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Introduction

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Economic insights are increasingly finding their way into the design of environmental policy. While environmental taxes and permit trading programmes as efficient regulatory instruments play a growing role in environment policies, concerns with the environment are not fading: Sustainable development, climate policy, biodiversity conservation, energy production and consumption – all are examples of issues on the current political agenda in many countries. While these themes are also subject to intensive economic research, both the reception of academic insights by policy makers as well as the timely identification and treatment of policy-relevant questions by researchers often seem to be problematic.

This volume attempts to vitalise the exchange between policy makers and academics. It offers a snapshot of environmental economic research on a range of policy-relevant problems. Academic contributions are complemented by views of policy makers on priority fields in environmental policy, the usefulness of academic research for decision making, and requirements to applied research in the future.

All contributions in this volume are based on presentations given at the Workshop "Frontiers in Applied Environmental and Resource Economics" at the Centre for European Economic Research (ZEW), Mannheim, Germany, in March 2004. They cover the following areas: Sustainability Assessment, Transport and the Environment, Energy Market Regulation, Trade, Environment and Biodiversity, and the Political Economy of Environmental Regulation.

Sustainability Assessment

Sustainable Development (SD) has meanwhile become one of the most prominent catchwords on the world's policy agenda. Nearly all governments and multinational firms have committed themselves to the overall concept of SD. Taking a lead role, the European Union requires Sustainability Impact Assessment in terms of a "careful assessment of the full effects of [any larger] policy proposal ... [that] ... must include estimates of its economic, environmental and societal inputs inside

and outside the EU". Yet, SD, which is not just about environment, but also about economy and society, has proven hard to define and rather susceptible for ambiguities. Monitoring progress towards SD requires in the first place the identification of operational indicators that provide manageable units of information on economic, environmental and social (including institutional) conditions. An issue that cannot be clearly measured will be difficult to improve. Therefore, indicator systems that measure sustainability in a meaningful way are a central prerequisite for formulating policy goals.

Against this background, Heinz Welsch, University of Oldenburg, investigates the possibilities and limitations in constructing meaningful sustainability indices. Based on methodological considerations, he defines an index as "meaningful" if it allows unambiguous ordering of the underlying situation, in particular independent of the units in which relevant variables are measured: A sustainability index should allow an unambiguous judgement of whether a situation has improved or worsened. Welsch distinguishes two index categories according to the property of commensurability vis-à-vis incommensurability. In the case of commensurability, the construction of meaningful indices is possible if either monetary welfare measures or bio-physical metrics can be used. In the case of incommensurability, the lack of measures or the desire to aggregate several variables generally leads to the non-existence of meaningful indices.

Despite these fundamental difficulties, indicators are needed in the political arena to monitor and to communicate progress on sustainability issues. Pascal Wolff, Eurostat, provides an overview of how sustainable development indicators are defined for different policy fields in the European Union. Among other criteria, Wolff lays out that the indicators should be consistent, should have an accepted normative interpretation and should be responsive to policy intervention but without becoming subject to manipulation. Most notably, they should allow coherent assessment and comparison of sustainability issues across different countries.

Thilo Goodall, SAM Sustainable Asset Management, Zurich, discusses the problem of measuring corporate sustainability performance and its impact on corporate financial performance. Corporate sustainability is defined as "a business approach to create long-term shareholder value by embracing opportunities and managing risks deriving from economic, environmental and social developments", thereby emphasising a long-term strategy which does not conflict with shareholders' interests. After defining indicators to assess a company's sustainability orientation, Goodall turns to ways and problems of measuring its impact on the financial performance. The hypothesised link between corporate sustainability and shareholder value is, however, still subject to further research.

The integration of different indicators and assessment methods is addressed by Marialuisa Tamborra, European Commission. She describes the efforts of the European Commission to develop an Impact Assessment method which allows a comprehensive analysis of given policy proposals and the identification of trade-offs in achieving different objectives. As ultimate goal it is proposed to combine and integrate assessments of specific policy fields such as business impact assessment, gender assessment, and small and medium enterprises assessment.

