Fondazione Eni Enrico Mattei

Global Warming and Financial Umbrellas

Cesare Dosi* and Michele Moretto*

NOTA DI LAVORO 87.2001

OCTOBER 2001

CLIM – Climate Policy and Modelling Policy

*Department of Economics, University of Padova

Fondazione Eni Enrico Mattei
Corso Magenta, 63, 20123 Milano, tel. +39/02/52036934 – fax +39/02/52036946
E-mail: letter@feem.it
C.F. 97080600154

SUMMARY

A new instrument for hedging weather risks has made its appearance in the financial arena. Trade in 'weather derivatives' has taken off in the US, and interest is growing elsewhere. Whilst such contracts may be simply interpreted as a new tool for solving a historical problem, the question addressed in this paper is if, besides other factors, the appearance of weather derivatives is somehow related to anthropogenic climate change. Our tentative answer is positive. Since 'global warming' does not simply mean an increase in averaged temperatures, but increased climate variability, and increased frequency and magnitude of weather extremes, derivative contracts may potentially become a useful tool for hedging some weather risks, insofar as they may provide coverage at a lower cost than standard insurance schemes.

Keywords: Global warming, climate variability, insurance coverage, weather derivatives

JEL: G10, Q20

CONTENTS

1.	Introduction and scope of the paper	2
2.	Background	3
	2.1 Global warming and related impacts	3
	2.2 What are weather derivatives?	4
3.	Hedging risks through insurance contracts and weather derivatives: a text-book comparison	6
	3.1 A “standard” insurance contract	6
	3.2 A “put” contract	7
	3.3 Comparison	9
4.	Final remarks	10
	References	12

1 Introduction and the scope of the paper

Weather comes in many forms, and has always affected human activities in different ways. When weather patterns vary from the norm, individuals and businesses may incur serious welfare and financial losses. When they significantly vary from the norm, the effects can be catastrophic.

This explains why societies and individuals have always tried to protect themselves against the impacts of adverse weather. Societal or private protection has traditionally taken different forms: regulatory provisions (*e.g.* land-use planning in vulnerable areas) and public insurance (*e.g.* government relief programs); public or private real investments to moderate potential damages (*e.g.* water storage facilities to cope with fluctuations in precipitation rates); and private financial investments, namely purchasing insurance by paying a premium to a private company.

More recently, a new instrument for hedging weather risks has made its appearance in the financial arena: "In the past couple of years the trade in weather derivatives has taken off in America [and] interest is growing elsewhere, not least in Britain where, as everybody knows, weather is the main topic of conversation" (*The Economist*, January 22nd 2000, p. 84)).

The issue addressed in this paper can be summarised as follows: Is the appearance in the financial arena of so-called weather derivatives somehow related to anthropogenic climate change and its expected impacts? In other words: Can we elicit from this appearance that financial operators are tackling the 'global warming' scenario more seriously than politicians, and their constituencies, apparently are?

In order to get some preliminary insights about the relationship between global warming and weather derivative trades, we will exploit a very simple, 'textbook' model. By adopting a partial equilibrium framework, we will consider an agent, holding an asset whose future value depends on weather patterns. In order to acquire protection against financial losses, the agent can subscribe a 'standard' insurance contract. Alternatively, s/he may construct a risk-free portfolio, by buying a weather derivative. Then, we compare the 'price' paid to acquire protection against adverse weather conditions under the two alternative coverage schemes, in order to see whether the intrinsic features of global warming' s expected impacts may somehow explain the development of derivative contracts.

The remainder of the paper is organised as follows. Some general information about global warming related impacts, and the weather derivatives which have made their appearance in the market is provided in Section II. In Section III we compare the price paid to acquire protection against adverse weather conditions under the two alternative coverage schemes. Section 4 provides some concluding remarks.

2 Background

2.1 Global warming and related impacts

Climate, i.e. average weather, has always been subject to fluctuation and change. Ice ages and warmer periods have occurred in the past, as a result of various natural causes. However, more recently a non-natural cause of climate change has been identified, namely excessive concentrations of greenhouse gases (GHG) due to human activity, such as burning fossil fuels. According to a recent assessment report by the Intergovernmental Panel on Climate Change (IPCC), the globally averaged surface temperatures have increased by $0.6 \pm 0.2°$ C over the 20th century, and temperature is projected to warm between 1.4 to 5.8° C by 2100 relative to 1990 (IPCC, 2001).

