Gemeinsamer Schlussbericht (Sachbericht) für das Verbundprojekt

ECCUITY

Economics of Climate Change:

Distribution, Efficiency, and Policy under Uncertainty

Förderer:	Bundesministerium für Bildung und Forschung
Förderinitiative:	Ökonomie des Klimawandels
Förderkennzeichen:	01LA1104A, 01LA1104B, 01LA1104C
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Laufzeit:	1. Juli 2012 – 31. Dezember 2015
Berichtsdatum:	20. Juni 2016

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung
FONA Ökonomie des Klimawandels BMBF

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Kurzfassung

Das Forschungsprojekt „Economics of Climate Change: Distribution, Efficiency, and Policy under Uncertainty“ (ECCUITY) wurde als Verbundprojekt der Universitäten Lüneburg (Projektleiter und Verbund-Koordinator: Prof. Dr. Stefan Baumgärtner), Regensburg (Projektleiter: Prof. Dr. Wolfgang Buchholz) und Kiel (Projektleiter: Prof. Dr. Martin Quaas) durchgeführt.

Ziele des Projekts waren (1) ein besseres analytisches Verständnis der kombinierten Effekte alternativer Vermögensverteilungsziele und Risikoexternalitäten für intertemporale Verteilungsgerechtigkeit und Effizienz unter Unsicherheit, sowie (2) Entscheidungsunterstützung bei der Ausgestaltung internationaler Klimapolitik in Form geeigneter Instrumente, Versicherungsprodukte und internationaler Abkommen.

Die Forschung konzentrierte sich auf drei Schwerpunkte: (1) Vermögensverteilung und Bewertung der Kosten und Nutzen von Klimapolitiken (Leitung: U. Kiel), (2) Risikoexternalitäten, externes moralisches Risiko und Versicherung (Leitung: U. Lüneburg), (3) Politikinstrumente und internationalen Klima-Abkommen (Leitung: U. Regensburg).

Die detaillierten wissenschaftlichen Ergebnisse des Projekts wurden in 27 Manuskripten vorgelegt, von denen mehr als die Hälfte bereits in sehr guten internationalen Fachzeitschriften mit Peer-Review-Verfahren veröffentlicht oder zur Veröffentlichung eingereicht sind. Dieser Schlussbericht enthält eine systematische und umfassende Zusammenfassung der wissenschaftlichen Ergebnisse und ihrer möglichen Anwendungen.

1. Project aims

Any rational climate policy should be efficient and sustainable, taking into account the significant uncertainties in the long-term natural and economic dynamics. The normative goals of efficient allocation and sustainability, i.e. equitable distribution across and within generations, are analytically independent (Baumgärtner and Quaas 2010a, b). Yet, in the design of concrete policies, how one goal is addressed has repercussions on how to address the other one.

The general relationships between equitable distribution and efficient allocation under uncertainty comprise two major mechanisms that are often intertwined: (i) In general equilibrium, the distribution of wealth and income – over individuals, over time, and over uncertain states of the world – affects the price system, including market prices and monetary values of non-market environmental goods and services, and therefore affects the present value of costs of climate change and what is found to be the optimal climate policy (“**wealth-distribution effects**”) (Azar and Sterner 1996, Anthoff et al. 2009, Anthoff and Tol 2010, Baumgärtner and Quaas 2010a). (ii) Inefficiencies can arise from externalities, in particular

from the externalities of insuring in particular ways against particular (endogenous) risks associated with climate change (Heal and Kriström 2002, Heal and Kunreuther 2004), e.g. through self-insurance, self-protection or market insurance (Ehrlich and Becker 1972) of individual economic agents ("**risk-externalities**").

In this project, we have studied the combined effect of these two intertwined mechanisms and the implications for the **design of international climate policies**, i.e. instruments, insurance schemes and international agreements, which should be equitable and efficient under conditions of uncertainty. One important instance, where the combined effect of these two aspects becomes relevant is the so-called **catastrophic risk** of climate change (Weitzman 2009, Ackerman et al. 2010, Buchholz and Schymura 2010, Ikefuji et al. 2010), i.e. large-damage and potentially existence-threatening events that occur with low probability. Another increasingly important instance where the combined effect of these two aspects becomes relevant is **climate-engineering** (Moreno-Cruz and Keith 2009, Blackstock and Long 2010, Moreno-Cruz and Smulders 2010), i.e. the deliberate manipulation of the Earth's climate to counteract the effects of global warming. We have considered the two issues in combination, because measures of climate engineering can be regarded to be options of last resort against looming catastrophic consequences of climate change. It is against the backdrop of these two interrelated important practical instances that we have developed our analysis.

Overall, we have aimed at (1) *analytical understanding* of the combined effect of wealth-distribution effects and risk externalities for intertemporal equity and efficiency under uncertainty, and (2) *development of decision-support* for the design of international climate policies, i.e. instruments, insurance schemes and international agreements. Our analysis has aimed to yield insights that are in particular relevant for the practical context of employing climate engineering as an option of last resort against looming catastrophic consequences of climate change.

General-equilibrium integrated assessment models use social welfare functions to assess the outcome of coupled climate-economy models. Depending on the parameterization of these welfare functions the estimated costs of climate change and, hence, the ensuing policy recommendations differ extremely (Tol 2009, Stern 2006). **One aim** was to understand the influence of different normatively founded specifications of societal objectives with regard to the intra- and intergenerational distribution of wealth and risk on the estimated cost of climate change and the benefits of mitigating climate change, in particular through climate-engineering, that are derived by state-of-the-art integrated assessment models. Moreover, we have aimed at qualifying the results from the recent Weitzman-Gollier-debate on discounting under uncertainty that considers partial equilibrium, in a general equilibrium setting (Buchholz and Schumacher 2009, Gollier 2002, 2010, Traeger 2011, Weitzman

2001). In particular, we have considered the possibility of so-called “catastrophic risks”. This first aim was mainly addressed by the first sub-project [at the University of Kiel].

The **second major aim**, mainly addressed by the second sub-project [at Leuphana University of Lüneburg], was to understand how dynamic risk externalities interact with the distribution of wealth and the efficiency of climate policies. A *risk externality* prevails if risk-management of a decision-maker has an impact on risks faced by another actor without their consent or compensation. We have assessed insurance against the risks of climate change in view of both equitable distribution and efficient allocation of income and wealth as well as of risks.

The **third major aim**, mainly addressed by the third sub-project [at University of Regensburg], aimed at bilateral transfers improving the efficiency and distributional justice dimensions of climate agreements that are associated with an increase in acceptance and stability. Initially, we have considered the question how a global emission permit trading system can raise the funds needed for transfers. As a novel feature of the analysis we wanted to give special attention to the price uncertainties on carbon markets, e.g. the distributional effects caused by this risk and possible risk consolidation strategies by a central global climate agency. Regarding risk aspects, we also intended to include a comparison with a global carbon tax. Motivated by recent developments in the debate on climate policy in Germany, the focus has shifted in the course of the project to questions of climate finance.

2. Project organization

The work program was structured into four work-packages (WP), with several tasks (T) in each. WPs 1 through 3 dealt with the substantial questions of our project; while WP 4 comprised activities that served explicitly for integration and knowledge transfer. All work-packages ran in parallel.

While each partner had the lead-responsibility for one of the substantial work-packages WP1 – WP3, we worked together on the overall project in a highly integrated manner. This meant that all partners, besides doing research in their core work-package, were also actively involved in some tasks of the other substantial work-packages. [For each task, we specify the partners involved in brackets, with the leading partner underlined.]

Integration across work-packages was ensured through the commonly employed methodology of generic and specific modeling. Throughout all work-packages we used a common modeling framework, developed in parallel and in close cooperation in all three substantial work-packages’ first task (T1.1, T2.1, T3.1)), so that model extensions and results from one work-package could easily be related to other work-packages.

WP1. Wealth distribution and valuation of costs and benefits of climate policies (lead: CAU)

T1.1 Conceptual models [LEU, UR, CAU]

T1.2 Deterministic global model [CAU]

T1.3 Stochastic global model [LEU, CAU]

T1.4 Regionalized model [CAU]

WP2. Risk externalities, external moral hazard and insurance (lead: LEU)

T2.1 Development of generic risk models [LEU, UR, CAU]

T2.2 Development of evaluation criteria [LEU, UR, CAU]

T2.3 Model analysis and policy recommendations for normal risks [LEU]

T2.4 Model analysis and policy recommendations for catastrophic risks [LEU]

WP3. Instruments and international agreements (lead: UR)

T3.1 Model development and theoretical analysis [LEU, UR, CAU]

T3.2 Numerical analysis [UR]

T3.3 Political feasibility [UR]

T3.4 Policy recommendations [UR]

WP4. Integration and knowledge transfer

T4.1 Kick-off meeting [LEU, UR, CAU]

T4.2 Annual internal scientific workshops [LEU, UR, CAU]

T4.3 Stakeholder-Workshop with the application partner Moslener (KfW Development Bank) [LEU, UR, CAU]

T4.4 Stakeholder-Workshop with the application partner Graichen (Federal Ministry of the Environment) [LEU, UR, CAU]

T4.5 Annual summer school on Sustainability Economics [LEU, UR, CAU]

T4.6 Development of a web-based decision-support tool [CAU]

The project ran over 42 months, from July 1, 2012 through December 31, 2015.

3. Essential project results

In this section, we summarize the essential results from our project. A more detailed description of results, and the methods through which we derived them, can be found in the technical papers from this project. Throughout this section, we give references to these technical papers. Some of them are already published (listed in Appendix A.5.1 and A.5.2), some are still in the process of publication (listed in Appendix A.5.3), or are currently being prepared for publication (listed in Appendix A.5.4). Most of the technical papers have been presented to, and discussed with, the international scientific community at conferences and workshops (listed in Appendix A.7), to control for and improve, the scientific quality.

Work package 1: Wealth distribution and valuation of costs and benefits of climate policies (lead: M. Quaas, University of Kiel)

Task 1.1 Conceptual models

We have developed a conceptual overlapping-generations model of the economics of climate change and exhaustible resources in discrete time (Quaas and Bröcker 2015). The model features (i) irreversible climate change, in line with the most recent IPCC assessment report, (ii) the use of exhaustible, non-renewable resources in production and (iii) capital dynamics similar to the DHSS model, and (iv) endogenous accumulation of knowledge capital. The overlapping generations approach makes it possible to study questions of intergenerational wealth distribution.

In addition, we have analyzed the effects of the intra-generational wealth distribution and access to renewable resources on the scope for growth and development in resource-dependent economies (Noack et al. 2015). We found that regulating access to a renewable resource may broaden the scope for development, as resource rents are created that can be used to finance the transition towards more productive and sustainable occupations. Under certain conditions, increasing intra-generational inequality can also broaden the scope for development, as then some individuals can afford the transition to non-resource-based occupations, thus alleviating the over-use of the resource.

In related work (Baumgärtner, Drupp, Meya, Munz and Quaas 2015), we have studied how the distribution of income among members of society, and income inequality in particular, affects the average willingness to pay (WTP) for public environmental goods. Our analysis is based on the model of Ebert (2003), specified with a constant-elasticity-of-substitution utility function with a private consumption good and a pure-public-good environmental good, extended by the assumption of log-normally distributed income.

