUVET, Philippe MICHEL and Gilles ROTILLON: <u>Equilibrium with a Market of Permits</u></i>
CCMP	95.2004	<i>Bob van der ZWAAN and Reyer GERLAGH: <u>Climate Uncertainty and the Necessity to Transform Global Energy Supply</u></i>
CCMP	96.2004	<i>Francesco BOSELLO, Marco LAZZARIN, Roberto ROSON and Richard S.J. TOL: <u>Economy-Wide Estimates of the Implications of Climate Change: Sea Level Rise</u></i>
CTN	97.2004	<i>Gustavo BERGANTIÑOS and Juan J. VIDAL-PUGA: <u>Defining Rules in Cost Spanning Tree Problems Through the Canonical Form</u></i>
CTN	98.2004	<i>Siddhartha BANDYOPADHYAY and Mandar OAK: <u>Party Formation and Coalitional Bargaining in a Model of Proportional Representation</u></i>
GG	99.2004	<i>Hans-Peter WEIKARD, Michael FINUS and Juan-Carlos ALTAMIRANO-CABRERA: <u>The Impact of Surplus Sharing on the Stability of International Climate Agreements</u></i>
SIEV	100.2004	<i>Chiara M. TRAVISI and Peter NIJKAMP: <u>Willingness to Pay for Agricultural Environmental Safety: Evidence from a Survey of Milan, Italy, Residents</u></i>
SIEV	101.2004	<i>Chiara M. TRAVISI, Raymond J. G. M. FLORAX and Peter NIJKAMP: <u>A Meta-Analysis of the Willingness to Pay for Reductions in Pesticide Risk Exposure</u></i>
NRM	102.2004	<i>Valentina BOSETTI and David TOMBERLIN: <u>Real Options Analysis of Fishing Fleet Dynamics: A Test</u></i>
CCMP	103.2004	<i>Alessandra GORIA e Gretel GAMBARELLI: <u>Economic Evaluation of Climate Change Impacts and Adaptability in Italy</u></i>
PRA	104.2004	<i>Massimo FLORIO and Mara GRASSEN: <u>The Missing Shock: The Macroeconomic Impact of British Privatisation</u></i>
PRA	105.2004	<i>John BENNETT, Saul ESTRIN, James MAW and Giovanni URGÀ: <u>Privatisation Methods and Economic Growth in Transition Economies</u></i>
PRA	106.2004	<i>Kira BÖRNER: <u>The Political Economy of Privatization: Why Do Governments Want Reforms?</u></i>
PRA	107.2004	<i>Pehr-Johan NORBÄCK and Lars PERSSON: <u>Privatization and Restructuring in Concentrated Markets</u></i>
SIEV	108.2004	<i>Angela GRANZOTTO, Fabio PRANOVI, Simone LIBRALATO, Patrizia TORRICELLI and Danilo MAINARDI: <u>Comparison between Artisanal Fishery and Manila Clam Harvesting in the Venice Lagoon by Using Ecosystem Indicators: An Ecological Economics Perspective</u></i>
CTN	109.2004	<i>Somdeb LAHIRI: <u>The Cooperative Theory of Two Sided Matching Problems: A Re-examination of Some Results</u></i>
NRM	110.2004	<i>Giuseppe DI VITA: <u>Natural Resources Dynamics: Another Look</u></i>
SIEV	111.2004	<i>Anna ALBERINI, Alistair HUNT and Anil MARKANDYA: <u>Willingness to Pay to Reduce Mortality Risks: Evidence from a Three-Country Contingent Valuation Study</u></i>
KTHC	112.2004	<i>Valeria PAPPONETTI and Dino PINELLI: <u>Scientific Advice to Public Policy-Making</u></i>
SIEV	113.2004	<i>Paulo A.L.D. NUNES and Laura ONOFRI: <u>The Economics of Warm Glow: A Note on Consumer's Behavior and Public Policy Implications</u></i>
IEM	114.2004	<i>Patrick CAYRADE: <u>Investments in Gas Pipelines and Liquefied Natural Gas Infrastructure What is the Impact on the Security of Supply?</u></i>
IEM	115.2004	<i>Valeria COSTANTINI and Francesco GRACCEVA: <u>Oil Security. Short- and Long-Term Policies</u></i>
IEM	116.2004	<i>Valeria COSTANTINI and Francesco GRACCEVA: <u>Social Costs of Energy Disruptions</u></i>
IEM	117.2004	<i>Christian EGENHOFER, Kyriakos GIALOGLOU, Giacomo LUCIANI, Maroeska BOOTS, Martin SCHEEPERS, Valeria COSTANTINI, Francesco GRACCEVA, Anil MARKANDYA and Giorgio VICINI: <u>Market-Based Options for Security of Energy Supply</u></i>
IEM	118.2004	<i>David FISK: <u>Transport Energy Security. The Unseen Risk?</u></i>
IEM	119.2004	<i>Giacomo LUCIANI: <u>Security of Supply for Natural Gas Markets. What is it and What is it not?</u></i>
IEM	120.2004	<i>L.J. de VRIES and R.A. HAKVOORT: <u>The Question of Generation Adequacy in Liberalised Electricity Markets</u></i>
KTHC	121.2004	<i>Alberto PETRUCCI: <u>Asset Accumulation, Fertility Choice and Nondegenerate Dynamics in a Small Open Economy</u></i>
NRM	122.2004	<i>Carlo GIUPPONI, Jaroslaw MYŚIAK and Anita FASSIO: <u>An Integrated Assessment Framework for Water Resources Management: A DSS Tool and a Pilot Study Application</u></i>
NRM	123.2004	<i>Margaretha BREIL, Anita FASSIO, Carlo GIUPPONI and Paolo ROSATO: <u>Evaluation of Urban Improvement on the Islands of the Venice Lagoon: A Spatially-Distributed Hedonic-Hierarchical Approach</u></i>