Since the Earth Summit held in 1992 in Rio de Janeiro, countries have declared their determination to reduce GHG emissions to prevent interference in the climate system. During the 3rd Conference of the Parties to the United Nations Framework Convention on Climate Change, held at Kyoto in 1997, industrial nations agreed to cut their collective emissions to 5 per cent below 1990 levels, in the period 2008-2012. Under the Kyoto Protocol, the United States – which produces almost a quarter of the world's GHS - would have to undertake a 7% cut, Japan 6%, and the European Union 8%.

In November 2000, countries that backed the Kyoto Protocol met at The Hague, The Netherlands, in order to define the mechanisms to implement emission abatement commitments. However, the Conference failed, officially because of disagreements about these mechanisms. Whilst the US (backed by Japan, Australia and Canada) took the position that countries should be allowed maximum flexibility in meeting their targets (including 'paying' other countries, either by trading emission permits or by so-called joint-implementation measures), the EU's position was that each country should primarily take domestic actions to meet its obligations.

A few weeks later, after President Bush's appointment, the US Administration took a different position: instead of simply questioning the Kyoto's implementation mechanisms, President Bush announced the intention to re-define the entire Protocol, namely the timing as well as the countries' abatement targets. Although this astonished many Americans and the international community, President Bush's statement is consistent with his electoral program. In fact, during the presidential campaign, Mr. Bush had declared his intention to "oppose the Kyoto protocol, because it is ineffective, inadequate and unfair to America. It exempts 80 per cent of the world, including major population centres such as China and India, from compliance".[1]

Whilst the prospects for effective international action to tackle GHG emissions are bleak, scientists have continued to additional evidence about the adverse impacts and disasters from global warming. In February 2001, the Intergovernmental Panel on Climate Change (IPCC) released a new report, which summarises a large research into "Climate Change 2001: Impacts, Adaptation and Vulnerability". Besides updating previous forecasts about the expected changes in globally averaged surface temperatures, the Report provides an indepth overview of the potential consequences of climate change.

One of the major emerging findings is that, "there would be changes in the variability of climate, and changes in the frequency and intensity of some extreme climate phenomena" (IPCC, 2001, p.3). Both "simple extremes" – such as higher maximum temperatures, higher minimum temperatures, more intense precipitation events – and "complex extremes" – such as intensified droughts and floods - are "very likely" or "likely" in nearly all or many areas.

According to the IPCC Report, such developments "would place upward pressure on insurance premiums and/or could lead to certain risks being reclassified as uninsurable with subsequent withdrawal of coverage" (p. 13). In fact, the costs of ordinary and extreme weather events have already increased rapidly in recent decades. "Part of the observed upward trend in disaster losses over the past 50 years is linked to socioeconomic factors, such as population growth, increased wealth, and urbanization in vulnerable areas, and part is linked to climatic factors, such as the observed changes in precipitation and flooding events" (IPCC, 2001, p.13).

2.2 What are Weather Derivatives ?

Weather derivatives were originally designed to provide energy companies with a means of protection against financial losses resulting from unfavourable weather patterns, namely from local temperature fluctuations (Marcus, 1998). However, even firms operating in other sectors – *e.g.* agriculture and the leisure industry - are beginning to be attracted

[1] George W. Bush for President Official Site: Issues, "Environment and Natural Resources", www.georgebush.com/issues/environment.html, December, 2000).

by derivative contracts as a weather risk management tool.

According to Speedwell Weather Derivatives Limited an estimated $4 billion over-the-counter market in weather derivatives has developed over the last two years in the US (McIntyre, 2000). The world's first exchange-traded weather derivatives were launched in September 1999, when the Chicago Mercantile Exchange (CME) launched contracts based on cold temperatures in New York, Chicago, Atlanta and Cincinnati; later on, the CME added six other cities. In January 2000, the London International Financial Futures and Options Exchange launched and Internet-based experimental market for European weather derivatives (*The Economist*, January 22nd 2000).

The term 'weather derivative' is used to encompass a variety of products used in the weather risk management market (swaps, collars, call and put options). As it goes beyond the scope of the paper to carry out an indepth technical analysis of these products, let us briefly focus only on put contracts which are considered in the comparative analysis proposed in the following Section.