Trade, Environment, and Resource Use

Many environmental problems, such as climate change or biodiversity loss, involve transboundary pollution and thereby can only be tackled efficiently at an international level.

Cees Withagen, Free University Amsterdam and Tilburg University, gives an overview on the relationship between environmental policy and international trade. A government which tries to unilaterally implement emission targets, usually faces considerable political pressure from interest groups of different sectors, in particular from those exporting products to other countries and therefore fearing competitive disadvantages on the world market. Withagen demonstrates in a simple theoretical model that a preferential treatment for those sectors might be suboptimal. That is, there is no clear a priori reason to use "over lax" taxation in these sectors. He urges policy makers to be aware of the trade-off between pollution and production, and the impact of environmental policy on trade.

Frank Wätzold, Martin Drechsler, Volker Grimm, and Jaroslav Myšiak, all from UFZ-Centre for Environmental Research Leipzig-Halle, deal with biodiversity loss, a theme which ranks high on the international environmental policy agenda. After an overview of European biodiversity conservation programmes, they address approaches to measure the cost-effectiveness of such policies. In their opinion, adequate approaches involve integrated research between ecologists and economists. Wätzold et al. discuss different state-of-the-art approaches to ecological-economic modeling as well as problems in integrating those two disciplines. They single out important "cultural" differences between ecological and economic models, in particular with respect to the treatment of uncertainty and the resolution of time and space.

Transport and Environment

In contrast to substantial progress in reducing emissions in many sectors of the economy, pollution caused by traffic has increased in the past few years due to a rise of passenger and freight traffic combined with a shift towards motorised road transport. There is a controversial debate on appropriate policy initiatives to promote environmentally compatible transport systems (e.g., based on hydrogen). The interaction between environmental externalities, knowledge spillovers as well as network externalities poses complex challenges to environmental regulation.

The peculiarities of transportation research are deepened by Romain Molitor, Trafico Verkehrsplanung, Wien, and Karl W. Steininger, University of Graz. They point out the spatial structure of transport and its interdependencies with infrastructure, living and working locations. These determinants of traffic generate inertia and explain long-term impacts on transportation system design. Molitor and Steininger start discussing early visions of transport and cities and their impact on today's transport structures before turning to areas of current policy and research needs: interaction of land-use and transport, distributional impacts of transport policy, and behavioral changes.

Armin Schmutzler, University of Zurich, provides an overview of research issues in the field of "transportation and environment". He argues that – different from many textbook approaches – there are good reasons for transportation-

specific policies. Policies and associated research problems can be structured by decomposing aggregate emissions from transportation into total amount of transport, modal split, and specific emissions. At each level, normative and positive research questions arise which often require interdisciplinary approaches and exchange between economists, psychologist, engineers, etc.

Wolfgang Schade and Werner Rothengatter, University of Karlsruhe, describe different approaches to perform cost-benefit analyses of transport policies: macro- and micro-economic approaches, computable general equilibrium models, and evolutionary approaches using system dynamics models. Acknowledging that transport policies may evoke reactions inside and outside the transport system, they present a system dynamics approach which allows for dynamic cost-benefit analyses of direct and indirect effects. Finally, they discuss illustrative applications to policy-induced changes in gasoline and diesel taxes.

Günter Hörmandinger, European Commission, comments on the three preceding academic contributions on transportation research and policy. He supports the general findings, but argues that in order to obtain policy-relevant results one has to "take into account the messy details of the 'real' world". Although recognising difficulties in handling complex models, he calls for detailed analyses of transport-specific problems that include network externalities, (natural) monopolies, as well as the spatial structure of traffic.

Energy Market Regulation

Energy utilization plays a central role in solving environmental problems and in implementing sustainable economies in the medium to long term. To promote the transition towards environmentally compatible energy systems, far-reaching policy measures are required. Due to the network-based structure and the transnational dimension of resource use and pollution, the institutional parameters in the national, European and global energy markets must be taken into account when policy recommendations are formulated.