We have shown that (i) average WTP for environmental goods increases with mean household income; (ii) average WTP for environmental goods decreases (increases) with income inequality, if environmental goods and manufactured goods are substitutes (complements); (iii) average WTP for environmental goods normally changes more elastically with mean household income than with income inequality, except for extreme cases.

We have quantitatively estimated and illustrated our theoretical results with empirical data concerning how WTP for (1) a cultural ecosystem service in Sweden (from Broberg 2010), (2) a provisioning ecosystem service in rural China (from Wang et al. 2011), and (3) a proxy for global ecosystem services (from the meta-study of Jacobsen and Hanley 2009) depend on their respective distributions of income. Among other results we have found that, on global average, environmental goods are systematically undervalued by up to 16 per cent, if one assumes the current grossly unequal global income distribution rather than the hypothetical case of an equal distribution.

Our results are relevant in several respects. First, when doing benefit transfer, one should correct WTP-estimates for differences in both mean household income and income inequality. Second, when giving policy recommendations aimed at both allocative efficiency and distributive justice, one may correct WTP-estimates for grossly unjust income inequality, and use inequality-adjusted WTP-estimates for efficiency (e.g. cost-benefit)-analysis.

We have furthermore studied the determinants of the social discount rate, which is the most important parameter capturing concerns for intergenerational distribution in cost-benefit analyses. In Drupp et al. (2015), we present evidence from a survey of 197 experts on the determinants of the long-term social discount rate (SDR). The survey disentangles central components of discounting: the individual parameters of the Ramsey Rule, risk-free interest rates and experts' recommended SDR. We find a mean (median) recommended SDR of 2.27% (2%). While there is considerable disagreement on point SDRs, 92% of experts are comfortable with SDRs in the interval of 1% to 3%. Our results point towards key deviations from standard policy guidance. In particular, the prominent Ramsey Rule determines the SDR for only a minority of experts. Instead, many experts recommend more comprehensive approaches to intergenerational decision-making, addressing issues such as uncertainty, limited substitutability among heterogeneous goods and alternative justice concepts.

Furthermore, we have scrutinized the issue of substitutability between ecosystem services and manufactured consumption good in the presence of a subsistence requirement in the consumption of ecosystem services in two related papers. In Baumgärtner, Drupp and Quaas (2015) we have proposed a formal description of individual preferences that captures a subsistence requirement in consumption in an otherwise standard constant-elasticity-of-substitution (CES) utility specification. We have studied how substitutability between the subsistence good (e.g. environmental services) and another good depends on the

subsistence requirement and the level of consumption of the two goods. We have found that the Hicksian elasticity of substitution is zero below the subsistence consumption level, and approaches the standard non-subsistence CES value as consumption of the subsistence good goes to infinity. Above the subsistence threshold, it strictly monotonically increases with income. Whether the two goods are market substitutes or complements depends on, besides the CES-substitutability parameter, the level of income and the subsistence requirement. In a further step, we have applied this utility specification to the analysis of sustainable resource use and have found that the presence of the subsistence requirement may jeopardize the existence of an intertemporally optimal and sustainable consumption path. Our key result that with a subsistence requirement substitutability between different consumption goods is non-constant but increases with individual income has important implications for growth, development and in particular environmental policy.

In Drupp (2015), we have examined limits to substitution between ecosystem services and manufactured goods in consumer's utility and their implications for the economic evaluation of environmental policies in a dynamic context. The paper provides a survey on current evidence regarding substitution elasticities and discusses the case for subsistence requirements in the consumption of ecosystem services. Subsequently, the paper extends the theory of dual discounting by introducing such a subsistence requirement and analyses the properties of the relative price of ecosystem services, i.e. the difference in the good-specific discount rates. It further illustrates the findings from the theoretical model using four scenarios and finds that the `relative price' of ecosystem services is non-constant and depends on the level of the consumption of ecosystem services over and above the subsistence threshold. We have found that the resulting relative price of ecosystem services is non-constant and grows without bound as their consumption declines towards the subsistence level. An application suggests that the discount rate for ecosystem services should be, at present, more than a full percentage point lower compared to the rate for manufactured goods. The effect of considering limited substitutability in governmental project appraisal can thus be substantial. Furthermore, the results have implications for sustainability policy, in particular the management of climate change, and call for safeguarding critical ecosystem services. Moreover, this paper's specification of intertemporal welfare relates to the discussion on the intensely debated notions of `planetary boundaries' in general (Rockström et al. 2009) and `catastrophic' climate change more specifically (Millner 2013, Weitzman 2009). In our setting, `catastrophic' climate change would be conceptualized as the loss of ecosystem services required for subsistence, such as an adequate food supply, fresh water, and life-enabling ecosystem conditions. This certainly does not imply that a focus on fat-tailed probability distributions of climate damages is superfluous, indeed these `dismal' results would be even more `dismal' if catastrophe occurs already at a strictly

positive consumption level, but that more effort should be channeled into discussing the substance of the notion of `catastrophe'.

Task 1.2 Deterministic global model

The amount of carbon that eventually reaches the atmosphere is determined by the available stock of carbon resources like oil, coal and gas in the earth. Furthermore, with climate policy, the owners of these stocks lose part of their wealth. Thus, they anticipate announced climate policy and extract more of the resource to sell it at a lower price compare to no climate policy. This pushes current emissions up, possibly accelerating global warming.

In Riekhof and Bröcker (2014), we have developed a deterministic global model with economic and climate interactions that takes both aspects, resource availability as well as optimizing resource owners, into account. The climate module is close to the DICE model, while the economic part explicitly models resource extraction in a forward-looking manner. Results show that increasing the carbon stock in the earth by the factor 10 also increases the welfare effect of optimal climate policy compared to no policy by a factor of 10. With respect to announced climate policy, an announced and lagged implemented policy still increases overall welfare if the time between announcing the policy and implementing it is less than 66 years (for a carbon stock in the earth of 3000 GtC).

In a companion paper (Bröcker and Riekhof 2015), we have shown that allowing for a backstop technology – a technology that allows to produce output without using the polluting and exhaustible resource – increases the time that can elapse between the announcement and the implementation of climate policy to still obtain an overall positive welfare effect of climate policy.

Furthermore, Martin Hänsel, a PhD student supervised by Martin Quaas, has implemented a version of the DICE model in AMPL as part of his master thesis. The main task of the master thesis has been to study the effects of changing the objective function from the intertemporal discounted utility function of a representative infinitely lived agent to explicitly modeling the intertemporal distribution of consumption. Specifically, we have studied the maximin criterion and a generalization of maximin that maximizes the constant growth rate of consumption. Results indicate that the social costs of carbon are, compared to the version with Nordhaus' objective function, much lower under the maximin criterion, and much higher for the maximum growth rate specification. This manuscript has been further developed into a publishable manuscript (Hänsel and Quaas 2015). It uses a deterministic global integrated assessment model to show that the social cost of carbon, i.e. the societal cost of emitting an extra ton of CO_2 emissions, is very sensitive to the societal goal with respect to the intertemporal distribution of wealth.

Different studies arrive at remarkably different estimates for the social cost of carbon ranging from 30 US$ per ton of carbon (Nordhaus 2010) to 250 US$ per ton of carbon (Stern 2006). The main reason for these differences are different assumptions about how societal wealth should be intertemporally distributed. These assumptions are typically embodied in a specific parametrization of an intertemporal social welfare function (SWF) used for the evaluation of climate policies (Botzen and van den Bergh 2014). In other studies we could show that these assumptions are quite controversial (Drupp et al. 2015) and have a critical influence on the social cost of carbon (Quaas and Bröcker 2015). Hence, in Hänsel and Quaas (2015) we propose to shift the focus and directly assume a parametric form for the intertemporal distribution of wealth rather than studying the parametrization of a particular SWF. We use the deterministic modeling structure of the latest version of the well-known DICE Integrated Assessment Model (Nordhaus and Sztorc 2013) in order to use dynamic optimization methods to study how the intertemporal distribution of growth affects patters of investment in man-made capital, as well as carbon emissions into the atmosphere. By varying the time horizon until which the global economy is growing, we show how the desire for growth as well as the concerns for intergenerational distributive justice affect the social cost of carbon.

We have found that a more evenly intertemporally distributed growth rate of wealth more than strongly raises the social cost of carbon and increases the consumption sacrifice for early generations. While for 150 years of positive but linearly decreasing growth of wealth per capita the social cost of carbon in 2015 is US$ 10.63, it convexly increases to US$ 140.44 for 300 years (all in 2005 prices). We conclude that normative conceptions of intergenerational distributive justice crucially determine the social cost of carbon. Therefore specifying the societal goal with respect to the intertemporal distribution of wealth should be the starting point of any climate change related cost-benefit analysis.

Task 1.3 Stochastic global model

The model by Quaas and Bröcker (2015) has been extended to also include stochastic effects. Also the stochastic version is solvable in closed form, which allows to study the effects of risk on the intergenerational distribution. An increasing risk leads to a more equal distribution of wealth over time, if the elasticity of intertemporal substitution is small.

Furthermore, the models of Baumgärtner et al. (2015) and Drupp (2015) show that the effect of uncertainty and in particular `catastrophic' climate change (Millner 2013, Weitzman 2009) is even more severe than suggested previously. In our setting, `catastrophic' climate change would be conceptualized as the loss of ecosystem services required for subsistence, such as an adequate food supply, fresh water, and life-enabling ecosystem conditions. This certainly does not imply that a focus on fat-tailed probability distributions of climate damages

is superfluous, but that more effort should be channeled into discussing the fundamental substance of the notion of `catastrophe'.

Task 1.4 Regionalized model

The literature on regionalized integrated assessment modeling of climate change and the economy is moving far beyond the RICE model that we set out to use for our analysis. Recent advances include Dennig et al. (2015) and Krusell and Smith (2015). We constructed a regionalized version of the conceptual model (Quaas and Bröcker 2015). Yet, given the recent advances in the applied literature, we did not fully develop this model to a publishable state.

Work package 2: Risk externalities, external moral hazard and insurance (lead: S. Baumgärtner, Leuphana University of Lüneburg)

Survey of the literature on catastrophic risk and on risk externalities

Events occurring in the environment at low probabilities but with high impacts (`catastrophes') are becoming more prevalent globally and threaten human and nature. Also, catastrophes receive increasing attention in the risk-and-insurance economics literature and in the environmental-and-resource economics literature.

We have carried out a survey of the literature on catastrophic risk to explore the type of risk emerging from catastrophic events, and how to conceptualize and model catastrophic events, in order to provide guidance for future research (Fianu and Baumgärtner, 2015a). The survey therefore develops a broad concept of catastrophic risk: the basic economic concept for understanding the causes and effects of natural and artificial disasters.

For this survey, we have exploited various theoretical underpinnings in relation to the concept of catastrophic risk. In particular, we have investigated and highlighted the implications of a new risk structure in management models that endogenously accommodate the occurrence of a catastrophe. The relationship between catastrophic risk and insurance has also been reviewed, in particular, the role of insurance as a policy instrument for effective risk transfer. Only a few empirical studies on catastrophic events as well as catastrophic risk have been surveyed mostly due to lack of data.