Put options – which, to our knowledge, are probably the most common weather derivative contracts – provide protection against adverse weather. By paying a premium upfront, the buyer will be compensated if a weather variable falls below a predetermined level.[2]

An example of such put contracts has been recorded by *The Economist*. This example also serves the purpose of illustrating the rationale behind a weather derivative trade:

> "Corney & Barrow [is a chain of wine bars-cum-restaurants]; six have places where customers can sit outside. Although it has plenty of regulars, a fifth of the company's summer profits stem from those who come out with the sun [...] The firm wanted to avoid this volatility, so it bought what amounts to 'put' options on bad weather (the right to sell it) from Enron, an energy firm, through Speedwell Weather Derivatives, a consultancy. Enron will pay Corney & Barrow up

[2] The potential buyer of such options is an agent holding an asset (running an economic activity) closely correlated to the weather variable. However, many analysts have questioned the possibility of using the classic Black-Scholes option model to price weather derivative contracts. This because weather cannot be traded, whilst the Black-Scholes model assumes the existence of a tradable asset on which the pay out on the option is ultimately dependent. Hovewer, as argued by McInteyre (2000), this general criticism is wrong, because "the pay out on a weather option [...] is based on a series of weather events, not on the value of weather" (p.1). In other words, the trick consists of finding tradable assets which behave very like the weather variable of interest.

to £15,000 [. . .] for each Thursday and Friday between June and September on which the temperature in London falls below 24° Celsius [. . .], up to a maximum of £100,000 for the whole period. This, you might think, is free money for Corney & Barrow: London is not, after all, famed for its blue skies. But Enron [says] it knows what is doing. The knack is to hedge a position with something that is closely correlated. You cannot trade weather, so the next best thing is to trade something that behaves very like it: gas (as it happens, gas prices, which according to Enron are closely correlated with temperature)" (*The Economist*, June 17th 2000, p.99).

3 Hedging risks through insurance contracts and weather derivatives: a text-book comparison

3.1 A 'standard' insurance contract

Let us consider a simple two-period economy in which at time one only two states of nature are possibile: 'good weather' (GW) or 'bad weather' (BW). In this economy only two original assets are negotiated: one risk-free asset with an interest rate r that we set to zero, and a risky asset W.

Under GW the value of the risky asset would rise up to $W + M$, whilst under BW the value would fall to $W - L$. The stationary binomial process of the risky asset's value can then be represented by the following tree:

$$
\begin{array}{lll}
 & \nearrow W^+ = W + M & \text{with probability } 1 - q \\
W & & \\
 & \searrow W^- = W - L & \text{with probability } q
\end{array}
$$

The difference $W^+ - W^- = M + L$ indicates the value loss attributable to adverse weather conditions (*e.g.* property damages, sales losses, etc.). Furthermore, to avoid arbitrage profit opportunities, indicating with $R^+ = \frac{W^+ - W}{W}$ and $R^- = \frac{W^- - W}{W}$ the rate of return if the value of the asset moves up (+) and down (-) respectively, we assume that $R^+ > 0 > R^-$.

Consider now an agent holding at time zero the risky asset, which gives her/him utility $u(W)$, where u is a VNM utility function that shares the standard properties, i.e. $u(0) = 0, u'(W) > 0$ and $u''(W) < 0$. Let us assume the agent faces a risk-neutral insurance company which, in return for a premium, p, offers risk coverage. In particular, without any restricition, the insurance policy may consist of partial ($a < 1$) or total ($a = 1$) coverage: by paying ap, under BW the agent will get back $a(M + L)$.

Within this framework, the basic insurance problem is to determine the optimal coverage and the current value of p. If the utility function is defined over the asset end value, to determine the optimal coverage the agent maximizes (Kreps, 1990):

$$\max_a (1 - q)u(W^+ - ap) + qu(W^- - ap + a(M + L))$$

Taking the derivative with respect to a and setting it equal to zero, the optimality condition is:

$$\frac{u'(W + M - ap)}{u'(W - L - ap + a(M + L))} = \frac{q}{1 - q}\frac{p - (M + L)}{p} \tag{1}$$

If, due to competition between insurance companies or to regulatory constraints, the insurance contract is *actuarially fair* - i.e. the premium p is equal to to the payout $aq(L + M)$ - the first-order condition (1) reduces to:[3]

$$\frac{u'(W + M - ap)}{u'(W - L - ap + a(M + L))} = 1$$

As the agent is strictly risk adverse this condition is satisfied only if $a = 1$. Thus the agent will acquire full coverage $(L + M)$, by paying a premium:

$$p = q(L + M) \tag{2}$$

3.2 A 'put' contract

In order to explore the role that weather derivative contracts can play to hedge weather risks, we consider the simplest financial option, i.e. a European put option. We assume that the variability of asset W may be spanned by existing tradable assets which are closely correlated to the climate variability affecting W. In other words, we assume that capital markets are sufficiently complete so that it is possible to construct a

[3] Our assumptions imply the use of expected losses as the fair-value benchmark. However, it is worth noting that, in reality, premiums are often greater than expected losses. As far as catastrophic natural hazards, such as hurricanes, are concerned, Foot(2001) shows that (re)insurance premiums are more than seven times expected loss (US data, 1989-1998).

portfolio of traded securites (a 'tracking portfolio') which is perfectly correlated with W.

