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Introduction: Special Issue on the Economics of Climate Change and Sustainability

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The recent report from the IPCC (2018) on the urgency of action to ensure that global warming is limited to 1.5 °C above pre-industrial levels underlines the critical risks of catastrophic climate change impacts now facing the world. Without rapid reductions in anthropogenic emissions of greenhouse gases, serious detrimental impacts on the global economy and the natural environment appear unavoidable. Understanding climate change along with its economic dimension is a complex issue that involves climate science, economics and their interactions.

To contribute to the ongoing scientific discussion regarding understanding the economic impacts of climate change and the design of efficient climate policies, in April 2017 the Economics Department of the University of Bologna—Rimini Campus organized an international workshop on "The Economics of Climate Change and Sustainability". The intention is to organize this workshop on an annual basis and in this way to provide a forum for scientists, both senior and junior, to present their research and to engage in exchange of ideas. This special issue consists of a selection of eleven papers presented at this first workshop.

The first group of contributions included in this Special Issue consists of four papers discussing issues directly related to climate change policies and in particular to carbon taxes and the social cost of carbon.

The paper "As Bad as it Gets: How Climate Damage Functions Affect Growth and the Social Cost of Carbon", by Bretschger and Pattakou (2019), analyzes the effects of varying climate impacts on the social cost of carbon and economic growth by using polynomial damage functions in a model of an endogenously growing two-sector economy. The results suggest a big effect on the social cost of carbon and a significant impact on the growth rate when the selected damage function is quadratic. It is also shown that high marginal climate damages under the quadratic specification require stringent climate policies but do not preclude positive economic growth when these policies are efficient.

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In "Pricing Carbon and Adjusting Capital to Fend off Climate Catastrophes", van der Ploeg and de Zeeuw (2019) discuss the optimal response to a potential productivity shock arising from a climate-related tipping point. The results suggest that a substantial carbon tax would be required in order to curb the risk of such tipping points. Quantitatively, the results are investigated with a calibrated model of the world economy.

Brock and Xepapadeas (2019), in "Regional Climate Change Policy under Positive Feedbacks and Strategic Interactions", analyze the impacts, on temperature paths and optimal carbon taxes, of earth surface albedo feedback and of the heat and moisture transport from the Equator to the Poles, which are associated with polar amplification. Optimal climate policy is derived in the context of a non-cooperative framework in which open loop and feedback solutions are determined.

The fourth paper in this group, "Simple Rules for Climate Policy and Integrated Assessment", by Van der Ploeg and Rezai (2019), develops a straightforward integrated assessment framework which develops rules for the optimal carbon price, for transition to a carbon-free era and for related economic analysis of stranded assets which are left in situ because of climate policies. The paper highlights the ethical, economic, geophysical and political drivers of optimal climate policy and offers a back-of-the-envelope analysis of climate policy, which can be used for teaching and for communication with policy makers.

The second group of contributions, consisting of a further four papers, deals with the impact of anthropogenic actions in terms of emissions on the natural and the economic environment, and showcases various assessment methodologies including both empirical and theoretical sectoral analyses.

In the paper "On the Relationship between GHGs and Global Temperature Anomalies: Multi-level Rolling Analysis and Copula Calibration", Agliardi et al. (2019) employ some advanced statistical methods to assess the increasing rates of global climate change resulting from higher levels of anthropogenic emissions. Copula methods are also introduced to evaluate tail dependence, representing simultaneous occurrence of extreme events. In particular, positive upper tail dependence is obtained, suggesting that climate policies should avoid extreme events in emissions to prevent possibilities of excessive warming.

The next paper, "The Dynamics of Foreign Direct Investments in Land and Pollution Accumulation", by Borghesi et al. (2019), studies the effects of foreign investments on a local economy, under the assumption that the external sector is polluting, but that its production activities can be taxed to finance environmental defensive expenditures. Using numerical simulations, they show that a revenue-increasing path may occur only if the pollution tax is sufficiently high and the impact of the external sector on pollution sufficiently low; otherwise, foreign direct investments may end up impoverishing the local economy.

The paper by Ingrid Dallmann (2019), "Weather Variations and International Trade", studies the effects of weather variations in exporting and importing countries and on bilateral trade flows. The paper contains a rich analysis performed at the country, sectoral and product levels, worldwide, and over the 1992–2014 period. Negative effects of temperature variations prevail in exporting countries, especially those closer to the Equator, at the product level and mainly on the agricultural and manufacturing sectors. This negative effect is persistent and cumulative through several years after a temperature shock. Adaptation seems to be scarcely significant over the long-term.

In the final paper of this group, "Forest Fires across Italian Regions and Implications for Climate Change: A Panel Data Analysis", Michetti and Pinar (2019) employ panel data techniques to study the determinants of monthly variations in forest fire frequency and on the size of the area burnt for Italian regions between 2000 and 2011. Significant spatial and temporal heterogeneity of drivers is observed and the authors forecast forest fire frequency,

examine the contribution of socio-economic factors and the role of education, and investigate the containment of fraudulent activity.

Next are two papers which deal with risk analysis in climate change. The first of these, "Cost Risk Analysis: Dynamically Consistent Decision-Making under Climate Targets", by Held (2019), contains a critical review of cost risk analysis (CRA), which combines the expected utility-based structure of cost–benefit analysis with the target-based approach of cost effectiveness analysis (CEA). A comparison between CRA-optimal solutions and the solutions based on CEA is developed. Moreover, it is shown that CRA, unlike CEA, allows for the determination of the economic value of climate information.

Roshan et al. (2019), in "Cost-Risk Trade-Off of Mitigation and Solar Geoengineering: Considering Regional Disparities under Probabilistic Climate Sensitivity", investigate the extent to which policy-makers would apply solar geoengineering (SGE) in conjunction with mitigation in view of regional disparities in temperature and precipitation. They evaluate the optimal mix of SGE and mitigation under probabilistic information about climate sensitivity and generalize cost risk analysis (CRA) in order to include regional temperature and precipitation risks.

The final paper of this special issue, "Using Genuine Savings for Climate Policy Evaluation with an Integrated Assessment Model" by Tokimatsu et al. (2019), studies the effect of climate change and climate change policies, both in terms of impact measures beyond GDP, and in terms of modelling complexity beyond DICE/RICE models. They propose a unifying model to analyze multiple environmental and well-being outcomes and show how a Genuine Savings-based assessment of climate change can result in a re-evaluation of the consequences and costs of inaction in terms of various climate change-related policies.

Although there has been extensive analysis of the economics of climate change, we believe that there are still a large number of open issues in terms of both theory and applied policy. Some of these open research questions refer to carbon taxes and the social cost of carbon, the impact of climate on different sectors of the economy, the appropriate statistical modeling of the relationship between carbon emissions and temperature, the impact of risk, or the effects of climate change on sustainability. We hope that our special issue provides some new insights into these important questions and identifies new directions for future research.

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