The area of risk and insurance is one particular area where externalities emerge. We have therefore also carried out a brief review of the literature on risk externalities (Fianu and Baumgärtner, 2015b). We have identified some of the features that characterize these types of externalities and their detrimental impacts, which contribute to climate change. In addition, the different valuation methods for these externalities have been explored.

Risk, externalities, and insurance in international climate policy

We have studied how risk, risk aversion, and financial insurance interact in a coupled economy-environment system, in which two countries utilize a local resource fossil fuel to produce GDP and emit greenhouse gases as a by-product, thereby causing and being affected by risky climate change (Baumgärtner and Fianu 2016). This model setting captures the essential features that are relevant for the practice of risk transfer when externalities are prevalent, and for policy recommendations aimed at both the efficient and equitable allocation of resources, consumption, and risk-taking. We have employed a random-damage model with a mean-standard-deviation utility function to analyze the implications for individually and socially optimal allocations. Our findings demonstrate that the availability of financial insurance in one or both countries gives rise to risk externalities and external moral hazard. Introducing risk-adjusted country-specific Pigouvian taxes on emissions in both countries may remove the inefficiencies and therefore limit climate change.

In terms of policy implications, our results are relevant in several respects. (i) The levels of resource use, consumption, and emissions are influenced, amongst others, by the extent of damage risk, the degree of risk aversion, and the costs of insurance. Hence, ignoring the risk-and-risk-management dimension, and only studying the expected mean effects of climate change, misses an important part of the overall picture. (ii) The inefficiency present in the economy may be resolved through the introduction of risk-adjusted country-specific Pigouvian taxes on emissions in both countries. That is, the conventional policy instrument for regulating harmful emissions still works in principle, also when taking into account the risk-and-risk-management dimension; but the tax rate needs to be adjusted for risk and insurance effects. (iii) The redistribution of wealth between countries in the absence of optimal regulations may increase or decrease the extent of inefficiency, depending on the resource-productivity of countries and their ability to purchase insurance. All taken together, this analysis has shown that risk aversion and insurance are essential for the understanding and implementation of efficient and equitable climate policy when the damaging effects of climate change are uncertain.

Willingness to pay for environmental goods under uncertainty

Loss of public environmental goods, such as e.g. climate stability but also many ecosystem services, is one of the biggest threats to human well-being emanating from climate change. It is imperative to understand the effect of such losses on social welfare, taking into account that the quantity available of such goods is often uncertain to the individual user as well as to society at large.

We have therefore developed a microeconomic approach for valuing the benefits from a public environmental good under uncertainty (Baumgärtner, Chen and Hussain 2016). Most

public environmental goods are non-market-traded, and benefits from such goods are typically enjoyed under conditions of uncertainty. Uncertainty can arise on the environmental side (e.g. the provision of environmental good is uncertain), or from the economics side (e.g. income or prices are uncertain). In our analysis, we have considered (binary) uncertainty in (i) consumer's income and (ii) the provision of an environmental good, as well as insurance against income uncertainty We have used a constant-elasticity-of-substitution (CES) utility function, where utility depends on a market-traded consumption good and an environmental good, which is exogenously provided in a fixed quantity. The CES function is nested in a constant-relative-risk-aversion form. As a benefit measure, we have employed the marginal willingness to pay (WTP) for changes in (i) the probability of loss, (ii) the size of potential loss, and (iii) the current level of the environmental good.

As a benchmark under certainty, we have recovered the well-known result that the marginal WTP for the environmental good is increasing in income and decreasing in the amount of the environmental good. Furthermore, the income elasticity of marginal WTP is constant and given simply by the inverse elasticity of substitution between the two goods, which may be greater or smaller than one.

When environmental-good provision is uncertain, our results show that the marginal WTP for the amount of the environmental good is increasing in income and decreasing in the amount of the environmental good – just like under certainty. It is also increasing in the degree of risk aversion, the probability of loss and the size of the potential loss. We also find that the income elasticity of marginal WTP is non-constant in income, and the environmental-good's-amount elasticity of marginal WTP is non-constant in the amount of the environmental good. Both elasticities depend, amongst thers, on the degree of risk aversion, the probability of loss, and the size of the potential loss.

The estimation, relative magnitude and (non-)constancy of the income elasticity of WTP for environmental goods is of high importance for benefit transfer and for the design of equitable environmental and climate policies. They are, therefore, a topic of intense current research (e.g. Barbier et al. 2015, Ebert 2003, Flores and Carson 1997, Hökby and Söderqvist 2003). Our analysis is the first one that shows that the income elasticity of WTP for environmental goods is essentially also determined by environmental uncertainty and the degree of risk-aversion of the users of environmental goods. In particular, risk and risk-aversion may be one reason for the non-constancy of the income elasticity of WTP for environmental goods.

Estimating the insurance premium in interlinked credit-output contracts

Climate change may especially affect poor households that depend on the environment for an income. Formal insurance is often not available for these households, but informal arrangements close the gap. Studying their set-up can help in designing policy interventions.

In Riekhof (2014), the insurance property of informal credit-fish contracts are considered. Instead of fixed interest payments, interest payments depend on income flows. They are lower (higher) when incomes are lower (higher). The implicit interest rates from these contracts contain an insurance premium that increases with the variability in fishing income.

Work package 3: Instruments and international agreements (lead: W. Buchholz, University of Regensburg)

Task 3.1 Model development and theoretical analysis

We have developed a theoretical model on technology transfers and their impact on global public good provision in terms of abatement efforts (Buchholz, Dippl and Eichenseer 2015). In this paper, we show that leading behavior by a coalition of countries, which is based on green technological innovations by members of the coalition and a subsequent costless transfer of the improved technology to other countries, may provide a sensible approach for combatting global warming through unilateral action. In particular, we have examined in an otherwise standard model of private public good supply how the effects of such a policy on total greenhouse gas mitigation and welfare of countries depend on the level of R&D-costs, the intensity and scope of technological spillovers, the size of the technological coalition and the number of countries outside the coalition. In particular, we have shown that such technological transfers, which can be considered as an instrument of “climate finance” in a broader sense, may be required to induce R&D-activities and thus formation of a technological coalition in the strategic context of global public good provision.

Another central topic of our work package was the distribution of the costs of producing the global public good “climate protection” among the countries. On the one hand, there are normative criteria for an equitable distribution in a cooperative setting, which have also implications for the stability of agreements. On the other hand, an even more fundamental question of interest is how patterns of burden sharing in the non-cooperative Nash solution. A very famous result in this context is the “exploitation of the rich by the poor” hypothesis which has been formulated in a seminal work by Olson (1965) and is also of relevance in this context of climate change. The basic idea is that voluntary provision of a public good works as a mechanism of an indirect redistribution from rich to poor (see, e.g., Sandler 2015). We have generalized this result showing in particular that also the countries which have a higher preference for the public good or are more productive in producing the public good automatically will contribute more to the public good in the non-cooperative solution and, in addition, how the different partial effects can balance each other (Buchholz and Sandler 2015b).

Concerning the effects of distribution on the resulting allocation a focal issue in the theory of public goods in general and climate protection in particular is, which welfare effects international redistribution measures, i.e. transfers between countries, can bring about. When public goods are provided through voluntary contributions, a country may introduce unilateral matching in order to reduce underprovision of the global public good and thus the inefficiency of the allocation. We have confirmed that, under fairly general conditions, mere unilateral matching, while increasing the donor country's welfare, reduces the recipient country's welfare so that unilateral matching is not incentive compatible (Buchholz, Cornes, Peters and Rübbelke 2015). This paradoxical situation, however, may be overcome through a self-commitment strategy of the donor country, which means that the donor country definitely binds itself to not under-cutting its public good contribution in the original Nash equilibrium. Then, a Pareto improvement can be achieved through unilateral matching, and no conflict arises between the donor and the recipient country.

In a cooperative setting, we have explored the relationship between an equitable distribution of the cost shares in global public good provision and the core property of Pareto-optimal allocations (Buchholz, Haupt and Peters 2014). Core allocations do not only fulfill an important stability condition, but are also the only promising candidates for efficient public good allocations that are acceptable to all parties in a negotiation process. In particular, the analysis has shown that it is an unequal distribution of costs that motivates a coalition of countries to separate and to block (or not accept) an initially given Pareto-optimal allocation. In our approach, distributional equity is assessed by a specific sacrifice measure for country-specific public good contributions, the "Moulin Sacrifice", which is derived from the egalitarian-equivalent concept suggested by Moulin (1987). In particular, we have shown that a Pareto-optimal allocation outside the core will be rejected by that group of countries, which have the highest Moulin sacrifices, which gives a novel equity-based interpretation of the core property. A balanced (and thus fair) distribution of Moulin sacrifices among the countries is not only necessary, but also sufficient for core stability of a Pareto optimal allocation. From this perspective, a grand coalition can be sustained if and only if the members are treated equally according to their Moulin sacrifice.

This result provides some specific guidelines for the design of an agreement that aims at full cooperation and a Pareto-optimal allocation. For instance, everything else equal, a richer country should contribute more to the public good than a poorer country, reflecting the ability-to-pay principle. Also, a country with weak preferences for the public good might only need to bear a small share of the costs of public good provision, possibly even if it is quite rich. This reflects the benefit principle. From the perspective of our paper the negligence of this criterion, which is deeply rooted in Public Economics, can be seen as an important source of

the failure of climate negotiations and the instability of international cooperation in climate polic

Also in the framework of a model with conditional transfers, we have addressed the problems of partial cooperation (Buchholz, Rübbelke and Cornes 2014). We have considered a scenario where only members of a subgroup of countries cooperate by reciprocally matching their public good contributions. In a two-stage game, matching rates are set at stage 1 then national contributions are chosen at stage 2. In the case of small coalitions, negative matching may result in the subgame-perfect equilibrium that decreases global public good provision and outsiders' welfare. Moreover, a growing number of partially cooperating countries may entail a decline of equilibrium public good supply, which provides an additional paradoxical effect in the context of conditional transfers.

Apart from distributional features in the narrow sense, we have analyzed a country's leading behavior in global public good provision, which is not successful in the standard model of voluntary public good provision (Buchholz and Sandler 2015a): In this model, a unilateral increase of this country's greenhouse gas abatement measures, i.e., contributions to the global public good of climate protection, will not lead to a positive reaction by the other countries but instead trigger a reduction of their abatement efforts and thus a crowding-out effect. In this paper we have shown how this undesired consequence need no longer occur when elements of behavioral economics are incorporated in the otherwise standard model of public good pro vision. In particular, strategic complementarities between the public good contribution of the leading country and those of the follower may result either if the follower has specific non-egoistic or other-regarding preferences or if the leader's contribution positively affect the follower's beliefs, i.e., his conjectural variations, about the leader's behavior.

Task 3.2 Numerical analysis

Providing an empirical application of one of our theoretical results (Buchholz, Dippl and Eichenseer 2015), we have calculated the size of technology transfers arising from the German energy policy in the context of the EEG in particular showing that these expenses not only are of a sizeable amount but also had a significant impact on the price of solar power plants and thus on the costs of greenhouse gas mitigation all over the world (Buchholz, Dippl and Eichenseer 2016). Thus, the German EEG can be seen as a quite successful part of leadership behavior in global climate policy.

