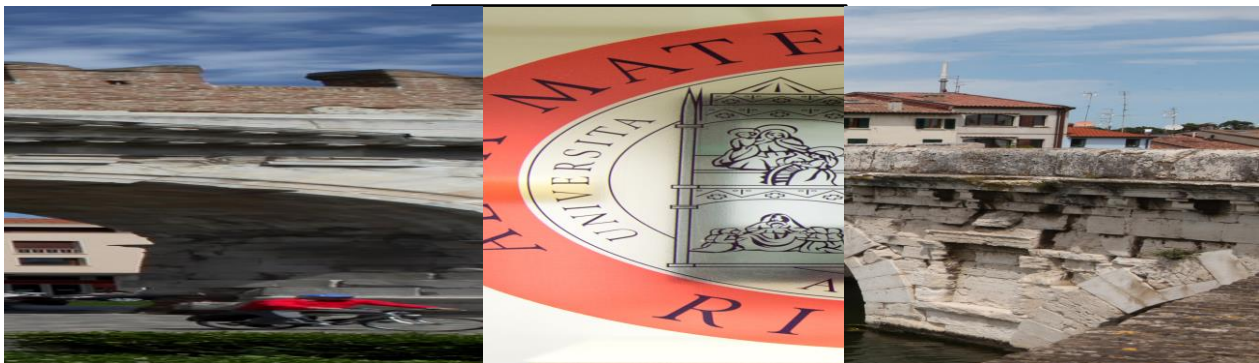


International Workshop on The Economics of Climate Change and Sustainability

University of Bologna - Rimini Campus



Booklet

April 28th -29th 2017

- Elettra Agliardi, Thomas Alexopoulos, Christian Cech, *On the relationship between GHGs and Global Temperature Anomalies: Multi-level rolling analysis and Copula calibration*

Abstract. The relationship between GHG emissions and global warming is studied through multi-level rolling analysis to assess whether or not there are increasing rates in global climate change as a result of higher levels of anthropogenic emissions, as we move forward in time. Furthermore, in order to assess whether we observe tail-dependence, representing simultaneous occurrence of extreme events, we employ copula methods. We find evidence of a constant or even a decreasing effect of emissions on temperature anomalies especially from 2005 onward. At the same time, our copula calibration shows that the Frank copula achieves the best fit. Since the Frank copula is a copula that assigns a low probability to joint extreme events, our analysis does not show tail dependence.

- Stergios Athanasoglou, Valentina Bosetti, Lauren Drouet, *A simple framework for climate-change policy under model uncertainty*

Abstract. We propose a novel framework for the economic assessment of climate-change policy. Our main point of departure from existing work is the adoption of a “satisficing”, as opposed to optimizing, modeling approach. Along these lines, we place primary emphasis on the extent to which different policies meet a set of goals at a specific future date instead of their performance vis-a-vis some intertemporal objective function. Consistent to the nature of climate-change policy making, our model takes explicit account of model uncertainty. To this end, the value function we propose is an analogue of the well-known success-probability criterion adapted to settings characterized by model uncertainty. We apply this decision criterion to probability distributions constructed by Drouet et al. (2015) linking carbon budgets to future consumption. The main result that emerges is the superiority of “medium” carbon budgets in line with a 3 C target (i.e., 2000-3000 GtCO₂) in preventing large future consumption losses with high probability. Insights from computational geometry facilitate computations considerably, and allow for the efficient application of the model in high-dimensional settings.

- Elizabeth Baldwin, Yongyang Cai, Karlygash Kuralbayeva. *Build Today, Regret Tomorrow? Infrastructure and Climate Policy*

Abstract. The timing of optimal policy to combat climate change is controversial: while some advocate a “gradual slope” in policy, others emphasise the importance of redirecting investments rapidly if we hope to meet a “2 degree” goal. We consider this question in the light of irreversible “dirty” and “clean” investments, such as in coal-fired and solar electricity generation. This leads to a “Reverse Green Paradox”: the knowledge of an increasing carbon tax will reduce investments in assets that pollute, and so reduce emissions in the short term. This contrasts with the well-known effects of such policy on the suppliers of fossil fuels, such as coal mines. So stranded assets play opposing roles, depending on whether these assets supply or demand fossil fuels. Additionally, we show that it is optimal to begin deployment of clean technologies early, if their cost decreases with their cumulative deployment (as has been clearly observed for solar power). We derive these results theoretically, and quantify optimal policies in a dynamic general equilibrium climate-economy model.

- Mariia Belaia, Nicole Glanemann. *Can India Prevent Summer Monsoon Extremes? An Integrated Assessment of Climate Change and Environmental Policies*

Abstract: We provide a unique integrated assessment framework for India’s environmental policy analysis in a view of region-specific climate risk. In particular, we explicitly account for potential increase in extreme Indian summer monsoon (ISM) rainfall events under global warming and regional air pollution. We demonstrate that the ISM system is at global-regional environmental policy nexus. Albeit, South Asian countries feature marked vulnerability to deviations in the ISM rainfall. Comparing two alternative scenarios of international cooperation, we establish the inherent benefits of global action on combatting climate change in terms of relatively lower frequency of future extremes. Yet, we show that even joint

global efforts may not be sufficient to fully eliminate the risk as i) changes may already be locked in due to inertia in climate system and ii) discrepancy in costs and benefits among the regions gives rise to a conflict of interests. Thereby, we conclude that adaptation to monsoon extremes is of utmost importance for future regional welfare.

