Rheinische Friedrich-Wilhelms-Universität Bonn
Institut für Lebensmittel- und Ressourcenökonomik (ILR)
- *und* -
Zentrum für Entwicklungsforschung (ZEF)

International Cooperation for the Conservation and Sustainable and Fair Use of Biodiversity

Inaugural-Dissertation

zur

Erlangung des Grades

Doktorin der Agrarwissenschaften
(Dr. agr.)

der

Landwirtschaftlichen Fakultät

der

Rheinischen Friedrich-Wilhelms-Universität Bonn

vorgelegt am 16. April 2015

von

Dipl.-Ing. agr. Sarah Margareta Winands-Kalkuhl, M.Sc.

aus
Bonn

Vorsitzender:	Prof. Dr. Jan Börner
Erstgutachterin:	Prof. Dr. Karin Holm-Müller
Zweitgutachter:	Prof. Dr. Joachim von Braun
Fachnahes Mitglied:	Prof. Dr. Thomas Heckelei
Tag der mündlichen Prüfung:	8. Juli 2015
Erscheinungsjahr:	2015

Danksagung

Ein ganz großer Dank gebührt meiner Doktormutter Prof. Dr. Karin Holm-Müller für die großartige Förderung schon während meines Studiums, insbesondere als Betreuerin meiner Diplomarbeit, und anschließend meiner dreieinhalbjährigen Promotionszeit. Hierzu zählen vor allem auch anregende Diskussionen und viele hilfreiche Kommentare zu meiner Promotionsforschung. Zudem hat sie mir ermöglicht, an einer Reihe nationaler und internationaler Konferenzen teilzunehmen. Als studentische Hilfskraft und wissenschaftliche Mitarbeiterin an ihrem Lehrstuhl durfte ich überdies die universitäre Lehre kennenlernen. Sehr dankbar bin ich Frau Prof. Dr. Holm-Müller, dass sie meine Promotion neben meiner späteren außeruniversitären Berufstätigkeit immer unterstützt hat.

Dem Zentrum für Entwicklungsforschung der Universität Bonn, insbesondere dem Zweitgutachter meiner Promotion Prof. Dr. Joachim von Braun, danke ich herzlichst für die ansprechenden Vorlesungen und Kurse des Graduiertenkollegs. Danken möchte ich ebenfalls Prof. Dr. Thomas Heckelei und meinem Betreuer der Masterarbeit an der Universität Wageningen und späteren Koautor Prof. Dr. Hans-Peter Weikard für Anregungen und Feedback zu meiner Forschung.

Allen Experten, die ich interviewen durfte, bin ich sehr verbunden, da sie sich Zeit genommen und ihr Wissen mit mir geteilt haben. Für die Unterstützung bei der Durchführung meiner Feldforschung in Peru danke ich neben meiner Doktormutter Prof. Dr. Karin Holm-Müller zudem Dr. Lily Rodriguez und Elsa Cardona Santos. Vier Kapitel dieser Arbeit habe ich als Artikel verfasst. Hierbei waren die Kommentare von Reviewern und die Anregungen von Konferenzteilnehmern oftmals sehr hilfreich. Der Bischhöflichen Studienförderung Cusanuswerk danke ich für mein Promotionsstipendium, den großzügigen finanziellen Beitrag zur Durchführung meiner Feldforschung und nicht zuletzt auch für die ideelle Förderung.

Meinen Institutskolleginnen und -kollegen möchte ich meinen Dank für die freundschaftliche und gute Zusammenarbeit aussprechen. Hervorheben möche ich Daniel und Elsa, mit denen ich das Büro teilen durfte. Meinen Freunden, insbesondere

Christian, Gregor, Jan, Klara, Susanne, Thekla und Till, bin ich überaus dankbar für den Rückhalt und die vielen anregenden Gespräche während des Studiums und der Promotionszeit.