Concerning further empirical applications the decision-making process in climate negotiations was another point of interest. As the decision concerning a single country's public good contributions is generally made by a group of delegated representatives, we have conducted an experiment in order to shed light on team behavior. For this purpose, we

have chosen a public good game setting with ostracism. We have found that the ostracism mechanism works in increasing the contribution to the public good not only of individuals but also teams. Moreover, we have found teams earning significantly more than individuals due to a difference in using the punishment mechanism (Huber, Model and Städter 2014). This experimental study provides additional evidence that the fear of becoming an outsider provides an effective incentive for cooperation on global public supply.

Task 3.3 Political feasibility

Since there is no established supranational organization yet that can enforce cooperation in climate protection, our main focus was on transfers between countries. These are known to be politically feasible and thus can very well be implemented uni- or bilaterally. We have developed a categorization of transfers and have evaluated their effectiveness in achieving increased mitigation. We have paid special attention to donor countries' motivation in providing financial or in-kind aid especially when it comes to adaptation transfers (Buchholz, Dippl and Eichenseer, in prep.).

Task 3.4 Policy recommendations

The demand for transfers from industrialized countries to developing and threshold countries has played an important role during the crucial COP21 conference in Paris which has produced the follow-up agreement for the Kyoto Protocol. Our results so far cast doubts on the significance of financial transfers for a successful climate policy. The theoretical analysis from a public-good-model shows that technology transfers are certainly important. In order to achieve an equitable burden sharing, preliminary contributions made by industrialized countries in terms of investment in green technologies have to be acknowledged as well. If additional demands for unconditional monetary transfers are made this creates a dual burden and might weaken public support for an ambitious climate policy in developed countries. We have quantifed the investments into green technology made by Germany in the context of the EEG (Buchholz, Dippl and Eichenseer 2016).

Work package 4: Integration and knowledge transfer (lead: S. Baumgärtner, Leuphana University of Lüneburg)

Task 4.1 Kick-off meeting [LEU]

Wegen der Verzögerung bei der Besetzung der Wissenschaftlichen-Mitarbeiter-Stellen in allen drei Arbeitspaketen haben wir das Kick-Off-Meeting erst im Jahr 2013 durchgeführt, als alle Stellen besetzt waren und das Team vollständig war. Das Kick-Off-Meeting fand vom 20. bis 22. August 2013 in Lüneburg statt (Programm: Anlage 34).

Task 4.2 Annual internal scientific workshops [LEU]

Da das Kick-Off-Meeting mit dem kompletten Projektteam im August 2013 stattfand (vgl. Task 4.1), haben wir darüber hinaus im Jahr 2013 kein zusätzliches Projekttreffen mit dem kompletten Projektteam veranstaltet. Es gab aber zwei kleinere Forschungsworkshops zu spezialisierten Themen, an denen jeweils nur ein Teil des Projektteams teilnahm (vgl. Anhang A.3 für Details).

Zur Koordinierung, internen Evaluation und Steuerung der Forschungsaktivitäten des Projekts haben wir am 7. August 2014 in Camp Reinsehlen einen Projektworkshop abgehalten. Auf diesem Workshop wurde (a) der Stand der Forschungsarbeiten der einzelnen Mitglieder präsentiert, (b) Ansätze, Ergebnisse und offene Fragen diskutiert, (c) geplante Publikationen besprochen sowie (d) das weitere Vorgehen abgestimmt (Programm: Anlage 35).

Task 4.3 Stakeholder-Workshop with the application partner Moslener (KfW Development Bank) [LEU]

Da unser vorgesehener Projektpartner Dr. Ulf Moslener leider schon zu Beginn unseres Projekts den Arbeitgeber gewechselt hat und während der Projektlaufzeit daher nicht länger für die KfW Entwicklungsbank tätig war, konnten wir leider keinen Stakeholder-Workshop durchführen.

Task 4.4 Stakeholder-Workshop with the application partner Graichen (Federal Ministry of the Environment) [UR]

Da unser vorgesehener Projektpartner Dr. Patrick Graichen leider schon zu Beginn unseres Projekts den Arbeitgeber gewechselt hat und während der Projektlaufzeit daher nicht länger für das Bundesumweltministerium tätig war, konnten wir leider keinen Stakeholder-Workshop durchführen.

Task 4.5 Annual summer school on Sustainability Economics [LEU]

Während der Projektlaufzeit veranstalteten wir zwei international Sommerschulen zu Sustainability Economics, die sich an Promovierende und junge PostDocs richteten – 2014 und 2015. Beide wurden als forschungsorientierter Workshop durchgeführt.

International Summer School on Sustainability Economics 2014: Intergenerational Equity and Efficiency under Uncertainty

Vom 4. bis zum 7. August 2014 veranstalteten wir im Tagungszentrum Camp Reinsehlen, Schnevedingen, die *International Summer School on Sustainability Economics: Intergenerational Equity and Efficiency under Uncertainty*. Die Summer School richtete sich an Jungforscher und thematisierte die für die Klima- und Nachhaltigkeitspolitik elementare Frage, wie intergenerationelle Gerechtigkeit und Effizienz unter Bedingungen von Unsicherheit kombiniert verstanden und in ökonomischen Analysen behandelt werden können.

Um dem Anspruch der forschungsorientierten Ausbildung gerecht zu werden, fand die Summer School nicht im traditionellen Vorlesungsformat sondern als Workshop statt. Der Workshop brachte zehn ausgewiesene internationale Experten und acht Nachwuchsforscher (Doktoranden und PostDocs) zusammen. Durch dieses kleine und fokussierte Format ermöglichte er einen intensiven, interaktiven Austausch an der internationalen Front der Forschung über dieses neue Forschungsfeld. Die ausgewiesenen Experten waren:

Geir Asheim	University of Oslo, Norway
Stefan Baumgärtner	Leuphana University of Lüneburg, Germany
Johannes Bröcker	University of Kiel, Germany
Wolfgang Buchholz	University of Regensburg, Germany
Maik Heinemann	University of Potsdam, Germany
Vincent Martinet	French National Institute for Agricultural Research, France
Antony Millner	London School of Economics, UK
Paolo G. Piacquadio	University of Oslo, Norway
Martin F. Quaas	University of Kiel, Germany
Stéphane Zuber	Paris School of Economics; CNRS, France

Das detaillierte Programm der Summer School, die Abstracts der Beiträge und die vollständige Teilnehmerliste finden sich in den Anlagen 28, 29 und 30.

Thematic Background:

Policies addressing climate change should be both equitable and efficient, taking into account the substantial uncertainties in the natural and economic dynamics. The vision of sustainability requires that development paths must be equitable across and within generations, while man-made and natural resources should be allocated such that none are wasted in the pursuit of increasing well-being.

Although issues of inter- and intragenerational equity and allocative efficiency are analytically independent and have hitherto predominantly been addressed as such, how one goal is addressed has repercussions on how to deal with the other one in the design of concrete policies. On a more fundamental level, how equity and efficiency under conditions of uncertainty can be conceptualized remains an unsettled question. An answer to this question, however, is a necessary requirement for evaluating public policies on problems of intergenerational importance, such as climate change mitigation, that are entrenched with deep uncertainties.

The summer school explored how issues of intergenerational efficiency and equity can be studied in an integrated manner in view of an inherently uncertain future. In particular, it aimed at developing a better understanding of the influence of different normatively founded specifications of societal objectives with regard to the intra- and intergenerational distribution of wealth and uncertainty on the estimated cost of climate change and the benefits of mitigating climate change. The summer school discussed in particular:

- Conceptualization of intergenerational efficiency as well as equity under uncertainty,
- Trade-offs between the different normative objectives of intra- and intergenerational equity and efficiency,
- Policy evaluation and decision-making with respect to intergenerational equity and efficiency under uncertainty

Synthesis and conclusions from the workshop:

The workshop brought together a selection of the most eminent researchers in the field in a fruitful atmosphere. All contributions from the workshop participants were of very high quality. They gave a very good impression of the current research frontier in the field *Sustainability under Uncertainty*. The workshop contributions, in comparison with contributions to previous workshops, showed the following status and trends in that field:

- In comparison to previous workshops on the issue of sustainability under uncertainty, there are now more contributions, and more thorough contributions, that address the

issues of equity and uncertainty simultaneously, as well as the link between the two. With few exceptions, both issues hardly played any role at all, or were treated only in a superficial manner, in the literature some ten years ago.

- There are now technically very skillfull contributions for detailed problems of intergenerational equity and efficiency under uncertainty. At the same time, many concepts at the basic level are still not well understood and/or are not addressed.

- With sustainability addressing “the very long-term” and “the whole”, there is a need to take deeper forms of uncertainty than just “risk” more seriously. Some approaches for this are now appearing on the horizon.

- The discussion on the influence of uncertainty, especially risk, on intergenerational equity and efficiency played a prominent role. However, most contributions use the concept of certainty equivalents to capture uncertainty. This is an obvious first step, but it treats uncertainty in an aggregate and implicit manner, and does not seem to be well-suited to deal with deeper forms of uncertainty and ignorance. It needs to be discussed whether there are alternative, information-richer approaches to taking risk and uncertainty into account.

- In the field *Sustainability under Uncertainty*, a combination of many conceptual issues are relevant (e.g. equity, efficiency, uncertainty, time, person/generation, ought/is- or fact/value-distinction, to name just a few), so that addressing conceptual issues is much more pertinent to this field than to most other subfields of economics or ethics. This leads to a desire for a more general and fundamental discussion at the conceptual level that may include philosophers.

- It seems that the workshops on sustainability economics, held since 2004, with the current workshop being the fifth in this series, have a noticeable impact on shaping this field. There is now a community of people who share a research interest in this field, who have a similar idea of “sustainability”, and who have the workshop series as one of their intellectual references. Insisting on issues of equity and uncertainty in the topics and agenda of the workshops, rather than being content with mere efficiency and deterministic dynamics, has actually initiated research on these issues.

- As the workshops over the years have had an impact on the whole research field by stimulating mainstream research, this impact could be made more visible and fruitful by writing a survey paper on the topic of “conceptualizing sustainability under uncertainty” to structure already proposed ideas and concepts as well as to identify

open questions more precisely. Potential co-authors include keynote speakers from the workshops and, at a later stage, potentially other scholars as well.

International Summer School on Sustainability Economics 2014: Experiments on Intergenerational Justice under Uncertainty

Vom 11. bis zum 14. Oktober 2015 veranstalteten wir im Tagungszentrum Camp Reinsehlen, Schneverdingen, die *International Summer School on Sustainability Economics: Experiments on Intergenerational Justice under Uncertainty*. Die Summer School richtete sich an Jungforscher und thematisierte die für die Klima- und Nachhaltigkeitspolitik wichtige Frage, ob und wie über intergenerationelle Gerechtigkeit unter Bedingungen von Unsicherheit durch Labor- und Feldexperimente lernen können.