- Simone Borghesi, Giorgia Giovannetti, Gianluca Iannucci, Paolo Russu. *The dynamics of foreign direct investments in land and pollution accumulation*

Abstract: Following the recent increase of foreign direct investments in land, this paper studies their possible effects on the development of a local economy. To this aim, we use a two sector model (external and local) with heterogeneous agents: external investors and local land owners. We assume that both sectors are negatively affected by pollution, but only the external sector is polluting. The local government can tax the external sector's production activities to finance environmental defensive expenditures. We first examine the equilibria that emerge in the model from the dynamics of pollution and physical capital, and then investigate the conditions for the coexistence of the two sectors and the impact of the external sector on the welfare of the local population. Using numerical simulations, we show that a welfare-improving growth path may occur only if the pollution tax is high enough and the impact of the external sector on pollution is low enough. Otherwise, a welfare-reducing growth path may occur, with foreign direct investments decreasing the revenues of local land owners.

- Stefan Borsky, Paul A. Raschky. *Renewable Resources, Inter-annual Weather Variability and Regional Economic Activity: The Case of Maritime Fishery in Africa*

Abstract: Maritime fisheries in African coastal regions play an important role as a driver of economic and social development. Africa is also a highly fractionalized country and deeply-rooted ethnic institutions play a major role on how natural resources are managed. This paper constructs a novel panel dataset, which combines information on fish production with regional variation in economic activity. We use satellite data on nighttime light intensity to analyse the impact of inter-annual weather variability to fish production on subnational economic activity in 812 coastal regions from 31 African countries for 1992 to 2007. We address endogeneity by instrumenting fish production with yearly variation in sea-surface temperature. We find that a 10 % increase in fish production leads to a 3 % increase in contemporary regional economic activity. Further, we present evidence of the importance of pre-colonial political centralization on a regions vulnerability to contemporary negative shocks to fisheries. In particular, we find that a decrease in regional economic activity due to a negative climate shock to fish production is mitigated by up to 80 % in societies with strong pre-colonial political centralization.

- Lucas Bretschger. *Macroeconomic Analysis of Climate Change*

Abstract: Damages and disasters caused by climate change are potentially large in scale and uncertain in nature. They harm long-run development of the economy. Whether the net growth effect of climate policy is positive or negative has an important impact on policy assessment. How uncertainty has an impact on the optimal policy design, especially when thinking of catastrophic changes and possible tipping points, is of great public interest. To address these issues, the lecture will highlight the main links between global warming, climate policy, uncertainty, and economic growth using a basic general framework. It will also provide policy results and explain the underlying intuition.

- Lorenza Campagnolo, *Can Paris deal boost SDGs achievement? An assessment of climate mitigation co-benefits or side-effects on poverty and inequality.*

Abstract: Previous research literature focused on the conceptualization of possible linkages between mitigation policy and sustainable development suggesting how to strengthen potential synergies (Beg et al., 2002) or discussing the opportunities of integrated policy settings (Swart et al. 2003). Through the use of macro-economic models, a recent study explored the effects of emis-

sion reduction targets on the three pillars of sustainability (Campagnolo et al. 2016). However, up to now, little attention has been paid in understating the potential relation emerging from the two recently-adopted international structures.

This paper aims at filling this gap by providing an ex-ante assessment of the co-benefits and side effects of this new policy setting and, in particular, to shed some light on the influence of the commitments undertaken under the Paris Agreement on achieving SDGs, with a specific focus on poverty prevalence (SDG1) and inequality (SDG10).

- François Cohen, Antoine Dechezleprêtre. *Mortality Inequality, Temperature, and Public Health Provision: Evidence from Mexico*

Abstract: Because investments in protective measures are determined by income, climate change is predicted to affect the poorest people in developing countries the most. We examine the heterogeneous impact of temperature shocks on mortality across income groups in Mexico using individual death records and Census data for the period 1998-2010. We find that random variation in temperatures is responsible for the death of around 45,000 people every year, or 8% of annual deaths in the country. However, 88% of weather-related deaths are induced by mildly cold days (10-20°C), while extremely hot days (>32°C) kill a comparatively low number of people (less than 400 annually). As a consequence, we predict that climate change will significantly reduce the number of weather-related deaths in Mexico by the end of the 21st century even in the absence of any adaptation, illustrating the heterogeneity in climate change impacts across countries. We also find that vulnerability to weather shocks is strongly correlated with individual income. The impact of unusually cold days (<10°C) is 35% greater for those living below the median average income, and mildly cold temperatures (10-20°C) kill only in the bottom half of the income distribution. We exploit exogenous variation in the progressive extension of universal healthcare in Mexico and show that it significantly reduced cold-related mortality among the poor.

- Edoardo Croci, Benedetta Lucchitta, Janssens Maenhout, Simone Martelli, Tania Molteni. *Urban CO2 mitigation strategies under the Covenant of Mayors: an assessment on 124 European cities.*

Abstract: The aim of the study is i) to analyse the strategies adopted by cities to achieve their CO2 reduction targets, ii) to assess the relationship between baseline emissions and intended emission reductions and iii) to assess which drivers (local features and socio-economic characteristics) influence the adopted strategies. The analysis is based on data provided by a subset of cities participating at the Covenant of Mayors initiative. The sample is composed by 124 cities, with population ranging from about 108.000 to 7.67 million. Cities are spread across Europe: 42% are in Mediterranean Europe, 26% in Continental Europe, 14% in the UK and Ireland, 9% in Northern Europe and 9% in Eastern Europe. More than 5.400 actions planned by cities in the sample are analysed. Most relevant actions in terms of recurrence and mitigation impact are individuated. Cities are then categorized according to a set of features (population, income, climatic conditions, etc.) and a cluster analysis is performed in order to assess differences between clusters in emission reduction strategies. Finally a set of driver variables is tested through a regression to determine their influence on emission reduction strategies. The variables considered reflect socio-economic aspects, urban structure and geographical peculiarities. Results from regression analysis underline the role of population size, population density, climatic conditions, GDP and local electricity emission factors are as statically significant drivers of emissions. Baseline emissions prove to be the key driver of intended emission reductions across all sectors. Results of the experiment analysis can be useful to urban policy makers to shape their mitigation strategies. In fact the analysis underlines which are the most relevant measures in SEAPs and point out which are the most potentially effective measures according to cities' characteristics.