Diese Promotionsschrift widme ich meinen Eltern. Ihre immerwährende Unterstützung und ihr großartiges Vertrauen in mich haben die Grundsteine für meine Entwicklung und schlussendlich meine Promotion gelegt. Auch meinem Bruder und meinen Großeltern bin ich in tiefer Dankbarkeit verbunden. Ein großes und besonderes Dankeschön möchte ich meinem Ehemann Matthias aussprechen. Er hat mich stets ermutigt und liebevoll unterstützt, die gleichzeitige Berufstätigkeit neben meiner Promotion verständnisvollst mitgetragen und die Kapitel dieser Promotionsschrift Korrektur gelesen.

Contents

Summary

This thesis contributes to the modelling of intergovernmental cooperation for global biodiversity conservation and analyses multilateral cooperation on the genetic resource market. The inter- and transdisciplinary research consists of game theoretic modelling, economic analyses, the study of political and legal documents, as well as the conducting of expert interviews. The game theoretic biodiversity conservation model developed in this thesis considers countries that are heterogeneous in ecosystems and wealth. The ecosystems are characterised by imperfect ecosystem substitutability as well as an ecosystem resilience threshold and provide local as well as global benefits. One of the main findings of the numerical appraisal is that cooperation improves upon the conservation share in the Nash equilibrium and optimal transfers facilitate a large stable coalition. Moreover, it is evinced that established *'per-member partition functions'* are currently not applicable to the biodiversity conservation game. Based on expert interview results and technical feasibility and political economy considerations, an alternative benefit-sharing rule is derived. It is shown how this rule can be incorporated into the standard game-theoretic framework once countries have gained sufficient information to form expectations about biodiversity benefits. The main finding on multilateral cooperation on the market for physical genetic resources is that eco-regional cooperation and, even more so, a comprehensive global mechanism have the potential to significantly reduce transaction costs for both supplying countries and customers. They can thereby decrease prices for customers and increase demand, conservation levels and providers' benefits. A case study of the Andean Community's joint access legislation shows that the member countries realise few of their potential cooperation advantages. Collusion on the physical genetic resource market will not lead to high benefits as market power is limited by substitutes in form of *ex-situ* resources and freely available genetic information. The economically preferable instrument of a comprehensive global mechanism, in turn, is politically not feasible any time soon due to path dependencies and an arguably narrow understanding of national sovereignty.

Zusammenfassung

Diese Dissertation erweitert bestehende Ansätze zur Modellierung von zwischenstaatlicher Kooperation für den globalen Biodiversitätsschutz und analysiert multilaterale Kooperation auf dem Markt für genetische Ressourcen. Die inter- und transdisziplinäre Forschung beruht auf spieltheoretischen Methoden, ökonomischen Analysen, der Auswertung politischer und juristischer Dokumente sowie der Durchführung von Experteninterviews. Das in dieser Dissertation entwickelte spieltheoretische Biodiversitätsschutz-Modell berücksichtigt Länder, die heterogen in Ökosystemen und Wohlstand sind. Die Ökosysteme sind durch imperfekte Substituierbarkeit sowie Resilienzschwellen charakterisiert und stiften lokalen wie auch globalen Nutzen. Eines der zentralen Ergebnisse der numerischen Abschätzung ist, dass Kooperation zu einer Verbesserung des Schutzniveaus im Vergleich zum Nash-Gleichgewicht führt und optimale Transferzahlungen eine große stabile Koalition begünstigen. Außerdem zeigt sich, dass etablierte *'per-member partition functions'* (spieltheoretisch begründete Ausgleichszahlungen) zurzeit nicht auf das Biodiversitätsschutz-Spiel anwendbar sind. Basierend auf den Ergebnissen der Experteninterviews und unter Berücksichtigung der technischen Realisierbarkeit sowie polit-ökonomischer Erwägungen wird ein alternativer Bestimmungsfaktor für den Vorteilsausgleich entwickelt. Dabei wird herausgearbeitet, wie diese Verteilungsregel in den spieltheoretischen Standardmodellrahmen integriert werden kann, sobald die Länder ausreichende Kenntnisse erworben haben, um den Nutzen der Biodiversität zu bewerten. Das Hauptergebnis zu multilateraler Kooperation auf dem Markt für physische genetische Ressourcen ist, dass ökoregionale Kooperation und vor allem ein umfassender globaler Mechanismus das Potential haben, die Transaktionskosten sowohl für Anbieterländer als auch Nutzer signifikant zu verringern. Dadurch können sich die Preise für die Nutzer reduzieren und die Nachfrage, das Schutzniveau und die Gewinne der Anbieterländer erhöhen. In einer Fallstudie zur Andengemeinschaft wird aufgezeigt, dass die Mitgliedsländer wenige ihrer potenziellen Kooperationsvorteile realisieren. Kollusion auf dem Markt für physische genetische Ressourcen wird keine hohen Gewinne erzielen, da die Marktmacht durch Substitute in Form von *Ex-situ* Ressourcen und frei erhältlicher genetischer Information limitiert ist. Das aus ökonomischer Sicht vorzuziehende Instrument eines umfassenden globalen Mechanismus wiederum ist politisch in absehbarer Zeit aufgrund von Pfadabhängigkeiten und einem wohl engen Verständnis nationaler Souveränität nicht durchsetzbar.