Indicating with $\hat{p}$ the current value of the derivative under consideration, over the period it would be contingent on the value of W, that is:

$$\hat{p} \begin{cases} \nearrow p^+ = \max(E - W^+, 0) = 0 & \text{with probability } 1-q \\ \searrow p^- = \max(E - W^-, 0) = E - W^- & \text{with probability } q \end{cases}$$

where p^+ and p^- are the end values of the derivative under the event GW and BW, respectively. $E \in [W^-, W^+]$ is the exercise price that, under our assumptions, indicates the level of coverage against adverse weather conditions.

In words, under W^+ the put will not be 'exercised', as the underlying asset increases its value above the exercise price. On the contrary, if W^-, as $E - W + L > 0$, the put will be exercised and the asset will be sold at price E. Finally, if $E = W + M$, the agent holding the risky asset will get full coverage.

The put option for the problem at hand can be valued by designing a portfolio consisting of selling a particolar number, n, of units of the underlying asset W and lending against them an appropriate amount, $\$B$, at the riskless rate, so that it would exactly replicate the future returns of the option in any state of nature (Trigeorgis, 1996). That is:

$$\hat{p} = B - nW \tag{3}$$

Since after one period the value of the portfolio will be:

$$B - nW \begin{cases} \nearrow B - nW^+ & \text{with probability } 1-q \\ \searrow B - nW^- & \text{with probability } q \end{cases}$$

in order to provide the same return in each state as the option, we need to impose:

$$p^+ = B - nW^+ \quad \text{and} \qquad p^- = B - NW^-$$

Solving the two equations for the two unknown, n and B we get:

$$n = -\frac{p^+ - p^-}{W^+ - W^-} > 0, \quad \text{and } B = p^+ + nW^+ \equiv \frac{W^+p^- - W^-p^+}{(W^+ - W^-)} > 0$$

By substituting n and B back into (3) we get:

$$\hat{p} = B - nW \equiv (1 - \hat{q})p^{+} + \hat{q}p^{-} \tag{4}$$

where:

$$\hat{q} = \frac{W^{+} - W}{W^{+} - W^{-}} \equiv \frac{M}{M + L} > 0 \tag{5}$$

Note that $\hat{q}$ has certain probability-like-properties, namely $0 < \hat{q} < 1$. It indicates the 'risk-neutralized' probability, that is the probability that would prevail in a risk-neutral world where agents are indifferent to risk. Finally, if the agent holding the risky asset W requires full coverage, i.e. $E = W + M$, the price of the weather derivative simplifies to:

$$\hat{p} = \hat{q}(E - W^{-}) \equiv \hat{q}(L + M) \tag{6}$$

It is evident comparing (2) and (6) that, contrary to the insurance premium, the price of the weather derivative is neither affected by the agent's utility function, nor by the asset's intrinsic vulnerability to adverse climatic conditions (q). For instance, by the ability to construct such a riskless hedge, the asset's owner *de facto* behaves as a risk neutral agent.

3.3 Comparison

We may now compare the 'price' paid to acquire full coverage under the two alternative insurance contracts. For given coverage $(L + M)$, the price differential, i.e. the difference between the insurance premium (p) and the derivative value $(\hat{p})$ is given by $\Delta = (q - \hat{q})$. As the 'risk-neutralized' probability can be written as $\hat{q} = \frac{1}{1+L/M}$, we get:

$$\frac{\partial \Delta}{\partial L/M} > 0$$

In other words, as the relative magnitude of *harmuful* weather patterns (L/M) increases, the relative price of risk coverage by means of a standard insurance contract increases, i.e. it tends to become more appealing to hedge risks through a weather derivative (see Fig.1). Similarly, as:

$$\frac{\partial \Delta}{\partial q} > 0$$

an increase of the risky asset's intrinsic vulnerability would amplify the range over which it becomes more 'profitable' to hedge weather risks through buying a derivative instead of subscribing an insurance contract (see Fig.1).