- Sandy Dall'Erba. *The Ricardian Model Of Climate Change Impact Meets The Ricardian Model Of Interregional Trade: Theory And Evidence*

Abstract: The Ricardian framework is increasingly used for the study of the impact of climate change on farmland values. While most of the Ricardian studies assume no interaction between the geographical units under study, the few that do rely on traditional proximity-based dependence. In this paper we argue that since the larger share of agricultural goods produced by a state is not for its own local market, including interregional trade in the Ricardian framework provides new perspectives, avoids a missing variable bias and prevents erroneous conclusions. Our new framework is applied to the system of the 48 U.S. states over the five most recent censuses (1992-2012) and demonstrate that climate and socio-economic conditions experienced in a state's trade partners have a significant role on that state's agricultural profits.

- Ingrid Dallmann. *Weather Shocks and International Trade*

Abstract: International trade data is the best available source for measuring economic activity at a low aggregation level that is comparable worldwide. I study the impact of weather shocks on economic activity using export data from BACI, worldwide and for the 1992-2014 period. The empirical analysis is divided into three parts. First, I study the impact of weather shocks on export growth at a 2-digit product aggregation level and identified the products that are affected by temperature shocks. Second, I distinguish between the immediate and accumulated effects of temperature and precipitation shocks on export growth. Finally, I study the impact of weather shocks on the intensive and extensive margins of exports. I calculate the intensive and extensive margins for all the 5037 products in the 1-digit HS6 system, for the 698 products in the agricultural sector, and for the 2500 products sensitive to temperature shocks. Results show that there is a negative and significant effect of temperature shocks on export growth, and that there are both immediate and persistent effects. The effect of temperature shocks on the intensive and extensive margins are positive for the aggregate of all sectors and for the weather-sensitive sectors. All the statistically significant impacts occur only in poor countries.

- F. Bosello, S. Brown, E. Delpiazzo, J. Hinkel, D. Lincke, R. Parrado, Planned adaptation to sea level rise: an economy-wide assessment

Abstract: This paper aims to explore the costs of sea-level rise (SLR) impacts and adaptation not only in terms of GDP and production but taking into account their effects on public finance, considering public deficit and debt. Applying future projections of SLR damages, generated by the DIVA modeling framework we compare a reference SSP2 scenario with an impact and adaptation scenarios. Results suggest that SLR impacts has widespread negative effects on GDP and public finance mostly through a reduction in tax revenue as a consequence of tax base erosion. When adaptation, in form of sea dike building is considered, the negative effect of GDP is limited. Moreover, in the short to medium run effects of adaptation on public budget could be negative as huge investments have higher costs than the initial SLR impacts but in the long run avoided impact could repay for initial increases in deficit and debt, therefore adaptation could be beneficial for public budget even if it is financed through debt issuing.

- Aart de Zeeuw, Frederick van der Ploeg. *Climate tipping and economic growth: Precautionary capital and the price of carbon.*

Abstract: The optimal reaction to a climate tipping point which becomes more imminent with global warming is to price carbon to make catastrophic change less imminent and to accumulate precautionary capital to curb the adverse effects of the calamity. We decompose the optimal carbon price into its catastrophe components and a conventional marginal damages component, and show the separate effects of relative intergenerational inequality aversion and relative risk aversion using Duffie-Epstein preferences. Focusing on a productivity catastrophe, we calibrate our model and give estimates of the optimal carbon price and show how sensitive these are to the degrees of intergenerational inequality aversion and risk aversion, the trend rate of growth, the hazard rates, and how long it takes for the catastrophe to have its full impact. We also show how the tipping point affects the optimal amount of additional required saving

positively if the impact of the catastrophe is fast but negatively if the impact is slow.

- Tiziano Distefano, Simone D'Alessandro. *An Evolutionary approach to International Environmental Agreements*

Abstract: Our work contributes to explain the observation of two facts at odds: the number of signatories of international environmental agreements (IEA) has grown in time, meanwhile, the aggregate global level of greenhouse gas emissions is increasing at exponential rate. We introduce a novel multi-scale framework, composed by two tied games, to show under which conditions a country is able to fulfil the IEA: an Evolutionary Game which describes the economic structure through the interaction of households and firms strategies; and a 2x2 one-shot Game, with asymmetric nations that negotiate on the maximum share of emissions. The distance between international environmental targets and country's emissions performances is explained in terms of heterogeneous economic structure, without the need to impose any free-riding behaviour. Consumer's environmental consciousness (micro level) together with global income (and technological) inequality (macro level), are found to be the key variables towards the green transition path. We provide analytical results paired with numerical simulations.

- Moritz A. Drupp, Martin C. Hansel. *The relative price of environmental goods and climate policy evaluation*

Abstract: As environmental goods become relatively scarcer due to climate change, it gets increasingly important to consider their relative price changes when evaluating long-term public policies. We study fundamental determinants of the relative price effect of environmental goods, including limited substitutability, the magnitude of non-market climate damages, productivity growth and the key welfare parameters, including societal time preference. We use the integrated climate-economy model DICE to quantitatively explore how these drive the relative price effect, which amounts to the difference in the good-specific discount rates. Our results show that the magnitude of the relative price effect is substantial compared to commonly assumed discount rates: it ranges from 6 percentage points in the year 2020 to 3 percentage points in the year 2100. The key drivers of the relative price effect in DICE are the degree of substitutability between environmental and man-made goods and the economy's productivity growth. Neglecting relative prices would lead to an underestimation of the social cost of carbon of more than 30 (130) percent in the year 2020 (2100). Our findings offer guidance for discounting policy, and call for more stringent climate policies.