List of Figures

List of Tables

Abbreviations

ABS	Access and Benefit-Sharing
CAN	Andean Community *(Spanish: Communidad Andina)*
CBD	Convention on Biological Diversity
CES	Constant Elasticity of Substitution
CITES	Convention on International Trade in Endangered Species of Wild Flora and Fauna
COP	Conference of the Parties
GDP	Gross Domestic Product
GEF	Global Environment Facility
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GBO	Global Biodiversity Outlook
GMBSM	Global Multilateral Benefit-Sharing Mechanism
GPS	Global Positioning System
iBOL	International Barcode of Life
ICNP	Open-ended Ad Hoc Intergovernmental Committee for the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization
IEA	International Environmental Agreement
INBio	National Biodiversity Institute Costa Rica (Spanish: Instituto Nacional de Biodiversidad)
INSDC	International Nucleotide Sequence Database Collaboration
IPBES	Intergovernmental Platform on Biodiversity and Ecosystem Services
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture

IUCN	International Union for Conservation of Nature
LAC	Latin America and the Caribbean
LPI	Living Plant Index
MAT	Mutually Agreed Terms
MDGs	Millennium Development Goals
MEA	Millennium Ecosystem Assessment
MOP	Meeting of the Parties
NCBI	National Center for Biotechnology Information
NP	Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization
OECD	Organisation for Economic Co-operation and Development
PIC	Prior Informed Consent
PSSS	Proportional Surplus Sharing Scheme
PSSVF	Proportional Surplus Sharing Valuation Function
R&D	Research and Development
SBI	Subsidiary Body on Implementation
SBSTTA	Subsidiary Body on Scientific, Technical and Technological Advice
TEEB	The Economics of Ecosystems and Biodiversity
TEV	Total Economic Value
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
UNEP-WCMC	United Nations World Conservation Monitoring Centre
UNESCO	United Nations Educational, Scientific and Cultural Organization
WCED	World Commission on Environment and Development
WDI	World Development Indicator
WDPA	World Database on Protected Areas
WWF	World Wide Fund For Nature

> "Cur tot creaturae, quae sunt imagines Dei, nisi ut veritas melius in varietate explicetur, quae est, uti est, inexplicabilis?"
>
> *Why are there so many creatures, which are images of God, if not to express the truth better in diversity, which, in itself, is inexpressible?*
>
> *Nicholas of Cusa, Sermo CLXX, n. 8, 12-17*

Chapter 1

Thesis Introduction

Biodiversity is essential for all living beings including humans. Its multi-layered dimensions across local to global scales require a similarly multi-faceted reflection in human actions. In this thesis I focus on the global scale and consider several aspects of international cooperation for the conservation and sustainable and fair use of biodiversity. In the following, I introduce the thesis' motivation (Section 1.1), research objective (Section 1.2), and methods (Section 1.3), and outline the subsequent chapters (Section 1.4).