Um dem Anspruch der forschungsorientierten Ausbildung gerecht zu werden, fand die Summer School nicht im traditionellen Vorlesungsformat sondern als Workshop statt. Der Workshop brachte acht ausgewiesene internationale Experten und sechs Nachwuchsforscher (Doktoranden, PostDocs, JuniorProfs) zusammen. Durch dieses kleine und fokussierte Format ermöglichte er einen intensiven, interaktiven Austausch an der internationalen Front der Forschung über dieses neue Forschungsfeld. Die ausgewiesenen Experten waren:

Stefan Baumgärtner	Leuphana University of Lüneburg, Germany
Astrid Dannenberg	University of Kassel
Anke Gerber	University of Hamburg
Martin F. Quaas	University of Kiel, Germany
Arno Riedl	Maastricht University
Daan van Soest	Tilburg University
Sabrina Teyssier	INRA Versailles
Kimberly Wade-Benzoni	Duke University

Das detaillierte Programm der Summer School, die Abstracts der Beiträge und die vollständige Teilnehmerliste finden sich in den Anlagen 31, 32 und 33.

Thematic Background:

The vision of sustainability requires that development paths be equitable across and within generations, while human-made and natural resources be allocated such that none are wasted in the pursuit of increasing human well-being. Sustainability is thus essentially a normative concept. It requires taking into consideration the claims of future, not yet existing persons – also addressing trade-offs between inter- and intragenerational justice goals. Investigating the long-term future necessarily implies dealing with fundamental uncertainty, be-

cause uncertainty and uncertainty-attitudes affect how societies distribute resources to insure against such uncertainties.

Behavioral economics and experimental methods (in the lab and in the field) have substantially altered the way economists perceive the world and how they derive policy recommendations. For the emerging field of *sustainability economics* the question thus arises in what way one can and should employ experimental approaches to generate insights into a just and efficient intergenerational distribution of resources under conditions of uncertainty.

Aims and Scope of the Workshop

The workshop aimed at developing a better understanding of how and to what extent experiments can contribute to advancing the economics and policy of sustainability. For this, we took stock of existing scholarly work at the intersection of sustainability and experimental economics. Furthermore, we discussed and identified promising elements of a research agenda for experimental sustainability economics. Questions discussed at the workshop include, but were not limited to, the following:

- How to set up experiments that generate insights into intergenerational relations and very long time horizons?
- How to set up experiments studying fundamental uncertainty?
- To what extent and how can one employ experimental observations on individual or collective behavior to improve theories of sustainability, especially with respect to the normative content of sustainability conceptions?
- What is the contribution of experimental methods for sustainability economic research, compared to modelling, non-experimental empirics, and philosophical-conceptual reflection?
- On what theoretical basis and assumptions do experiments have to rest if their results should be instructive for sustainability policy?

Synthesis and conclusions from the workshop

From the discussions at the workshop, it emerged that *Experimental Sustainability Economics* is a very promising, newly emerging research field, with roots in many, often unrelated existing research strands within environmental and resource economics, ecological economics, behavioral economics. public economics and welfare economics. To bring together the various relevant roots and sources, and to systematically relate them to

Experimental Sustainability Economics, some of the workshop participants committed to jointly write a foundational survey article on this topic .

The aim of this survey is to take stock of existing scholarly work at the intersection of sustainability and experimental economics. It shall identify to what extent experimental studies enhance the scientific understanding and better management of sustainability. It should also show where the application of experimental methods faces fundamental challenges and limits due to the inherent nature of sustainability as a concept.

Task 4.6 Development of a web-based decision-support tool [CAU]

We intended to use the model by Hänsel and Quaas (2015) with a dynamic interface that allows the user to study how alternative intertemporal distributions of well-being change the social cost of carbon. The plan was to hire a professional company (the offer was included in the application) to set up the web interface and the web hosting. We had several discussions with the company how a communication between the model and the web interface could work. This turned out to be a major obstacle for the development of the web-based decision support tool. In the last months of the project it became clear that we were not able to find a solution to this problem in cooperation with the company. This was too late to find another professional partner for this project. Thus, we were not successful in Task 4.6. However, there were no costs for this task.

4. Exploitation of results

In our project proposal, we had envisaged that we would produce useful outputs for the scientific community and the political community, but not for the business sector.

Scientific community

We had proposed to produce the following outputs of relevance for the scientific community:

(1) to produce at least 12 manuscripts for international peer-reviewed publication and at least 36 contributions to international conferences and workshops with peer-review selection,

(2) to establish a distributed junior researcher group around three PostDocs. Each of the partners will employ one young PostDoc at a stage shortly after finishing the PhD and guide and support them in preparing their own grant proposals and setting up their own independent junior research group within the field of climate economics,

(3) to hold an annual international summer school on Sustainability Economics targeting graduate students in economics.

The actual realization of these proposed outputs is as follows:

(ad 1) We have already published 7 manuscripts in high-ranking international peer-reviewed journals (Appendix A5.1 and A5.2), 8 manuscripts are in the process of publication (Appendix A5.3), and 12 manuscripts are currently being prepared for publication (Appendix A5.4). Furthermore, we have given 50 presentations on project results at international conferences, workshops and colloquia (Appendix A5.5). Hence, the publication output from this project is excellent and much better than proposed.

(ad 2) Employing and developing young PostDocs, and establishing a network among them, turned out to be very difficult and, in the end, did not succeed. All three partners in our project encountered major difficulties with this objective, mainly because there were no suitable candidates available on the job market at the time when the project started. As a consequence of many fluctuations with the junior researcher positions, no stable network emerged.

At the University of Lüneburg, after some delay, we could hire Dr. Wenting Chen, who left the project already after five months to accept another position. We then hired, again after some delay, Dr. Emmanuel Fianu, who worked in the project for two and a half years.

At the University of Regensburg, we hired Christina Dietl as a PhD candidate. She was involved in the project from 09/2012 to 09/2013 and left to accept another position. After that Lisa Dippl and Michael Eichenseer worked for the project as PhD candidates, and then changed to regular positions in our department

At the University of Kiel, Mrs. Dr. Marie-Catherine Riekhof worked in the project for one year (April 2014 to March 2015), but then left the group to take a postdoc position at the ETH Zurich. We supported this decision, as it was a very natural and useful next step in her scientific career.

(ad 3) We held two annual international summer schools on Sustainability Economics targeting junior researchers (PhD students and young PostDocs), in 2014 and 2015. Both were a big success and served to transfer research from our project into PhD and PostDoc projects at an international scale. The format of the summer school – as a research-oriented workshop focused on a clearly defined specialized topic, bringing together a small number of juniors and established senior researchers in a one-to-one ratio in an intense workshop atmosphere – was enormously successful and can serve as a model for future events.

Policy community

We had proposed that each of the three substantial work-packages in the project would produce one major result of relevance for the policy community:

(4) as a result of WP 1, to provide a decision-support tool that enables decision makers to quantify how the intra- and intergenerational distribution of wealth affects benefits and costs of climate policies,
(5) as a result of WP 2, to transfer concrete recommendations for finance and insurance products to our application partner, KfW Development Bank, who acts worldwide on behalf of the German Federal Government in order to implement climate change mitigation and adaptation,
(6) as a result of WP 3, to transfer concrete recommendations for national and international climate policy instruments as well as for international negotiations to our application partner, the German Federal Ministry of the Environment.

The actual realization of these proposed outputs is as follows:

While we do have produced policy-relevant insights and recommendations in all three work packages, the proposed particular mode of transfer did not work in any of the work packages (see description of Tasks 4.3, 4.4 and 4.6 above): for WP1 the software company in charge of the technical implementation did not come up with a workable solution in time; for WP 2 and WP 3 the transfer was nor possible because our practice partners in these WPs left their employer – the KfW Development Bank and the German Federal Ministry of the Environment, respectively – and therefore could not serve as liaison any more.

But we did transfer our policy-relevant results to the policy community through the coordinated transfer process which was one accompanying action ("Begleitaktivität") of the funding initiative *Economics of Climate Change*. We took part in the meetings and contributed to the policy briefs on *Thematic Focus A: Costs of Climate Change, Climate Protection, and Adaptation to Climate Change* as well as on *Thematic Focus C: International Climate Negotiations and Regimes*.

References to other authors' and our own previous works

(References to our own works from this project are listed in Appendix A.5 below)

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Weitzman, M.L. (2009), On modeling and interpreting the economics of catastrophic climate change, *Review of Economics and Statistics* 91: 1–19.

Anhang: Tabellenteil

A1. Beteiligte Forschende und Studierende

1. Projektleitung

Name	*Zeitraum*	*Institution*	*Finanzierung*
Prof. Dr. Stefan Baumgärtner	07/2012 – 12/2015	LEU	Eigenmittel LEU
Prof. Dr. Wolfgang Buchholz	07/2012 – 12/2015	UR	Eigenmittel UR
Prof. Dr. Martin Quaas	07/2012 – 12/2015	CAU	Eigenmittel CAU

2. Wissenschaftliche Mitarbeit

Name	*Zeitraum*	*Institution*	*Finanzierung*
Dr. Wenting Chen	12/2012 – 04/2013	LEU	Projektmittel: TVL-13
Dr. Emmanuel S. Fianu	07/2013 – 12/2015	LEU	Projektmittel: TVL-13
Frederik Noack	09/2012 – 12/2013	CAU	Projektmittel: TVL-13
Moritz A. Drupp, M.Sc.	10/2013 – 12/2015	CAU	Projektmittel: TVL-13
Dr. Marie-Catherine Riekhof	04/2014 – 03/2015	CAU	Projektmittel: TVL-14
Lisa Dippl, M.Sc.	07/2014 – 09/2014 12/2014 - 09/2015	UR	Projektmittel:TVL-13
Dr. Jochen Model	01/2014 – 03/2015	UR	Eigenmittel UR
Dipl. Math. Kristina Dietl	09/2012 – 09/2013	UR	Projektmittel: TVL-13
Michael Eichenseer, M.Sc.	07/2014 – 09/2014 12/2014 – 06/2015	UR	Projektmittel:TVL-13
Lino Wehrheim, M.Sc.	08/2015 – 03/2016	UR	Projektmittel: TVL-13

3. Hilfskräfte und Studierende

Name	*Zeitraum (in Monaten)*	*Funktion*
Moritz Meyer	10/2012 – 02/2014 07/2013 – 09/2013, 01/2014 – 12/2014	Masterthesis LEU Hilfskraft LEU

Klaus Reiche	10/2012 – 04/2014	Masterthesis LEU
Martin Hänsel	09/2013 – 03/2014	Masterthesis CAU
Felix John	05/2013 – 06/2013	Hilfskraft LEU
Anna-Magdalena Biehler	07/2013	Hilfskraft LEU
Klara Stumpf	11/2013 – 12/2013	Hilfskraft LEU
Lewe Bahnsen	12/2012 – 03/2014	Hilfskraft CAU

Erläuterungen: LEU – Leuphana Universität Lüneburg, UR – Universität Regensburg, CAU – Carl-Albrechts-Universität zu Kiel

A2. Forschungsaufenthalte am jeweils anderen Institut und Forschungstreffen mit wissenschaftlichen Kooperationspartnern

Im Projektzeitraum gab es folgende internen wissenschaftliche Kooperationstreffen zur intensiven gemeinsamen Forschung sowie Forschungstreffen mit externen wissenschaftlichen Kooperationspartnern:

07.-08.10.2013 Forschungstreffen von M. Drupp mit Ben Groom (London School of Economics) und Mark Freeman (Loughborough University) an der London School of Economics zum Thema „Efficient and Just Intertemporal Decision-Making: Discounting under disagreement and uncertainty using expert advice“.