- Louis Dupuy, Nick Hanley, Koji Tokimatsu. *Using Genuine Savings for climate policy evaluation with an integrated assessment model*

Abstract: Climate policies can have impacts which show up in multiple sectors of the economy and which change consumption levels over time, besides the changes in emissions which such policies bring about. We show how the sustainability indicator Genuine Savings can be endogenised within a general equilibrium model and used as a criterion for judging the impacts of such policies or growth scenarios. We combine life cycle analytical approaches with a multi-country macroeconomic model which includes the economic costs of emissions from economic activity, and impacts on biodiversity and net primary productivity. The model is used to calculate values for Genuine Savings, where the shadow prices used to measure the value of asset changes is derived from the model structure. Differences in Genuine Savings over different greenhouse emission scenarios are discussed, scenarios which also consider effects of pricing impacts on other pollutants and on biodiversity, and the effects of changes in population and the rate of growth of productivity. A key result which emerges is the key role of the rate of technological change relative to the population growth rate, if wellbeing is to be sustained over the next 50 years.

- Johannes Emmerling, Massimo Tavoni. *The risk of unilateral climate engineering*

Abstract: There is a growing mismatch between actions to countervail climate change, which are based on voluntary national initiatives of limited effort, and the severity of climate impacts, whose estimates appear to be higher than previously thought (Burke et al., 2015; Dell et al., 2012). Climate engineering (CE) via solar radiation management has been proposed as a possible complement to traditional strategies such as mitigation and adaptation to keep temperature in check (Keith and MacMartin, 2015). However, climate engineering entails additional risks, particularly regarding its governance (Victor et al., 2009). Free driving, the possibility of unilateral geo-engineering to the detriment of other nations, has been recently proposed as a potentially powerful additional externality to the traditional one of free riding (Weitzman, 2015). This paper provides a first numerical evaluation of the risk of free driving. We use an integrated assessment model to quantify climate engineering in a cooperative scenario vis-à-vis a the non-cooperative Nash equilibrium. Our results indicate that in a strategic setting there is significant over-provision of climate engineering above what socially optimal. Free driving appears to be of similar size as free riding. Results are shown to be robust to different specification of damage function and climate engineering parametrization.

- Carolyn Fischer, William. A. Pizer. *Equity Effects in Energy Regulation*

Abstract: Choices in energy regulation often involve options with divergent impacts on household energy prices. In particular, because pollution taxes and cap-and trade programs price inframarginal emissions, they typically raise energy prices more than regulatory approaches like performance standards. At the same time, household energy use varies widely, both across income (a concern for vertical equity), as well as within any easily identifiable demographic or income class (a concern for horizontal equity). Policy choices thus can have significant distributional effects to be weighed alongside efficiency concerns. In this paper, we review the theoretical foundations underpinning horizontal as well as vertical equity concerns and consider how they might be influence the evaluation of environmental policies. We characterize policy tradeoffs in light of alternative welfare perspectives for making policy choices, and highlight the sufficient statistics that policymakers might need. We use Consumer Expenditure Survey data to generate such metrics for a hypothetical carbon price versus tradable performance standard regime. This study provides a guide for when equity effects could override efficiency concerns. In particular, when energy policies have horizontally inequitable consequences, it will be difficult to compensate stakeholders through traditional fiscal measures that address vertical inequality.

- Anton Hartl. *Some doubts about the carbon leakage effects of the Kyoto Protocol*

Abstract: In line with the recent literature, this study finds evidence for carbon leakage as a consequence of emission reduction commitments under the Kyoto Protocol using gravity model-style regression analysis on data from the WIOD project. On average, sectoral imports of embodied CO₂ from non-constrained countries to constrained countries increased by 10 percent (and vice versa). However, we see these results as giving only weak evidence, the reasons being: The different paths of Kyoto ratifiers and non-ratifiers seem to be very robust to the exact treatment date, hinting towards weak identification of treatment timing. The strongest contributions to the estimated effect are coming from the services sectors – where large percentage leakages often amount to small absolute changes – as well as from the least bindingly emission constrained countries under the Kyoto Protocol – among them Eastern European countries for which the simultaneity of ratification and EU accession implies serious identification problems. We conclude that the baseline estimates of Kyoto's carbon leakage are most likely upward biased.

- Hermann Held. *Cost Risk Analysis: Dynamically Consistent Decision-Making under Climate Targets*

Abstract: Rational response to the problem of global warming represents a key challenge for climate economics. Here we argue that the two most prominent schools of thought within climate economics that we cluster around cost benefit analysis (CBA) and target-based cost effectiveness analysis (CEA), both have their pros and cons in adequately representing society's preferences. Our group argues that given the

present stock of consolidated knowledge on global warming impacts, a hybrid decision-analytic tool that we call ‘cost risk analysis’ (CRA) might be an attractive intermediate alternative that would harvest most ‘pros’ of both methods. Here we summarize the structure, the key assumptions of that method and review three applications, assuming the 2°C target as prescribed: (i) the expected value of perfect climate information, (ii) the effect of delayed participation on mitigation cost in contrast to CEA, and (iii) the optimal mix of the climate engineering option ‘solar radiation management’ and mitigation when taking one risk category into account. Finally we sketch for which societal functions what method might currently be most appropriate.