1.1 Motivation

The motivation to study international cooperation for the conservation and sustainable and fair use of biodiversity is threefold. The first and broader underlying motive is the apparent need for conserving biodiversity and using it sustainably. This follows from the importance of biodiversity for life on earth in its present form in conjunction with the continued loss of biodiversity beyond sustainable levels, even beyond 'planetary boundaries' (as defined by Rockström et al. (2009), Steffen et al. (2015)). Biodiversity increases ecosystem resilience (Holling (1973, p. 18), Folke et al. (1996, p. 1020)), contributes to ecosystem functioning (Tilman 1999, p. 1470), and thereby to ecosystem services and benefits (Balvanera et al. 2006, p. 1155). Biodiversity, ecosystem functioning and ecosystem services have multiple ecocentric (Mazzotta and Kline 1995) to anthropocentric values of immense size (TEEB 2010). However, biodiversity decreases at rates higher than the average in geological time (Mace et al. 2005, p. 104).

The second motivation to focus on international biodiversity cooperation lies in the demanding concept and nature of biodiversity. Biodiversity–or biological diversity–is a multi-layered concept that includes genetic diversity, species diversity and ecosystem diversity (CBD, *Art. 1*) and is characterised by different spatial and temporal scales (Fisher et al. 2009, p. 648). Hence, it is difficult to operationalise (Sarr et al. 2008, p. 185). The complex nature of biodiversity provides a challenge for conserving biodiversity and using it sustainably.

The third motivation for this research is that the latter is especially demanding on the global scale. Albeit a large part of countries aspires strong cooperation, in most cases national and international efforts to reach global consensus targets for biodiversity conservation and sustainable use are not sufficient (UNEP 2014, p. 10). Worldwide biodiversity conservation and sustainable use requires effective self-enforcing cooperation by sovereign countries. The international community cooperates to this end under the United Nations *'Convention on Biological Diversity'*[1] (CBD) and its *'Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization'*[2]. Without a superior enforcement authority such cooperation needs to be in the self-interest of every cooperating country–and risks to merely codify the status-quo (Barrett 1994).

Together, the need for conservation and sustainable use of biodiversity, the multi-layered demanding nature of biodiversity, and the challenging international cooperation, motivate my research on aspects of international cooperation for the conser-

[1] United Nations (1992): Convention on Biological Diversity, 31 Int'l Leg. Mat. 818, Rio de Janeiro, 05.06.1992.

[2] United Nations (2010): Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity, Nagoya, 29.10.2010.

vation and sustainable and fair use of biodiversity.

1.2 Objective and research questions

The objective of my thesis is twofold: (I) to contribute to the game theoretic modelling of cooperation for biodiversity conservation and (II) to analyse multilateral cooperation for the internalisation of positive conservation externalities accruing to genetic resource users[3].

Game theory can be a valuable tool to analyze cooperation incentives, strategic interactions, and critical factors stabilising a biodiversity coalition. In contrast to climate change, the other major global environmental cooperation challenge, the game theoretic literature on international biodiversity agreements is relatively small. Barrett's (1994) *'Biodiversity Supergame'* is the most influential model. It seems to confirm that the CBD is unable to improve much upon global welfare compared to the non-cooperative scenario. However, the result is based on restrictive model assumptions (Weikard 2009, p. 578). Besides, established general game theoretic benefit-sharing rules (i.a. Carraro et al. (2006), Weikard (2009), Eyckmans et al. (2012)) may not be applicable to biodiversity conservation cooperation, because of informational limitations due to ecological uncertainty and economic valuation problems. Two sets of research questions thus relate to the first objective:

Q I.1 How can international cooperation for biodiversity conservation of sovereign heterogeneous states be modelled game theoretically? How does heterogeneity in wealth and imperfectly substitutable ecosystems impact the stability of international biodiversity conservation agreements among countries differing in these two dimensions? How do local benefits, ecosystem resilience thresholds, and transfers impact conservation levels and stability?

Q I.2 Are established sharing rules for coalition formation games (i.e. benefit surplus sharing rule, outside option sharing rule) applicable to the case of biodiversity conservation cooperation? If not, which ones are?