ETA	124.2004	<i>Paul MENSINK: <u>Instant Efficient Pollution Abatement Under Non-Linear Taxation and Asymmetric Information: The Differential Tax Revisited</u></i>
NRM	125.2004	<i>Mauro FABIANO, Gabriella CAMARSA, Rosanna DURSI, Roberta IVALDI, Valentina MARIN and Francesca PALMISANI: <u>Integrated Environmental Study for Beach Management: A Methodological Approach</u></i>
PRA	126.2004	<i>Irena GROSFELD and Iraj HASHI: <u>The Emergence of Large Shareholders in Mass Privatized Firms: Evidence from Poland and the Czech Republic</u></i>
CCMP	127.2004	<i>Maria BERRITTELLA, Andrea BIGANO, Roberto ROSON and Richard S.J. TOL: <u>A General Equilibrium Analysis of Climate Change Impacts on Tourism</u></i>
CCMP	128.2004	<i>Reyer GERLAGH: <u>A Climate-Change Policy Induced Shift from Innovations in Energy Production to Energy Savings</u></i>

- (lix) This paper was presented at the ENGIME Workshop on “Mapping Diversity”, Leuven, May 16-17, 2002
- (lx) This paper was presented at the EuroConference on “Auctions and Market Design: Theory, Evidence and Applications”, organised by the Fondazione Eni Enrico Mattei, Milan, September 26-28, 2002
- (lxi) This paper was presented at the Eighth Meeting of the Coalition Theory Network organised by the GREQAM, Aix-en-Provence, France, January 24-25, 2003
- (lxii) This paper was presented at the ENGIME Workshop on “Communication across Cultures in Multicultural Cities”, The Hague, November 7-8, 2002
- (lxiii) This paper was presented at the ENGIME Workshop on “Social dynamics and conflicts in multicultural cities”, Milan, March 20-21, 2003
- (lxiv) This paper was presented at the International Conference on “Theoretical Topics in Ecological Economics”, organised by the Abdus Salam International Centre for Theoretical Physics - ICTP, the Beijer International Institute of Ecological Economics, and Fondazione Eni Enrico Mattei – FEEM Trieste, February 10-21, 2003
- (lxv) This paper was presented at the EuroConference on “Auctions and Market Design: Theory, Evidence and Applications” organised by Fondazione Eni Enrico Mattei and sponsored by the EU, Milan, September 25-27, 2003
- (lxvi) This paper has been presented at the 4th BioEcon Workshop on “Economic Analysis of Policies for Biodiversity Conservation” organised on behalf of the BIOECON Network by Fondazione Eni Enrico Mattei, Venice International University (VIU) and University College London (UCL), Venice, August 28-29, 2003
- (lxvii) This paper has been presented at the international conference on “Tourism and Sustainable Economic Development – Macro and Micro Economic Issues” jointly organised by CRENoS (Università di Cagliari e Sassari, Italy) and Fondazione Eni Enrico Mattei, and supported by the World Bank, Sardinia, September 19-20, 2003
- (lxviii) This paper was presented at the ENGIME Workshop on “Governance and Policies in Multicultural Cities”, Rome, June 5-6, 2003
- (lxix) This paper was presented at the Fourth EEP Plenary Workshop and EEP Conference “The Future of Climate Policy”, Cagliari, Italy, 27-28 March 2003
- (lxx) This paper was presented at the 9<sup>th</sup> Coalition Theory Workshop on "Collective Decisions and Institutional Design" organised by the Universitat Autònoma de Barcelona and held in Barcelona, Spain, January 30-31, 2004

**2003 SERIES**

<b>CLIM</b>	<i>Climate Change Modelling and Policy</i> (Editor: Marzio Galeotti )
<b>GG</b>	<i>Global Governance</i> (Editor: Carlo Carraro)
<b>SIEV</b>	<i>Sustainability Indicators and Environmental Valuation</i> (Editor: Anna Alberini)
<b>NRM</b>	<i>Natural Resources Management</i> (Editor: Carlo Giupponi)
<b>KNOW</b>	<i>Knowledge, Technology, Human Capital</i> (Editor: Gianmarco Ottaviano)
<b>IEM</b>	<i>International Energy Markets</i> (Editor: Anil Markandya)
<b>CSRM</b>	<i>Corporate Social Responsibility and Management</i> (Editor: Sabina Ratti)
<b>PRIV</b>	<i>Privatisation, Regulation, Antitrust</i> (Editor: Bernardo Bortolotti)
<b>ETA</b>	<i>Economic Theory and Applications</i> (Editor: Carlo Carraro)
<b>CTN</b>	<i>Coalition Theory Network</i>

**2004 SERIES**

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