20.11.2013 Forschungsaufenthalt von S. Baumgärtner bei M.F. Quaas und M. Drupp in Kiel (Themen: Subsistence and substitutability in consumer preferences)

19.-22.05.2014 Forschungsaufenthalt von M.A. Drupp bei B. Groom an der LSE in London (Thema: Discounting Disentangled: An expert survey on the determinants of the long-term social discount rate)

31.8.-3.9.2014 Forschungsaufenhalt von M.-C. Riekhof bei Salvatore di Falco an der Univerversität Genf (Thema: Climate Change and Natural Resources as Insurance)

23.-27.09.2014 Forschungsaufenthalt von M.A. Drupp bei B. Groom an der LSE in London (Thema: Discounting Disentangled: An expert survey on the determinants of the long-term social discount rate)

18.12.2014	Forschungsaufenthalt von M.F. Quaas bei S. Baumgärtner in Lüneburg (Thema: Subsistence and substitutability in consumer preferences)
23.-28.03.2015	Forschungsaufenthalt von M.A. Drupp bei B. Groom an der LSE in London (Thema: Discounting Disentangled: An expert survey on the determinants of the long-term social discount rate)
16.-18.09.2015	Forschungsaufenthalt von M.A. Drupp bei B. Groom an der LSE in London (Thema: Discounting Disentangled: An expert survey on the determinants of the long-term social discount rate)
08 -12.2015	Forschungsaufenthalte von M.A. Drupp bei S. Baumgärtner in Freiburg (Thema: Income inequality and willingness to pay for public environmental goods)

A3. Gemeinsame Projekt-Workshops und Klausurtagungen

Zur Koordinierung, internen Evaluation und Steuerung der Forschungsaktivitäten des Projekts haben wir vom 20.–22. August 2013 in Lüneburg einen Projektworkshop abgehalten. Auf diesem Workshop wurde (a) der Stand der Forschungsarbeiten der einzelnen Mitglieder präsentiert, (b) Ansätze, Ergebnisse und offene Fragen diskutiert, (c) geplante Publikationen besprochen sowie (d) das weitere Vorgehen abgestimmt (Programm: Anlage 34).

Ebenfalls haben wir am 7. August 2014 in Camp Reinsehlen einen internen Projektworkshop abgehalten. Auf diesem Workshop wurde (a) der Stand der Forschungsarbeiten der einzelnen Mitglieder präsentiert, (b) Ansätze, Ergebnisse und offene Fragen diskutiert, (c) geplante Publikationen besprochen sowie (d) das weitere Vorgehen abgestimmt (Programm: Anlage 35).

A4. Von uns durchgeführte Tagungen, Workshops und Symposien

International Workshop on Sustainability Economics: Intergenerational Equity and Efficiency under Uncertainty, 4.–7. August 2014, Camp Reinsehlen, Schneverdingen

International Workshop on Sustainability Economics: Experiments on Intergenerational Justice under Uncertainty 11.–14. October 2015, Camp Reinsehlen, Schneverdingen

A5. Publikation von Forschungsergebnissen

1. Aufsätze in internationalen Zeitschriften mit peer-review Verfahren

Baumgärtner, S., Drupp, M.A. and Quaas, M.F. (2015). Subsistence, Substitutability and Sustainability in Consumer Preferences, forthcoming in *Environmental and Resource Economics*.

Buchholz, W., Cornes, R.C. and Rübbelke, D. (2014), Potentially Harmful International Cooperation on Global Public Good Provision, *Economica* 81, pp. 205–223.

Buchholz, W., Cornes, R.C., Peters, W. and Rübbelke, D. (2015), Pareto Improvement through Unilateral Matching of Public Good Contributions: The Role of Commitment, *Economics Letters* 132, pp. 9–12.

Buchholz, W. and Heindl, P. (2015), Ökonomische Herausforderungen des Klimawandels, *Perspektiven der Wirtschaftspolitik* 16, pp. 324-350.

Buchholz, W., Peters, W. and Haupt, A. (2015), Equity as a Prerequisite for Stability of Cooperation on Global Public Good Provision, forthcoming in: *Environmental and Resource Economics,*

Buchholz, W. and Sandler, T. (2015a), Successful Leadership in Global Public Good Provision: Incorporating Behavioural Approaches, forthcoming in: *Environmental and Resource Economics*.

2. Andere Veröffentlichungen

Buchholz, W., Dippl, L. and Eichenseer, M. (2015), Technological Transfers in Global Climate Policy. A Strategic Perspective, CESifo Working Paper No. 5548. Forthcoming in: A. Mayakandyar and D. Rübbelke, *Climate Finance: Theory and Practice*.

3. Diskussionspapiere (im Veröffentlichungsprozess)

Baumgärtner, S., M.A. Drupp, J.N. Meya, J.M. Munz, M.F. Quaas (2015), Income inequality and willingness to pay for public environmental goods, submitted to *Journal of Environmental Economics and Management*.

Buchholz, W. (2014), Discounting in an Uncertain World – Disentangling the Debate on the Weitzman-Gollier Puzzle. CESifo Working Paper No. 4967.

Drupp, M.A. (2015). Limits to substitution between ecosystem services and manufactured goods and implications for social discounting, revise and resubmit at *Environmental and Resource Economics*.

Drupp, M.A., Freeman, M.C., Groom, B. and Nesje F. (2015). Discounting Disentangled:. Grantham Research Institute on Climate Change and the Environment Working Paper No. 172, submitted to the *Journal of Political Economy*.

Huber, S., Model, J., and Städter, S. (2014), Team Behavior in Public Goods Games with Ostracism, GEABA Discussion Paper Series in Economics and Management, No.14-31.

Hänsel, M. and Quaas, M.F. (2015). Intertemporal Distribution of Well-Being and Integrated Assessment, revise and resubmit at *Environmental and Resource Economics*.

Noack, F., Riekhof, M.C., and Quaas, M.F. (2015). Development in a Dual Economy: The Importance of Resource-Use Regulation, submitted to *Journal of the Association of Environmental and Resource Economists*.

Riekhof, M.-C. and Bröcker, J. (2014), Does the Adverse Announcement Effect of Climate Policy Matter? - A Dynamic General Equilibrium Analysis.

Riekhof, M.-C. (2014), Estimating the Insurance Premium in Interlinked Credit-Output Contracts.

4. Manuskripte im Entstehen (aktuelle Version, noch nicht im Veröffentlichungsprozess)

Baumgärtner, S., W. Chen, and A.M.T. Hussain (2016), Willingness to pay for environmental goods under uncertainty.

Baumgärtner, S. and E.S. Fianu (2016), Risk, externalities and insurance in international climate policy.

Buchholz, W. and Sandler, T. (2015b), The Exploitation in a Public Good Economy: Some Extensions.

Buchholz, W., Dippl, L. and Eichenseer, M. (2016), Subsidizing Renewables as Part of Burden-Sharing in International Climate Policy.

Buchholz, W., Dippl, L., Eichenseer, M. (in prep), Transfers in International Climate Policy: A Discussion of Transfer-based Instruments in Climate Policy from a Donor’s Perspective.

Fianu, E.S. and S. Baumgärtner (2015a), A survey on catastrophic risk.

Fianu, E.S. and S. Baumgärtner (2015b), A survey on risk externalities.

Meyer, M., M.F. Quaas and S. Baumgärtner (2015), Shadow-price valuation of multifunctional natural capital under different sustainability conceptions.

Reiche, K., and S. Baumgärtner (2015), Generational accounting of the costs and benefits of different climate policies.

Quaas, M.F. and Bröcker, J. (2014) Peak wealth? Sustainability and substitutability in a solvable growth model with irreversible climate change.

5. Beiträge zu Konferenzen, Workshops und Kolloquien

Baumgärtner, S. W. Chen, and A.M.T. Hussain (2014), Willingness to pay for environmental goods under uncertainty, poster presented at the *Workshop in Sustainability Economics: Intergenerational Equity and Efficiency under Uncertainty*, Camp Reinsehlen, Germany (4-7 August, 2014)

Baumgärtner, S., W. Chen and A.M. Tanvir Hussain (2015), Willingness to pay for public environmental goods under uncertainty. 17th BIOECON Conference, Cambridge, UK (13–15 September 2015).

Baumgärtner, S., W. Chen and A.M. Tanvir Hussain (2015), Willingness to pay for public environmental goods under uncertainty. 21st *Conference of the European Association of Environmental and Resource Economists*, Helsinki, Finland (24-27 June 2015).

Baumgärtner, S., M.A. Drupp, J. Meya, J. Munz and M.F. Quaas (2013), Income inequality and willingness to pay for ecosystem services, *Kolloquium Umweltökonomie und Ressourcenmanagement, Universität Freiburg*, 18. April 2013.

Baumgärtner, S., M.A. Drupp, J. Meya, J. Munz and M.F. Quaas (2013), Income inequality and willingness to pay for ecosystem services, *10th International Conference of the European Society for Ecological Economics* (ESEE), Lille (France), 18-21 June 2013.

Baumgärtner, S., M.A. Drupp, J. Meya, J. Munz and M.F. Quaas (2013), Income inequality and willingness to pay for ecosystem services, *Applied Environmental Economics Conference*, The Royal Society, London (UK), 15 March 2013

Baumgärtner, S., M.A. Drupp, J. Meya, J. Munz and M.F. Quaas (2014), Income inequality and willingness to pay for ecosystem services, poster presented at the *Workshop in Sustainability Economics: Intergenerational Equity and Efficiency under Uncertainty*, Camp Reinsehlen, Germany (4-7 August, 2014)

Baumgärtner, S., M.A. Drupp, J. Meya, J. Munz and M.F. Quaas (2014), Income inequality and willingness to pay for ecosystem services,, Biennial Conference of the International Society for Ecological Economics (ISEE), Reykjavik (Iceland), (13–15 August 2014)

Baumgärtner, S., Drupp, M.A. and Quaas, M.F. (2015). Subsistence, substitutability and sustainability in consumer preferences. 21st *Conference of the European Association of Environmental and Resource Economists*, Helsinki, Finland (23-27 June 2015).

Baumgärtner, S., M.A. Drupp and M.F. Quaas (2015), Subsistence and substitutability in consumer preferences, Presentation at the 16th BIOECON Conference, Cambridge (UK), (21–23 September, 2014)

Baumgärtner, S. and E.S. Fianu (2014), Risk, externalities and insurance, poster presented at the *Workshop in Sustainability Economics: Intergenerational Equity and Efficiency under Uncertainty*, Camp Reinsehlen, Germany (August 4-7, 2014)

Baumgärtner, S. and E.S. Fianu (2015), Risk, externalities and insurance. 21st *Conference of the European Association of Environmental and Resource Economists*, Helsinki, Finland (24-27 June 2015).

Baumgärtner, S. and E.S. Fianu (2015), Risk, externalities and insurance. *World Risk and Insurance Economics Congress*, Munich, Germany (02-06, August 2015).