In conclusion: What is the current role of cost benefit analysis, cost effectiveness analysis, and cost risk analysis? Cost benefit analysis provides an excellent tool to understand the trade-offs between various values and uncertainties. For decision makers who can emotionally attach to the rather abstract inputs required it might be the optimal choice. For decision-makers who feel inspired by the idea that one would not like to leave the historically approved regime of global mean temperature – at least as long as not qualitatively more reliable impact valuations were available –, we see cost risk analysis as the optimal choice, and under some circumstances cost effectiveness analysis a good approximation thereof. In the meantime, impact research should move on. There are good chances that ‘soon’ the phase space on global warming impacts will be so well understood, that cost benefit analysis can be applied, however in a generalized form: by representing uncertainty as Knightian uncertainty (Millner et al., 2012). On the contrary, those practitioners who believe this tool is currently too ambitious for policy advice might utilize CRA as a ‘bridging technology’. Finally, CRA should further be the method of choice for those who might see the 2° target as ‘suboptimal’, but simply would like to acknowledge it – out of a ‘2nd best solution attitude’ – as the existing UNFCCC-based policy target. In any case we see it as timely to intensify a discussion on what decision-analytic tool serves what purpose best.

- Gianluca Iannucci, Angelo Antoci, Simone Borghesi, Paolo Russu. *In and out of the market: ETS and technological innovation in a dynamic evolutionary model*

Abstract: This paper studies the impact on the dynamics of the market of three types of firms: non-polluting, polluting with permits, polluting without permits. Using an evolutionary context, we analyse the stationary states of the model and the conditions under which there are attractive equilibria. Preliminary results show that, generally, there is no coexistence equilibrium, so that we always have the extinction of at least one “species” of firms at the equilibrium. Numerical simulations confirm that coexistence between firms exists only if the sanction on non-compliant firms and the probability of discovering them assume certain values. However, when this occurs, there are infinite attractive equilibria. Finally, by appropriately increasing the probability of discovering non-compliant firms and the correspondent sanction level, the government can influence the dynamics that emerge from the model leading non-compliant firms to exit the market.

- Julie Ing, Jean-Philippe Nicolai. *Public transfers of climate-mitigation technologies: The crowding-out effect on relocation*

Abstract: Technology transfers can come from government decisions or be a business choice. Indeed, when firms relocate, they generate technology transfer. These two types of decision seek divergent goals. The purpose of this paper is to investigate the relationship between the firms’ incentives to relocate and the countries’ incentives to transfer climate-mitigation technologies. We consider two countries (home and foreign) implementing a carbon tax. The government in the home economy decides to transfer or not its technology to the foreign economy, and firms located in the home economy may decide to relocate their production in the foreign economy. We consider two types of firms. At home, there are only relatively clean firms, while in the foreign economy relatively clean and dirty firms coexist. We show that the governments’ transfer of technology decreases the incentives to relocate.

- Larry Karp, Terry Iverson. *Carbon taxes and commitment with non-constant time*

preference

- M.M. Khabbazan, E. Roshan, H. Held. *Cost-Risk Trade-off of Solar Geoengineering and Mitigation – Considering Regional Disparities under Probabilistic Climate Sensitivity*

Abstract: Solar geoengineering (SGE) offers an option to ameliorate anthropogenic temperature rise. However, it cannot be expected from SGE to simultaneously compensate for anthropogenic changes in further climate variables in a perfect manner. Here, we ask to what extent a proponent of the 2°C-temperature target would apply SGE in conjunction with mitigation in view of regional disparities in precipitation changes. We apply cost-risk analysis (CRA), which is a decision analytic framework that makes a trade-off between the expected welfare-loss from climate policy costs and the climate risks from transgressing a climate target. Here, in ‘Giorgi’ regional-scale analyses, we evaluate the optimal mix of SGE and mitigation under probabilistic information about climate sensitivity and generalize CRA for the sake of including not only temperature risk, but also regional precipitation risks. Social welfare is maximized for the following three valuation scenarios: temperature-risk-only, precipitation-risk-only, and equally weighted both-risks. We find that for regionally differentiated precipitation targets, the usage of SGE will be restricted. Our results indicate that SGE would save 70% to 75% of the welfare-loss compared to a purely mitigation-based analysis (whereby the overall climate-induced welfare loss amounts to approximately 4% in terms of BGE, from economic costs and climate risks) when considering regional precipitation risks in precipitation-risk-only and both-risks scenarios.

- Vassiliki Manoussi, Soheil Shayegh and Massimo Tavoni, *Carbon dioxide removal and outgassing from the ocean*

Abstract: Oceans act as a natural sink for the carbon cycle. The speed of adjustment of the sink to any disturbance in the system is represented by an ocean-to-atmosphere transfer coefficient in the carbon cycle models of climate change. We study the sensitivity of optimal mitigation strategies to this coefficient. We consider abatement and carbon dioxide removal (CDR) as two main mitigation strategies in response to climate change. We develop a theoretical framework to study the impact of the ocean-to-atmosphere transfer on the optimal mitigation strategies under different regimes that control the relationship between outgassing from the ocean and the CDR level. We show that both optimal mitigation strategies (abatement and CDR) are negatively related to this coefficient. However this impact is more profound in the case of optimal CDR than optimal abatement. We incorporate the outgassing effect into a well-known integrated assessment model of climate and economy (DICE model) and verify our theoretical findings with numerical simulations. Further we perform a sensitivity analysis and stochastic optimization to find the range of optimal abatement and CDR actions under uncertainty about the ocean-to-atmosphere transfer coefficient.