In the second part of the thesis I focus on international cooperation under the CBD's *'Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization'*. Hence, genetic diversity, which is

[3]There are other positive externalities of biodiversity conservation. I focus only one those particular positive externalities that accrue to genetic resource users such as pharmaceutical firms.

one of the dimensions of biodiversity, is in the centre of the remaining research. The Andean Community passed community legislation[4] on access to genetic resources and serves as a case study for eco-regional cooperation. I address the second research objective with two sets of research questions:

Q II.1 Can eco-regional cooperation, as compared to the status-quo situation with bilateral contracts, increase payments for physical genetic resource use and thereby contribute to biodiversity conservation? How do different dimensions of cooperation impact on economies of scale and other institutional factors– and thereby on the volume of trade, monetary and non-monetary benefits of cooperating countries, and conservation levels? Is there a potential for collusion? Which insights can be gained in these respects from the case study of the Andean Community's joint access regulation?

Q II.2 Is a global mechanism that internalises positive biodiversity conservation externalities accruing to commercial users of physical genetic resources and genetic information with the objective of increasing biodiversity protection politically feasible?

1.3 Methods

To address these research questions I conduct inter- and transdisciplinary research consisting of game theoretic modelling, economic, political, and legal analyses, as well as expert interviews.

I model coalition formation for international biodiversity conservation with countries that are heterogeneous in wealth and ecosystems. The general modelling approach follows established non-cooperative game theoretic environmental models (e.g Barrett (2003); Hoel (1992)). It is solved sequentially in three stages by backward induction. The model approach differs from Barrett (1994) by assuming non-identical countries, modelling a continuous action space, explicitly considering local benefits, assuming an ecosystem resilience threshold, and most notably by respecting imperfect substitutability between ecosystem services. A fund redistributes coalition benefits according to a specific sharing rule. With the game theoretic model and a numerical appraisal I address the first set of research questions (Q I.1).

[4]Decisión 391 on a 'Common Regime on Access to Genetic Resources' (Comision del Acuerdo Cartagena (1996): Decisión 391: Régimen Común sobre Acceso a los Recursos Genéticos, Gaceta Oficial del Acuerdo de Cartagena, Año XII, Numero 213, Lima, 17.06.1996.).

To answer the second set of research questions (Q I.2), I transfer established per-member partition functions to the biodiversity conservation game and appraise these rules by conducting semi-structured expert interviews. The experts are selected decision makers from countries that host large parts of global biodiversity and are thus important members of a biodiversity coalition. Based on the interview results as well as on technical feasibility and political economy considerations, I derive an alternative benefit-sharing rule. Whereas sharing rules are generally determined theoretically, I differ in grounding it on empirical-qualitative research.

The methodology to address the third set of research questions (Q II.1) consists of both a theoretical and an applied institutional economic analysis, whereby the latter is based on legal and policy documents. I use transaction cost theory to study on a generic level how general dimensions of cooperation impact on economies of scale and other institutional factors, the volume of trade, monetary and non-monetary benefits of cooperating countries, and conservation levels. Besides, I analyse how a country's characteristics influence its share of cooperation induced benefits. I also discuss the potential of collusion and its impact on conservation. As a case study, I discuss the cooperation of the Andean Community, which passed community legislation on access to genetic resources, based on legal and policy documents in light of the institutional economic findings of the previous theoretical analysis. Moreover I use empirical data to explain cooperation incentives of Andean countries.

My approach to the fourth set of research questions (Q II.2) is the most inter- and transdisciplinary one: I study the genetic resource market from the economic and political perspective, draw on legal texts and studies, and involve stakeholders. For the economic analysis I employ economics of information and transaction costs economics and derive a simple economic model to illustrate the findings. The empirical research methodology is a triangulation that consists of the study of CBD documents and an online discussion forum organised by the CBD Secretariat on a global multilateral benefit-sharing mechanism as well as expert interviews with important political stakeholders. I consider this combination of economic theory and actors' perceptions essential for exploring appropriate policy tools.