Michael Kraus, University of Applied Sciences Darmstadt, provides an overview of different regulatory principles based on alternative economic paradigms. He then investigates electricity markets thereby highlighting different degrees of regulation along the value-chain from generation, transmission, distribution, to sales and wholesales. Electricity market reforms are distinguished by the degree to which they allow for competition or change the features of regulation at the different levels. Kraus finally addresses difficulties to measure the impacts of regulation and thereby the benefits of regulatory reforms for economic efficiency.

Christoph Weber and Alfred Voß, University of Stuttgart, discuss the specifics of energy-markets in more detail. Characteristics such as peak-load demand, non-storability, and grid-dependency must be considered when describing markets and the impact of changes in their regulation. Weber and Voß portray efficiency and security of supply in the longer run as the "key challenges" for energy policy. In particular, they discuss problems of sufficient investments incentives under uncertainty, i.e., the difficulties to predict revenues and, hence, the refinancing of investment costs. The authors also point out the importance of stochastic market models as supply and demand fluctuate over the day, week, and seasons as well as

across locations. Beyond more narrow short-term efficiency issues, one should also consider the robustness of energy systems when designing market reforms.

Eberhard Jochem, ETH Zurich and Fraunhofer Institute for Systems and Innovation Research, Karlsruhe, fits the regulatory issues of energy markets into a broader innovation policy framework designed for sustainable development. In his view, environmental pollution on the one hand and resource scarcity on the other hand call for an active role of government in the stipulation and coordination of innovation activities thereby assessing the large portfolio of technologies and their economic perspectives.

Domenico Rossetti di Valdalbero, European Commission, uses the examples of emissions trading, energy taxation, and renewable electricity targets to show how the European Union backs its policy decisions with research results from academia. The majority of the EU energy-socio-economic research projects addresses links between energy and the environment. The author describes several models and tools which have been used in the EU's policy making process. He argues that EU energy-related initiatives will be more frequent in the future and calls on researchers to elaborate scientifically sound quantitative tools which in particular address energy-related long-term problems like resource depletion, climate change, or waste management.

Political Economy of Environmental Regulation

Political feasibility of environmental policies depends crucially on the specific interest of regulated parties. Stiff opposition by adversely affected influential interest groups explains why regulatory measures suggested by academic research often do not translate into actual policy making.

Friedrich Schneider, University of Linz, and Hannelore Weck-Hannemann, University of Innsbruck, investigate reasons for the gap between theoretical research and actual policy practice by looking into the incentives of key political players. Based on Public Choice Theory, they argue that many incentive-based instruments are neither in the interest of political decision makers nor favoured by the most influential interest groups. Schneider and Hannemann use the examples of an Austrian ecological tax reform and road pricing to demonstrate how Public Choice Theory might guide economists in proposing policy measures that are suboptimal on overall (theoretical) efficiency grounds but increase the political chances of their implementation.

Gebhard Kirchgässner, University of St. Gallen, discusses the discrepancy between economists' policy advice and actual policy implementation from a complementary angle: By applying Public Choice Theory to the advice given by economists themselves, i.e. by looking at economists as interest-driven rather than benevolent scientists, he points out that researchers rarely give unambiguous clear-cut answers but provide rather quite often even contradictory results. Referring to the example of an ecological tax reform in Switzerland, Kirchgässner demonstrates how – hidden behind a myriad of assumptions which often drive the results – economic studies can provide scientific "support for nearly every political position". Given potential self-interest of researchers, Kirchgässner points out the

need for a rigorous critical discussion of models and methods before associated results are used in decision making.