- Emanuele Massetti. *Statistical Learning for Climate Change Impact Research: an Application to US Agriculture.*

Abstract: We apply “statistical learning” methods to estimate how climate and weather affect US agriculture using the largest dataset of climate variables ever used in the literature. The goal of this paper is to provide a more precise estimation of the relationship between agricultural productivity and climate. This will lead to a clearer understanding of the potential impacts of climate change on US agriculture. The paper will also test a large set of statistical learning methods in the literature that studies the effect of climate on the economy. A growing concern in the literature is that omitted variables may bias the climate coefficients. This problem is particularly acute in cross-section studies (Dêschenes and Greenstone, 2007), but panel studies also suffer from omitted

variables that vary over time and are correlated with climate variables. For example, the typical study in the literature controls for temperature and precipitation but omits many other climate variables – such as humidity, cloudiness, wind – which directly affect agricultural productivity and are correlated with temperature and precipitation (Masseti, 2016; Zhang, Zhang and Chen, 2016). Unfortunately, there has been virtually no progress in the literature in providing a more careful description of climate. The consequences of this omission in terms of climate change impacts estimates are not known. This paper fills this gap in the literature by providing a comprehensive assessment of the relationship between climate variables and agricultural productivity using both cross-section land value data and fixed effects panel crop yields models. We use a large set of climate variables from the North American Regional Reanalysis model (NARR). Data is available on a 32x32 Km grid at 3-hour time intervals from 1979 to present day. This is the richest climate dataset ever used in the literature, to our knowledge. We use many functional forms that allow non-linear responses between the climate variables and the dependent variable. We also test for interactions between the climate variables to capture complex meteorological events such as heat waves, blizzards, thunderstorms, all of which are typically not immediately available in climate datasets but affect agriculture. Model specification and variable interactions will be constrained as much as possible using evidence from the economic, agronomic and climatological literatures. However, with such a large number of variables the number of possible model combinations quickly becomes intractable with standard regression techniques. For this reason we use statistical learning methods to select the model that best predicts land values and crop yields in the United States. The performance of the model will be assessed using the ability to predict out-of-sample.

- Andi Mehmeti, Francesca Santoni, Carlos Boigues Muñoz, Stephen J. McPhail · Massimiliano Della Pietra, Marco Graziadio, *High Temperature Fuel Cells for Energy Sustainability: Opportunities and Challenges*

Abstract: High-temperature fuel cells, such as molten carbonate and solid oxide fuel cells are touted as key elements of a transition to a cleaner and more secure energy scenario. In this paper, the opportunities for using high-temperature fuel cells as part of a sustainable energy strategy and the challenges that need to be overcome to take advantage of these opportunities are discussed.

- Melania Michetti, Mehmet Pinar. *Shedding light on deadly flames: what drives fires in Italian forests.*

Abstract: We analyze the determinants of monthly and yearly variations in forest fire frequency and on the size of the area burnt (i.e., intensity) for Italian regions during 2000-2011. Panel data techniques allow capturing the dynamical aspects of fire danger due to changes in both climatic and socio-economic conditions, after accounting for regional fixed effects to consider region-specific unobserved factors. Two different dependent variables (measuring frequency and intensity of fires) are alternatively employed and several *ad hoc* tests are performed to corroborate estimation outputs. Results highlight a significant regional heterogeneity across the Italian peninsula. Different regions are governed by dissimilar patterns. Weather variables significantly affect fire frequency and intensity with the expected sign and with persistent effects in time. High temperatures affect fire risk conditions more than precipitation in terms of magnitude. A seasonality path is clearer when looking at fire intensity rather than frequency with a stronger connotation as we move from north to south of Italy. As for socio-economic drivers, we find that higher levels of education negatively influence the number of fire events as well as their intensity in the north and central Italy. In the south, the presence of illegal activities significantly affects fire danger, after controlling for the regional fixed effects and climatic data.

- Mathias Mier, Klaus Eisenack. *Policy implications in a world with renewables, limited dispatchability, and fixed prices*

Abstract: Most electricity systems face contractual fixed consumer prices in the short-term, i.e. Load is fixed before the fluctuating production of renewable capacity like wind turbines or solar PV realizes. Furthermore, conventional capacity like nuclear or other steam power plants make production decisions before these fluctuations realize. Most conventional capacity cannot react instantly on such random fluctuations, which in turn requires for imbalance energy by highly-dispatchable capacity. We approach these dynamics by considering fluctuating renewables, inflexible conventionals, and highly-dispatchables. Efficient capacities and efficient price is determined. Either electricity systems with conventionals only or systems with renewables and highly-dispatchables occur. The latter system poses a major challenge for a benevolent regulator, who tries to decentralize capacity and load decisions, also in competitive markets. We show how a regulator can implement transfer schemes, which lead to the efficient choices. Allowing conventionals to be at least partly flexible at higher costs, retain conventionals - together with renewables and highly-dispatchables – longer in the system.

- Antony Millner, Daniel Heyen. *Valuing Predictability*

Abstract: How important is it to be able to predict the distant future? We study this question in a model of an agent who operates in a non-stationary stochastic environment. Payoffs depend on how well adapted activities are to current conditions, and activities may be adjusted to account for anticipated environmental changes, at a cost. We compute the value of prediction systems, which produce forecasts of the future with a given profile of accuracy as a function of lead time in every period. This allows us to quantify the importance of predictive accuracy at each lead time. Even if adjustment costs, discount factors, and long-run uncertainty are large, short-run predictability is often more important than long-run predictability. We discuss applications to a variety of decision problems, including preparing for natural disasters and adaptation to climate change.

- Farid Hossain. *Climate Change Impact on Rural Economy of Bangladesh*

Abstract: Bangladesh is an agricultural country with an area of 147,570 sq. Km having a population of 160 million. The majority of the population depends on agriculture and natural resources for their food and livelihood. Forest is a very important renewable resource in Bangladesh accounting 17.37% of the total area. It provides materials like timber, fuel wood, food and primary base for biodiversity. Over one million people directly or indirectly depend on the forest for their livelihood. Natural calamities, such as floods, tropical cyclones, tornadoes, and tidal bores occur almost every year, combined with the effects of deforestation, soil degradation and erosion. ‘Sundarban’ is the world’s largest contiguous natural mangrove forest covers an area of 4.07% of total area of Bangladesh. The ‘Sundarban’ has been declared as ‘World Heritage site’ by the UNESCO in 1997. It provides important ecosystem services in the region as well as protects coastal people from many natural disasters. The severity of salinity problem in Bangladesh has increased much due to the intrusion of saline sea water. Forest degradation directly leads to lower rainfall and higher temperatures. The forest and agricultural land areas are drastically decreasing annually. However, Climate change is now a major challenge in Bangladesh. Regional collaborative efforts are inevitable to mitigate adverse impact of climate change.