Buchholz, W. (2015), Umverteilungs-Systeme in Internationalen Abkommen, Poster Session, Statuskonferenz Förderschwerpunkt Ökonomie des Klimawandels, Potsdam (11.-12. November 2015)

Buchholz, W. (2015), Mehr Klimaschutz durch mehr Gerechtigkeit?, Forum Klimaökonomie, Berlin (04. Mai 2015)

Buchholz, W. (2015), Die Nutzung der Natura aus umweltethischer Sicht, 66. Berg- und Hüttenmännischer Tag, TU Bergakademie Freiberg (18-19 June 2015).

Buchholz, W. (2015) Discounting in an Uncertain World – Disentangling the Weitzman-Gollier Puzzle, 21st *Conference of the European Association of Environmental and Resource Economists*, Helsinki, Finland (24-27 June 2015).

Buchholz, W. (2015), Behavioral Approaches in Public Good Models, Nachfolgetreffen RECAP 15, Regensburg (23.-25. July 2015)

Buchholz, W., Haupt, A. and Peters, W. (2014), Equity as a Prerequisite for Stability of Cooperation on Global Public Good Provision, presented at a Climate Policy Workshop at ZEW Mannheim (April 14–16, 2013) and at the World Congress of Environmental and Resource Economists (WCERE), Istanbul, Turkey (June 28 – July2, 2014).

Dippl, L. (2015), Das Vorreiterverhalten in der Klimapolitik: Die Rolle des EEG, Nachfolgetreffen RECAP 15, Regensburg (23.-25. July 2015)

Dippl, L., Eichenseer, M. (2015), Gerechtigkeit in der Klimapolitik. Die Ökonomische Perspektive, Fachworkshop Internationale Klimaverhandlungen und Klimaregimes, Potsdam (23. Februar 2015)

Drupp, M.A. (2014). Limits to substitution between ecosystem services and manufactured goods and implications for social discounting. Presentation at the 4th International Conference on Degrowth, Leipzig (2-6. September 2014)

Drupp, M.A. (2014). Limits to substitution between ecosystem services and manufactured goods and implications for social discounting. Presentation at the Workshop in Sustainability Economics: “Intergenerational Equity and Efficiency under Uncertainty“, Camp Reinsehlen (August 4-7, 2014)

Drupp, M.A. (2014). Limits to substitution between ecosystem services and manufactured goods and implications for social discounting. Presentation at the 5th World Congress of Environmental and Resource Economics (WCERE), Istanbul (June 28-July 2, 2014)

Drupp, M.A. (2014). Limits to substitution between ecosystem services and manufactured goods and implications for social discounting. Presentation at the IfW Centenary Conference “Fair and Sustainable Prosperity in the Global Economy”, IfW Kiel (June 13-14, 2014)

Drupp, M.A. (2014). Limits to substitution between ecosystem services and manufactured goods and implications for social discounting. Presentation at the Monte Verità Conference on Sustainable Resource Use and Economic Dynamics (SURED), Ascona (June 9-12, 2014)

Drupp, M.A. (2014). Limits to substitution between ecosystem services and manufactured goods and implications for social discounting. Presentation at the AURÖ young researcher workshop on Environmental and Resource Economics, IfW & CAU Kiel (February 9-12, 2014)

Drupp, M.A., Freeman, M.C., Groom, B. and F. Nesje (2015). Discounting Disentangled: An expert survey on the determinants of the long-term social discount rate. Presentation at the AUROE Junior Workshop, Hamburg, (09–10 Februar, 2015)

Drupp, M.A., Freeman, M.C., Groom, B. and F. Nesje (2015). Discounting Disentangled: An expert survey on the determinants of the long-term social discount rate. Presentation at the EAERE Conference, Helsinki (Finland), (23–27 June, 2015)

Drupp, M.A., Freeman, M.C., Groom, B. and F. Nesje (2015). Discounting Disentangled: An expert survey on the determinants of the long-term social discount rate. Presentation at the EEA Conference, Mannheim, (23–28 August, 2015)

Drupp, M.A., Freeman, M.C., Groom, B. and F. Nesje (2015). Discounting Disentangled: An expert survey on the determinants of the long-term social discount rate. Presentation at the PhD Workshop in Climate Policy, Berlin (27–29 May, 2015)

Eichenseer, M. (2015), Technologische Spillover im Rahmen des Aggregative Game Approach, Nachfolgetreffen RECAP 15, Regensburg (23.-25. July 2015)

Hänsel, M. and Quaas, M. (2014), Intertemporal Distribution of Well-Being and Integrated Assessment. Poster presented at the *Workshop in Sustainability Economics: Intergenerational Equity and Efficiency under Uncertainty*, Camp Reinsehlen, Germany (August 4-7, 2014)

Hänsel, M. and Quaas, M. (2014), Intertemporal Distribution of Well-Being and Integrated Assessment. Paper presented at the *CERE Ulvön Conference on Environmental Economics.* Ulvön, Sweden (June 17-19, 2014)

Hänsel, M. and Quaas, M. (2015), Intertemporal Distribution of Well-Being and Integrated Assessment. Paper presented at the EAERE Conference, Helsinki, Finland (23–27 June, 2015)

Hänsel, M. and Quaas, M. (2015), Intertemporal Distribution of Well-Being and Integrated Assessment. Paper presented at the World Conference on Natural Resource Modeling, Bordeaux, France (29th June to 1st July 2015)

Noack, F. (2013). Resource productivity, investment in education and the transition to resource-independent production in rural India. Annual conference of the European Association of Environmental and Resource Economists (EAERE), Toulouse, France.

Noack, F. (2013). Resource productivity, investment in education and the transition to resource-independent production in rural India. German Economic Association Research Group on Development Economics, Munich, Germany

Quaas, M. (2012): Markets for Sustainable Resource Use under Uncertainty: Auctioned Limited-Tenure Use Rights with Refunding. Environment and Resource Economics Seminar, Department of Agricultural and Resource Economics, University of California in Berkeley, November 14, 2012.

Quaas, M.F. (2014) Peak wealth? Sustainability and substitutability in a simple solvable growth model with irreversible climate change. Paper presented at the *Monte Verità Conference on Sustainable Resource Use and Economic Dynamics* (SURED), Ascona (June 9-12, 2014).

Quaas, M.F. (2014) Peak wealth? Sustainability and substitutability in a simple solvable growth model with irreversible climate change. Paper presented at the IfW Centenary Conference “Fair and Sustainable Prosperity in the Global Economy”, IfW Kiel (June 13-14, 2014).

Riekhof, M.-C. (2014), *Estimating the Insurance Premium in Interlinked Credit-Output Contracts*, AEL Jahrestagung 2014 "Development Economics and Policy", Passau, Germany (27. -28. June 2014)

Riekhof, M.-C. (2014), *Estimating the Insurance Premium in Interlinked Credit-Output Contracts*, Summer School in Development Economics, Ascea, Italy (23. -26. June 2014)

Riekhof, M.-C. (2014), *Estimating the Insurance Premium in Interlinked Credit-Output Contracts.* Presentation at the IfW Centenary Conference “Fair and Sustainable Prosperity in the Global Economy”, IfW Kiel (June 13-14, 2014)

Riekhof, M.-C. and Bröcker, J. (2014), *Does the Adverse Announcement Effect of Climate Policy Matter? - A Dynamic General Equilibrium Analysis?*, poster presented at the *Workshop in Sustainability Economics: Intergenerational Equity and Efficiency under Uncertainty*, Camp Reinsehlen, Germany (August 4-7, 2014)

Riekhof, M.-C. and Bröcker, J. (2014), *Does the Adverse Announcement Effect of Climate Policy Matter? - A Dynamic General Equilibrium Analysis?* World Congress of Environmental and Resource Economist, Istanbul, Turkey (June 28-July 2, 2014)

Riekhof, M.-C. and Bröcker, J. (2014), *Does the Adverse Announcement Effect of Climate Policy Matter? - A Dynamic General Equilibrium Analysis?* Presentation at the

AURÖ young researcher workshop on Environmental and Resource Economics, IfW & CAU Kiel (February 9-12, 2014)

Riekhof, M.-C. and Bröcker, J. (2014), *Does the Adverse Announcement Effect of Climate Policy Matter? - A Dynamic General Equilibrium Analysis?* Presentation at the Monte Verità Conference on Sustainable Resource Use and Economic Dynamics (SURED), Ascona, Switzerland (June 9-12, 2014)

Reiche, K. and S. Baumgärtner (2015), Generational accounting as a tool for sustainability policy. 21st *Conference of the European Association of Environmental and Resource Economists*, Helsinki, Finland (24-27 June 2015).

Riekhof, M.-C., Noack, F., Di Falco, S. and S. Wunder: Ownership of the Commons and Informal Insurance against Climate Shock, Presentation at the AUROE Junior Workshop, Hamburg, (09–10 Februar, 2015).

A6. Qualifizierungsarbeiten im Rahmen des Projekts

1. Dissertationen

Dippl, L. (in prep.). Effizienz und Verteilungsgerechtigkeit bei der Bereitstellung eines globalen öffentlichen Gutes (Arbeitstitel), PhD Dissertation, Universität Regensburg (Fertigstellung geplant: 03/2018).

Drupp, M.A. (in prep.). Essays in Sustainability Economics (Arbeitstitel). PhD Dissertation, Economics department of the CAU (Fertigstellung geplant: 2017/2018).

Eichenseer, M. (in prep). Kooperation und Verteilung im globalen Klimaschutz (Arbeitstitel), PhD Dissertation, Universität Regensburg (Fertigstellung geplant: 03/2018).

Noack, F. 2013. Structural change in resource-abundant economies. PhD Dissertation, Economics department of the CAU (Fertigstellung: 11/2013).

Riekhof, M.-C. (2014): Essays in Resource and Development Economics, PhD Dissertation, Economics department of the CAU (submitted beginning of May, defended June 18th).

2. Diplom-, Master- und Bachelorarbeiten

Hänsel, M.: Intertemporal Distribution of Well-Being in a Dynamic Integrated model of Climate and the Economy (Fertigstellung 03/2014). Master thesis im Studiengang VWL, Universität Kiel.

Meyer, M.: Shadow-price valuation of natural renewable resources under different sustainability conceptions (Fertigstellung: 02/2014), Masterthesis im Studiengang Nachhaltigkeitswissenschaften, Leuphana University of Lüneburg.

Reiche, K.: Generational accounting as a tool for sustainability policy (Fertigstellung 04/2014), Masterthesis im Studiengang Nachhaltigkeitswissenschaften, Leuphana University of Lüneburg.

A7. Transfer von Forschungsergebnissen in die Öffentlichkeit und Praxis

Transfer in die akademische Lehre

Baumgärtner, S.: Integrierte Veranstaltung Grundlagen der Nachhaltigkeitsökonomie und –politik im Modul Grundlagen der öffentlichen Nachhaltigkeitssteuerung, Bachelor-Studiengang Umweltwissenschaften, Leuphana Universität Lüneburg, Wintersemester 2012/2013.

Baumgärtner, S.: Vorlesung und Übung Wirtschaft, Wohlstand, (Post-)Wachstum im Modul Nachhaltigkeitsökonomie, Bachelor-Studiengang Umweltwissenschaften, Leuphana Universität Lüneburg, Wintersemester 2012/2013.