Kai Schlegelmilch, German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, puts the discussion and implementation of an Ecological Tax Reform in Germany into a dynamic policy context. He points out that – during the last decades – academic advice was increasingly used in environmental policy design. Studying the varying position of industrial groups on their preferred policy instruments, Schlegelmilch identifies strategic options to delay or avoid regulation. In his view, the bundling of different political interests is crucial to promote environmental taxation. In this vein, a larger share of revenues of the Ecological Tax Reform in Germany is earmarked to reduce labour costs such that interests of various stakeholders can be satisfied.

Constructing Meaningful Sustainability Indices*

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Keywords. *Environmental Index, Sustainability Index, Preference Ordering, Comparability, Measurability, Environmental Indicator*

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Abstract. This paper surveys and evaluates the possibilities and limitations of sustainability indices from the point of view of meaningfulness. A sustainability index is defined as meaningful if it allows unambiguous orderings of the relevant 'situations' over time independent of the measurement units in which the variables describing the situations are expressed. The cases of commensurability and incommensurability are distinguished. In the former, the comparison of situations is unambiguous be-cause all legitimate choices of measurement units can be accommodated on the basis of exogenously given relationships among the variables. These relationships may define a monetary welfare-metric or a bio-physical effects-metric. In the case of incommensurability, common approaches (both cardinal and ordinal) may fail to yield meaningful indices. A systematic assessment of which indices are meaningful in which circumstances is provided.

1 Introduction

"Don't run down your assets!" – The sustainability imperative can be put as simple as that. There are, however, a variety of assets that may be worth preserving: natural capital, man-made (physical) capital, human capital, not to speak of 'social capital' (governance, trust, and other social institutions). Different notions of sustainability differ with respect to the degree of substitutability which is presumed to exist between the various types of capital. A hypothetical extreme position might entail that each and every asset should be preserved: Not only should the stocks of natural capital, physical capital, human and social capital be non-decreasing but also the different kinds of natural capital, down to individual species, minerals, or fuels.

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Such a position could be called 'ultra-strong sustainability'. It has a big advantage: To be monitored, it does not need the construction of any 'sustainability index' whatsoever. But ultra-strong sustainability is not a tenable position in the real world, be it only since it would imply that all non-renewable resources remain untouched indefinitely. By contrast, both analysts and policy makers will normally be prepared to tolerate some trade-off between different assets, and this begs the need for sustainability indices, that is, tools for answering the question: "Have the relevant assets been kept intact *overall*?" (weak sustainability of some degree).

Speaking somewhat loosely, a sustainability index should permit an assessment of whether 'the situation' (e.g. the environmental situation) has become better or worse between time t and $t+1$. This *sustainability problem* is slightly different from the *ranking problem*: How do places (e.g. countries) rank in terms of 'the situation' in question? Though both problems are related, I will mainly focus on the former, touching upon the latter only occasionally.

A basic requirement when constructing a sustainability index is that it should be meaningful, in the sense that the comparison of situations over time should be unambiguous with respect to the choice of measurement units of the relevant variables.

With respect to meaningfulness it is useful to distinguish between the case of commensurability and the case of incommensurability. In the former case, the comparison of situations is unambiguous because all legitimate choices of measurement units can be accommodated on the basis of exogenously given relationships among the variables. This is not the case with incommensurable variables: Here an ambiguity problem may arise, depending on the measurability and comparability properties of the variables involved. The two cases will be addressed in separate sections (Section 2, and Sections 3 and 4, respectively).

The focus of the paper is on methodological issues. Indices actually proposed or applied are mentioned mainly for illustrative purposes. A comprehensive survey of actual indices is not intended.

2 Commensurability

Two types of sustainability indices considered in the literature fall into the category of commensurability: indices based on a monetary welfare metric and indices based on a bio-physical effects-metric, respectively.

2.1 Monetary Welfare-Metric

To illustrate the welfare-based approach to constructing sustainability indices, consider a welfare function defined over consumption C and the stock of natural capital N. Natural capital is an aggregate which comprises various types of exhaustible and renewable resources as well as various dimensions of environmental quality. The welfare function reads