- Stefan Nabernegg, Birgit Bednar-Friedl, Fabian Wagner, Thomas Schinko, Janusz Cofala, Yadira Mori Clement. *The Deployment of Low Carbon Technologies in Energy Intensive Industries: A Macroeconomic Analysis for Europe, China and India*

Abstract: Industrial processes currently contribute 40% to global CO₂ emissions and therefore substantial increases in industrial energy efficiency are required for reaching the 2°C target. We assess the macroeconomic effects of deploying low carbon technologies in six energy intensive industrial sectors in Europe, China and India in 2030. By combining the GAINS technology model with a macroeconomic

computable general equilibrium model, we find that output in energy intensive industries declines in Europe by 6% in total, while output increases in China by 11% and in India by 13%. The opposite output effects emerge because low carbon technologies lead to cost savings in China and India but not in Europe. Consequently, the competitiveness of energy intensive industries is improved in China and India relative to Europe, leading to higher exports to Europe. In non-energy intensive sectors, output also declines in Europe and increases in China and India. We find a rebound effect in China and India, in the size of 42% of CO2 reduction and 34% respectively, but not in Europe. Within energy intensive industries, the only sector gaining in Europe is Electricity. Since more than 70% of reductions in CO2 emissions are achieved in this sector, climate policy should support technological development there.

- Chiara Ravetti, Tania Theoduloz, Giulia Valacchi. *Buy coal or kick-start green energy? An open economy perspective*

Abstract: This paper analyses two unilateral policies available to countries that do not own fossil fuel resources, in order to rapidly curb global carbon emissions. We compare a pigouvian policy approach, which requires subsidizing green energy prices, and a coasian strategy, which entails supply side interventions, such as buying coal deposits abroad. Using a dynamic North-South trade model with endogenous innovation, we show that both policies can avoid an environmental disaster, inevitable under laissez-faire. We find that green price subsidies are often cheaper to implement, however buying deposits yields a higher welfare if fossil fuel owners are not too far from the frontier of green energy technology. Moreover, technology transfers to fossil fuel owners can make a supply side policy cheaper and more politically feasible.

- Karolina Safarzyńska. *Policy lessons from integrating behavioral economics in climate-economy models*

Abstract: Various macroeconomic models have been proposed to study the effects of climate policies. But from many corners now, it has been argued that these models are inadequate as tools for policy analysis. Especially extreme impacts of climate change, inherent uncertainty, and discounting have been widely discussed as flaws of current models. Surprisingly, unrealistic assumptions about individual behaviors, which ignore well-documented behavioral ‘anomalies’ and social interactions, have attracted little attention so far in the economic analysis of climate change impacts and policies. The paper provides an overview of formal macro-behavioral models, designed to incorporate into economic theory a variety of realistic behaviors, such as present bias, habit formation, loss-aversion, and social status. We show that ignoring realistic behaviors may undermine the effectiveness of climate policies, which we illustrate with examples of a pollution tax and a social cost of carbon. In addition, we study the magnitude of the energy backfire for each behavioral model. The energy backfire describes a phenomena when energy use can paradoxically increase after improvements in energy efficiency. We show that status concerns make the economy more conducive to the energy backfire compared to a model with fully rational agents. Models of habit formation and loss aversion have the opposite effect.

- Milan Ščasný, Iva Zvěřinová, Alistair Hunt, Zuzana Martínková. *Nature-based, structural, or soft measures of adaptation? Preferences for climate change adaptation measures to limit damages from floods and droughts*

Abstract: The objective of this study is to examine preferences of citizens of three European countries for adaptation plans and measures to limit damages from floods and droughts. For this purpose, we conducted a questionnaire survey in the Czech Republic, Italy, and the United Kingdom. We utilized discrete choice experiments to elicit individual preferences for adaptation options and estimated marginal willingness-to-pay for the several types of technical, natural, and supplementary soft measures of adaptation. We find that respondents are on average willing to pay 110 EUR, 107 EUR, and 56 EUR a month and household, respectively for public adaptation measures to limit impacts of droughts. Mean WTP is almost twice larger

for the adaptation measures to limit impacts of flooding. Among the measures to limit impacts of droughts, nature-based measures on rainwater harvesting and creating wetlands belong to the most preferred in each of the three countries, followed by small water reservoirs in the Czech Republic, while the Brits also prefer large reservoirs. Preference for the complementary soft measures vary considerably across the types and countries; but Italians prefer them the most. Same pattern is found for the adaptation to reduce impacts of flooding. However, Italians prefer technical measures more, a maintenance of riverbeds in particular, while the Brits prefer the natural measures relatively more and creating woodland or wetland seems to be most preferred option. Again, preference for soft measures vary, with the considerable strong preference for control on construction in vulnerable areas.

- Thomas Sterner. *International Climate Economics: the importance of treaties and politics versus underlying trends in technology and taste*

Abstract: The Paris Agreement was acclaimed as a milestone for climate negotiations. We evaluate its impact on the stock market value of energy sector firms. Using event study and impulse indicator saturation methods, we show the agreement had only moderate effects, perhaps because the result was anticipated. To evaluate the importance of surprise, we analyze the unexpected election of Donald Trump. Although he is on record in favor of fossil industries, we again find little effect. However, using the difference in performance of renewables versus coal as an indicator of climate adaptation, we do find small but significant effects.