[fig. 1 about here]

Since, as underlined in the previous Section, global warming is expected to involve changes in the variability of climate, and changes in the frequency and intensity of some extreme climate phenomena (IPCC, 2001), weather derivatives may in principle become an appealing tool for hedging weather risks.

4 Final remarks

Trades in weather derivatives have only recently taken off, and it is too early to say whether they will proliferate in the coming years. For instance, there are many examples of quirky financial products, which did not work, because of the lack of buyers, and then disappeared.

Various market and institutional factors may explain the development and the potential interest towards weather derivatives. Because weather cannot be traded, hedging weather risks through derivative contracts requires finding tradable assets that behave very like it. Since there are plenty of businesses which are exposed to weather conditions, the continuous enlargement and globalisation of financial markets provides dealers with a new opportunity to solve a historical problem, i.e. managing some weather risks, by finding assets closely correlated to climate variability.

Among the other factors which may explain the development of weather derivatives it is also worth mentioning the deregulation of the energy industry, which makes managing the traditional risks related to temperature fluctuations more compelling. Not surprisingly, besides insurance companies, which appear to be natural candidates for weather derivative trades, these products have mostly attracted energy companies, and the mostly actively traded of these products up till now is temperature. However, trades involving companies operating in other sectors, as well as "deals involving precipitation, both snowfall and rainfall, have also been written as well as deals combining precipitation and temperature" (Speedweel Weather Derivatives, 2000, p.1).

Whilst weather derivatives may then be simply interpreted as a new tool for solving a historical problem, the question addressed in this paper has been if, besides the afore-mentioned institutional and economic factors, which undoubtedly play a primary role, other factors may contribute to explain the take-off of these products. In particular, we have focussed on global warming, in order to see whether its related impacts could make weather derivatives an appealing tool for risk coverage.

Our tentative answer is positive. Since, according to scientists, global warming does not simply mean an increase in averaged temperatures, but increased climate variability, and increased frequency and magnitude of weather extremes, weather derivatives may potentially become a useful tool for hedging risk, insofar as they may provide coverage at a lower cost than 'standard' insurance coverage schemes.

It is worth noting that our results stem from a very simple analytical framework which assumes, *inter alia*, that the agent, holding an asset exposed to weather variability, is able to construct a risk-free portfolio, by finding tradable assets which are closely correlated to the climate conditions which affect the asset of interest. Moreover, as an alternative to constructing such a portfolio, we have considered a 'textbook' insurance contract, by assuming that insurance premium calculation is based upon actuarial principles. However, if insurers behaved as 'investors' - i.e. when selling an insurance contract they considered that they are acquiring an asset - insurance premiums would look more like asset prices, and the potential benefits stemming from directly buying weather derivatives could vanish.

These assumptions obviously affect the possibility of generalising our results, whose robustness should be assessed through a more sophisticated theoretical framework as well through empirical analysis.

However, if more indepth analysis substantially confirms our preliminary findings, it is legitimate to state that, although weather derivatives may appear as quirky products, global warming – and policy-makers' inaction - is likely to favour their proliferation.

The question is: Will all activities and people, in all continents, be able to hedge the increasing weather risks, they are going to face, by constructing appropriate 'risk-free portfolios' ? We guess that the answer is no, and we should expect to witness over the next years increasing asymmetries, within and between countries, not only in terms of climate vulnerability, but also in terms of risk coverage.