Baumgärtner, S.: Integrierte Veranstaltung Zukunftsgerechtigkeit herstellen im Modul Öffentliche Nachhaltigkeitssteuerung, Master-Studiengang Sustainability Science, Leuphana Universität Lüneburg, Wintersemester 2012/2013

Baumgärtner, S.: Integrierte Veranstaltung *Zukunftsgerechtigkeit herstellen* im Modul *Öffentliche Nachhaltigkeitssteuerung*, Master-Studiengang Sustainability Science, Leuphana Universität Lüneburg, Wintersemester 2012/2013.

Baumgärtner, S.: Veranstaltung *Marktversagen und Marktregulierung* im Modul *Öffentliche Nachhaltigkeitssteuerung*, Bachelor-Studiengang Umweltwissenschaften, Leuphana Universität Lüneburg, Sommersemester 2013.

Baumgärtner, S.: Integrierte Veranstaltung *Grundlagen der Nachhaltigkeitsökonomie und –politik* im Modul *Grundlagen der öffentlichen Nachhaltigkeitssteuerung*, Bachelor-

Studiengang Umweltwissenschaften, Leuphana Universität Lüneburg, Wintersemester 2013/2014.

Baumgärtner, S.: Vorlesung und Übung *Wirtschaft, Wohlstand, (Post-)Wachstum* im Modul *Nachhaltigkeitsökonomie*, Bachelor-Studiengang Umweltwissenschaften, Leuphana Universität Lüneburg, Wintersemester 2013/2014.

Buchholz, W.: Vorlesung und Übung Internationale Umweltökonomie, Master-Studiengang Volkswirtschaftslehre, Universität Regensburg, Sommersemester 2013 und 2014.

Buchholz, W.: Seminar zu Internationale Umweltökonomie, Master-Studiengang Volkswirtschaftslehre, Universität Regensburg, Wintersemester 2013/2014 und 2014/2015.

Buchholz, W. and Heindl, P. (2015), Ökonomische Herausforderungen des Klimawandels, *Perspektiven der Wirtschaftspolitik*, 16, pp. 324-350.

Quaas, M. F.: Vorlesung Sustainability Economics, Master of Sustainability, Science and the Environment und Bachelor Volkswirtschaftslehre, Christian-Albrechts-Universität zu Kiel, Wintersemester 2013/2014

Quaas, MF.: Vorlesung Theories of Distributive Justice and Sustainability. Master-Studiengänge Economics; Environmental and Resource Economics; Quantitative Economics; Sustainability, Science and the Environment, Universität Kiel, Wintersemester 2013/2014.

Quaas, M.F.: Vorlesung Resource Economics. Master-Studiengänge Economics; Quantitative Economics; Sustainability, Science and the Environment, Universität Kiel, Sommersemester 2014.

Verzeichnis der Anlagen

Publikationen von Forschungsergebnissen und Diskussionspapiere im Veröffentlichungsprozess

1. Baumgärtner, S., M.A. Drupp and M.F. Quaas (2015), Subsistence, substitutability and sustainability in consumer preferences, forthcoming in *Environmental and Resource Economics*.

2. Baumgärtner, S., M.A. Drupp, J.N. Meya, J. Munz, M.F. Quaas (2015), Income inequality and willingness to pay for public environmental goods, submitted to the *Journal of Environmental Economics and Management*.

3. Buchholz, W. (2014), Discounting in an Uncertain World – Disentangling the Debate on the Weitzman-Gollier Puzzle, CESIfo Working Paper No. 4967.

4. Buchholz, W., Cornes, R.C. and Rübbelke, D. (2014), Potentially Harmful International Cooperation on Global Public Good Provision, *Economica*.

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6. Buchholz, W. and Sandler, T. (2015a), Successful Leadership in Global Public Good Provision: Incorporating Behavioural Approaches, forthcoming in: *Environmental and Resource Economics*.

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29. Teilnehmerliste des *International Workshop on Sustainability Economics: Intergenerational Equity and Efficiency under Uncertainty*, 4.–7. August 2014, Camp Reinsehlen, Schneverdingen

30. Book of Abstracts des *International Workshop on Sustainability Economics: Intergenerational Equity and Efficiency under Uncertainty*, 4.–7. August 2014, Camp Reinsehlen, Schneverdingen

31. Programm des *International Workshop on Sustainability Economics: Experiments on Intergenerational Justice under Uncertainty* 11.–14. October 2015, Camp Reinsehlen, Schneverdingen

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33. Book of Abstracts des *International Workshop on Sustainability Economics: Experiments on Intergenerational Justice under Uncertainty* 11.–14. October 2015, Camp Reinsehlen, Schneverdingen

34. Programm des internen Projektworkshops, 20.-22.08.2013 Lüneburg

35. Programms des internen Projektworkshops am 7. August 2014 in Camp Reinsehlen, Schneverdingen

Berichtsblatt

1. ISBN oder ISSN --	2. Berichtsart (Schlussbericht oder Veröffentlichung) Schlussbericht

3. Titel
Economics of Climate Change: Distribution, Efficiency, and Policy under Uncertainty (ECCUITY)

4. Autor(en) [Name(n), Vorname(n)]	5. Abschlussdatum des Vorhabens 31. Dezember 2015
Baumgärtner, Stefan Buchholz, Wolfgang Quaas, Martin F.	6. Veröffentlichungsdatum 20. Juni 2016
	7. Form der Publikation Broschüre
8. Durchführende Institution(en) (Name, Adresse) Leuphana Universität Lüneburg, Scharnhorststr. 1, D-21335 Lüneburg Universität Regensburg, Universitätsstraße 31, D-93053 Regensburg Christian-Albrechts-Universität Kiel, Christian-Albrechts-Platz 4, D-24118 Kiel	9. Ber. Nr. Durchführende Institution --
	10. Förderkennzeichen 01LA1104A, 01LA1104B, 01LA1104C
	11. Seitenzahl 45
12. Fördernde Institution (Name, Adresse) Bundesministerium für Bildung und Forschung (BMBF) 53170 Bonn	13. Literaturangaben 65, davon 26 eigene Veröffentlichungen von Projektergebnissen
	14. Tabellen --
	15. Abbildungen --

16. Zusätzliche Angaben
Bericht als Ganzes wurde nicht veröffentlicht. Stattdessen wurden 26 einzelne Publikationen mit Ergebnissen aus dem Forschungsprojekt veröffentlicht bzw. sind derzeit zur Veröffentlichung geplant. Ergebnisse wurden zudem in 50 Präsentationen auf wissenschaftlichen Konferenzen und Workshops vorgestellt.

17. Vorgelegt bei (Titel, Ort, Datum)
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18. Kurzfassung

Das Forschungsprojekt „Economics of Climate Change: Distribution, Efficiency, and Policy under Uncertainty“ (ECCUITY) wurde als Verbundprojekt der Universitäten Lüneburg (Projektleiter und Verbund-Koordinator: Prof. Dr. Stefan Baumgärtner), Regensburg (Projektleiter: Prof. Dr. Wolfgang Buchholz) und Kiel (Projektleiter: Prof. Dr. Martin Quaas) durchgeführt.

Ziele des Projekts waren (1) ein besseres analytisches Verständnis der kombinierten Effekte alternativer Vermögensverteilungsziele und Risikoexternalitäten für intertemporale Verteilungsgerechtigkeit und Effizienz unter Unsicherheit, sowie (2) Entscheidungsunterstützung bei der Ausgestaltung internationaler Klimapolitik in Form geeigneter Instrumente, Versicherungsprodukte und internationaler Abkommen.

Die Forschung konzentrierte sich auf drei Schwerpunkte: (1) Vermögensverteilung und Bewertung der Kosten und Nutzen von Klimapolitiken (Leitung: U. Kiel), (2) Risikoexternalitäten, externes moralisches Risiko und Versicherung (Leitung: U. Lüneburg), (3) Politikinstrumente und internationalen Klima-Abkommen (Leitung: U. Regensburg).

Die detaillierten wissenschaftlichen Ergebnisse des Projekts wurden in 27 Manuskripten vorgelegt, von denen mehr als die Hälfte bereits in sehr guten internationalen Fachzeitschriften mit Peer-Review-Verfahren veröffentlicht oder zur Veröffentlichung eingereicht sind. Dieser Schlussbericht enthält eine systematische und umfassende Zusammenfassung der wissenschaftlichen Ergebnisse und ihrer möglichen Anwendungen.

19. Schlagwörter
Nachhaltigkeit, Ökonomie, Gerechtigkeit, Effizienz, Klimawandel, Unsicherheit, Bewertung, Politikinstrumente

20. Verlag --	21. Preis --

Document Control Sheet

1. ISBN or ISSN --	2. type of document (e.g. report, publication) Final report
3. title Economics of Climate Change: Distribution, Efficiency, and Policy under Uncertainty (ECCUITY) Original title (German): Ökonomie des Klimawandels: Verteilung, Effizienz und Politik unter Unsicherheit (ECCUITY)	
4. author(s) (family name, first name(s)) Baumgärtner, Stefan Buchholz, Wolfgang Quaas, Martin F.	5. end of project December 31, 2015
	6. publication date June 20, 2016
	7. form of publication brochure
8. performing organization(s) (name, address) Leuphana Universität Lüneburg, Scharnhorststr. 1, D-21335 Lüneburg Universität Regensburg, Universitätsstraße 31, D-93053 Regensburg Christian-Albrechts-Universität Kiel, Christian-Albrechts-Platz 4, D-24118 Kiel	9. originator's report no. --
	10. reference no. 01LA1104A, 01LA1104B, 01LA1104C
	11. no. of pages 45
12. sponsoring agency (name, address) Bundesministerium für Bildung und Forschung (BMBF) 53170 Bonn	13. no. of references 65, including 26 own publications of project results
	14. no. of tables --
	15. no. of figures --
16. supplmentary notes This report as a whole has not been published. Instead, 26 separate publications with results from the project have been published or are presently planned for publication. Results were also presented in 50 presentations at scientific conferences and workshops.	
17. presented at (title, place, date) --	
18. abstract The research project "Economics of Climate Change: Distribution, Efficiency, and Policy under Uncertainty" (ECCUITY) was a cooperative research project between the universities of Lüneburg (principal investigator and project-coordinator: Prof. Dr. Stefan Baumgärtner), Regensburg (principal investigator: Prof. Dr. Wolfgang Buchholz) and Kiel (principal investigator: Prof. Dr. Martin Quaas). Its aims were (1) a better analytical understanding of the combined effect of different wealth-distribution targets and risk externalities for intertemporal equity and efficiency under uncertainty, and (2) development of decision-support for the design of international climate policies, i.e. instruments, insurance schemes and international agreements. Research focused on three areas: (1) wealth distribution and valuation of the costs and benefits of climate policies (lead: U of Kiel), (2) risk externalities, external moral hazard and insurance (lead: U of Kiel), (3) policy instruments and international climate agreements (lead: U of Regensburg). The detailed scientific results from the project were laid out in 27 manuscripts. More than half of those are already published by, or submitted for publication to, very good international peer-reviewed scientific journals. This final report gives a systematic and encompassing summary of the scientific results and their applications.	
19. keywords sustainability, economics, justice, efficiency, climate change, uncertainty, valuation, policy instruments	
20. publisher --	21. price --