- Koji Tokimatsu, Kentaro Yoshida, Kayo Murakami, Norihiro Itsubo, Koichi Kuriyama, Rieko Yasuoka, Masahiro Nishio. *Benefit transfer in an integrated assessment model: how is it important?*

Abstract: This article stresses following three critical issues in damage functions of climate change economics by plugging a life cycle impact assessment (LCIA) modeling into our integrated assessment model (IAM). One is economic valuation, another is its transfer for weighing intra- and inter- generations and the other is so-called highly aggregated, algebraic form of the functions. The functions in past IAMs are specified by modeler's choice by literature survey of i) a particular formula ii) with its economic damage for benchmark temperature rise, and iii) damage increase by temperature rise using a coefficient.

Contrary to this, we conducted surveys (face-to-face, Internet) to obtain over 7,600 samples from 30 countries to estimate the economic valuation in the benchmark and the coefficient in the LCIA modeling with dose-response relations. This article specifically focus on the transfer in the IAM, whose forms are functions and the coefficient σ (called income elasticity), both derived from the survey. We combine the LCA approaches with a multi-country macro-economic model which includes the economic costs of emissions from economic activity, and impacts on human health, biodiversity and net primary productivity. The economic valuation are treated as external environmental costs. The decision to invest and consume is taken in the macroeconomic model based on the (internal) cost of resources, the (external) cost of environmental impacts. Formulated as such, this is an economic problem we solvw using a modified Ramsey-Cass-Koopmans model adapted from the Nordhaus's RICE framework. Results showed that external costs, fossil fuel consumption, and the greenhouse gas emissions were greatly changed by σ and the transfer function, suggesting transfer issue should be paid more attention in climate change economics while central discussion on had long be focused on ρ (pure rate of time preference) and η (elasticity of marginal utility of consumption) in their determination of parameter settings.

- Jascha Tutt, Michael Berlemann, Max Steinhardt. *Do natural disasters affect individual saving? Evidence from a natural experiment in a highly developed country*

Abstract: While various empirical studies have found negative growth-effects of natural disasters, little is yet known about the microeconomic channels through which disasters might affect short- and especially long-term growth. This paper contributes to filling this gap in the literature by studying how natural disasters affect individual saving decisions. This study makes use of a natural experiment created by the European Flood of August 2002. Using micro data from the German Socio-Economic Panel that we combine with geographic flood data, we compare the savings behavior of affected and non-affected individuals by using a difference-in-differences approach. Our empirical results indicate that natural disasters depress individual saving decisions, which might be the consequence of a Samaritan's Dilemma.

- Rick van der Ploeg. *Challenges in Climate Policy: Dealing with Conflicting Views on Global Warming*

Abstract: We discuss various obstacles to ambitious climate policy such as procrastination, fear of pricing carbon, green paradoxes and carbon leakage, and then focus on climate deniers which with the election of Donald Trump as President of the United States has gained prominence. To deal with this, we consider the max-min policy which tries to do the best under the worst possible view of the world and is surprisingly close to the policy set by a non-denialist climate scientist. This is also true for the min-max regret policy. Smooth ambiguity aversion biases down the prior probability that climate deniers are right. Robust or safe policy makers conduct an ambitious climate policy even if the subjective probability of climate deniers being right is high

- Anastasios Xepapadeas. *Spatio-temporal aspects of climate change policies*

Abstract: Two-box climate models, which allow for heat and moisture transport from the southern region to the northern region, can be used to capture a number of important spatial aspects which could be significant for climate policy design. One such aspect which becomes clear in spatial models is the process of polar amplification. Polar amplification (PA) is an established scientific fact which has been associated with the surface albedo feedback and with heat and moisture transport from the Equator to the Poles. In a recent paper, W. Brock and A. Xepapadeas (Climate Change Policy under Polar Amplification, *European Economic Review*, 2017, forthcoming) unified a two-box spatial climate model, with a simple economic model of welfare optimization. The main contribution was to show that by ignoring spatial heat and moisture transport and the resulting PA, the regulator may overestimate or underestimate the tax on greenhouse gas emissions. The present research extends the model in two directions. First, it analyses non-cooperative solutions in which each region unilaterally decides its own emissions under conditions of heat transfer and PA. Second, by allowing for capital accumulation, it explores how the two-region model with PA can be unified with a Ramsey-type optimal growth model and characterizes the cooperative solution.

- Jinshan Zhu, *The Economics of Greenhouse Gas reduction and stratospheric aerosol injection*

Abstract: This study analyzes how the involvement of SAI option will set impact on the GHG reduction. It is widely agreed that the involvement of SAI will negatively impact the amount of GHG reduction. Economically, involvement of SAI option will also imply a new optimal level of financial commitment in the sector dealing with climate change. But how such effect takes place is still not full resolved. The finding of this work are as follows: (1) Apart from a new optimal level of financial commitment, there has to be a optimal mixture of GHG reduction and SAI deployment at any given level of financial commitment. (2) Except the budget is trivial compared with current level, for all the other circumstance, a higher budget means that a smaller the scale of SAI deployment would be needed. (3)The impact of involving SAI option

on the amount of GHG reduction can be decomposed into three factors, which are (a) The budget shift; (b) the substitute effect works along a given budget line; (c) the income effect. The significant factor is the shift of total budget for climate change campaign, but with regard to the social and political reality, this factor is exogenous to the economic model of optimization. On the contrary, substitute effect and the income effect are Endogenous to the model, but their impacts on the amount of GHG reduction are insignificant. Economic optimization may appear to be the rescue that saves people from making hard choice, but it is not.