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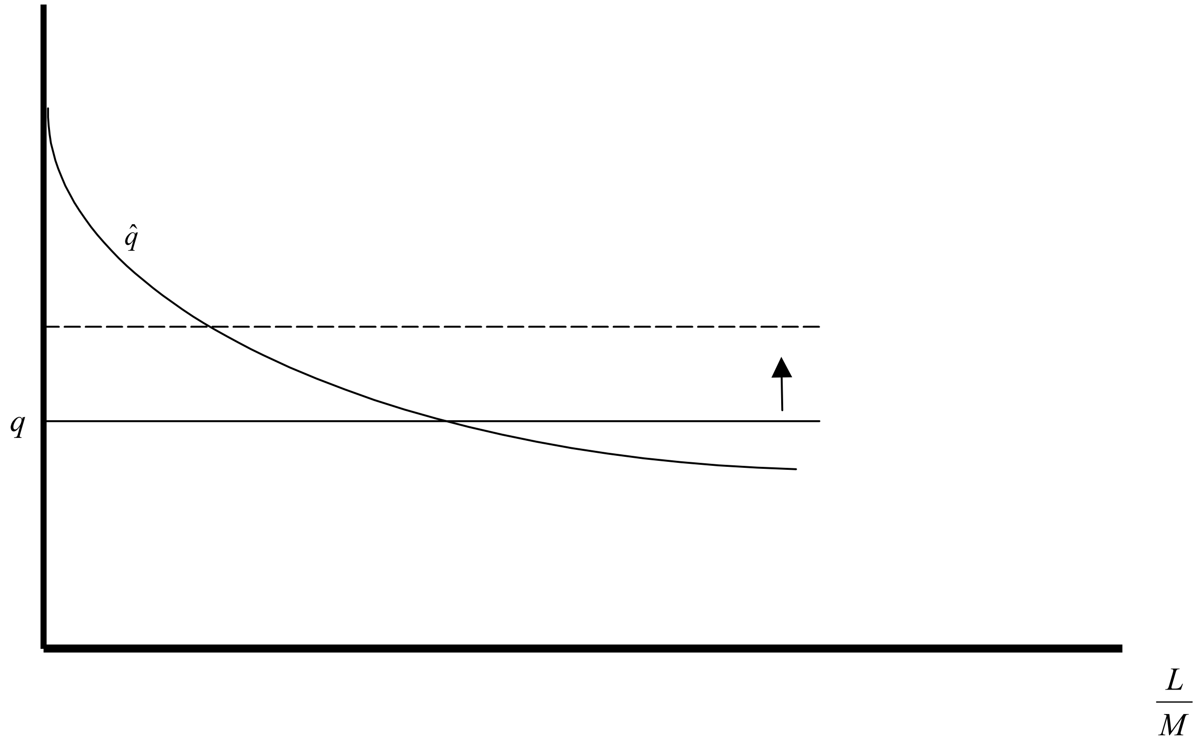

Figure 1

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(xxxvii) This paper was presented at the Fourth Meeting of the Coalition Theory Network organised by the Fondazione Eni Enrico Mattei, CORE of Louvain-la-Neuve and GREQAM of Marseille, Aix-en-Provence, January 8-9, 1999
(xxxviii) This paper was presented at the International Conference on "Trade and Competition in the WTO and Beyond" organised by the Fondazione Eni Enrico Mattei and the Department of International Studies of the University of Padua, Venice, December 4-5, 1998
(xxxix) This paper was presented at the 3rd Toulouse Conference on Environment and Resource Economics, organised by Fondazione Eni Enrico Mattei, IDEI and INRA and sponsored by MATE on "Environment, Energy Uses and Climate Change", Toulouse, June 14-16, 1999
(xl) This paper was presented at the conference on "Distributional and Behavioral Effects of Environmental Policy" jointly organised by the National Bureau of Economic Research and Fondazione Eni Enrico Mattei, Milan, June 11-12, 1999
(xli) This paper was presented at the Fifth Meeting of the Coalition Theory Network organised by the Fondazione Eni Enrico Mattei and the CODE, Universitat Autonoma de Barcelona, Barcelona January 21-22, 2000
(xlii) This paper was presented at the International Workshop on "Climate Change and Mediterranean Coastal Systems: Regional Scenarios and Vulnerability Assessment" organised by the Fondazione Eni Enrico Mattei in co-operation with the Istituto Veneto di Scienze, Lettere ed Arti, Venice, December 9-10, 1999.
(xliii)This paper was presented at the International Workshop on "Voluntary Approaches, Competition and Competitiveness" organised by the Fondazione Eni Enrico Mattei within the research activities of the CAVA Network, Milan, May 25-26,2000.
(xliv) This paper was presented at the International Workshop on "Green National Accounting in Europe: Comparison of Methods and Experiences" organised by the Fondazione Eni Enrico Mattei within the Concerted Action of Environmental Valuation in Europe (EVE), Milan, March 4-7, 2000
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(xlvi) This paper was presented at the Sixth Meeting of the Coalition Theory Network organised by the Fondazione Eni Enrico Mattei and the CORE, Université Catholique de Louvain, Louvain-la-Neuve, Belgium, January 26-27, 2001
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(lii) This paper was presented at the International Conference on "Economic Valuation of Environmental Goods", organised by Fondazione Eni Enrico Mattei in cooperation with CORILA, Venice, May 11, 2001
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