1.4 Outline

The thesis is structured into a wider background chapter, two parts that each comprise two chapters and address the two research objectives, and a conclusion. *Chapter 2* sets the scene. In this chapter I introduce the terms and concepts of biodiversity, ecosystem functioning, ecosystem functions, services and benefits as well as biological and genetic resources as a background for the further analysis. In addition, I outline and motivate in more detail the rationale for biodiversity conservation and its sustainable and fair use–and thereby for investigating aspects of multilateral cooperation to this end. The chapter also provides an overview of international cooperation under the United Nations *'Convention on Biological Diversity'* and its Nagoya Protocol. Thesis *Part I* on *'Modelling cooperation for biodiversity conservation'* covers the third and fourth chapter. *Chapter 3*[5] address the first set of research questions (Q I.1) on modelling a biodiversity game with countries heterogeneous in wealth and ecosystems. *Chapter 4* focuses on the second set of research questions (Q I.2) on benefit-sharing rules applicable to biodiversity coalition formation games. *Part II* on *'Multilateral cooperation on the genetic resource market'* consists of the fifth and sixth chapter. *Chapter 5*[6] pertains to the third set of research questions (Q II.1) and covers eco-regional cooperation advantages to obtain payments for in-situ conservation of genetic resources. *Chapter 6* addresses the fourth set of research questions (Q II.2) on a global mechanism to internalise positive conservation externalities accruing to genetic resource users. These main chapters are self-contained in that they each include a specific introduction, background to the respective research question, overview of the relevant literature, methodology and conclusion. In *Chapter 7* I provide an overall conclusion of the main findings together with a discussion of their relevance for international cooperation under the CBD and its Nagoya Protocol.

Bibliography

Balvanera, P., A. B. Pfisterer, N. Buchmann, J.-S. He, T. Nakashizuka, D. Raffaelli, and B. Schmid (2006). Quantifying the evidence for biodiversity effects on ecosystem functioning and services. *Ecology Letters 9*, 1146–1156.

Barrett, S. (1994). The biodiversity supergame. *Environmental and Resource Economics 4*(1), 111–122.

[5] Chapter 3 has been published as: *Winands, S., K. Holm-Müller, and H.-P. Weikard (2013). The biodiversity conservation game with heterogeneous countries. Ecological Economics 89, 14-23.* A first analysis can be found in Winands (2011), which has partly been published in Winands (2012).

[6] Chapter 5 has been published as Discussion Paper as: *Winands, S. and K. Holm-Müller (2014). Eco-regional Cooperation on the Genetic Resource Market and the Case of the Andean Community. ILR Food and Resource Economics Discussion Paper 2014 (2), updated version, 1-32.*

Barrett, S. (2003). *Environment and Statecraft: The Strategy of Environmental Treaty-Making*. New York: Oxford University Press.

Carraro, C., J. Eyckmans, and M. Finus (2006). Optimal transfers and participation decisions in international environmental agreements. *The Review of International Organizations 1*(4), 379–396.

Eyckmans, J., M. Finus, and L. Mallozzy (2012). A new class of welfare maximizing stable sharing rules for partition function games with externalities. *Working Paper, Department of Economics, University of Bath*.

Fisher, B., R. K. Turner, and P. Morling (2009). Defining and classifying ecosystem services for decision making. *Ecological Economics 68*(3), 643–653.

Folke, C., C. S. Holling, and C. Perrings (1996). Biological diversity, ecosystems, and the human scale. *Ecological Applications 6*(4), 1018–1024.

Hoel, M. (1992). International environmental conventions: The case of uniform reductions of emissions. *Environmental and Resource Economics 2*(2), 141–159.

Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics 4*(4), 1–23.

Mace, G., H. Masundire, and J. Baillie (2005). Biodiversity. In R. Hassan, R. Scholes, and N. Ash (Eds.), *Ecosystems and Human Well-being: Current State and Trends, Volume 1*, The Millennium Ecosystem Assessment Series, Chapter 4, pp. 77–122. Washington, DC: Island Press.

Mazzotta, M. J. and J. Kline (1995). Environmental philosophy and the concept of nonuse value. *Land Economics 71*(2), 244–249.

Rockström, J., W. Steffen, K. Noone, A. Persson, F. S. Chapin, E. F. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. J. Schellnhuber, B. Nykvist, C. A. de Wit, T. Hughes, S. van der Leeuw, H. Rodhe, S. Sörlin, P. K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Karlberg, R. W. Corell, V. J. Fabry, J. Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen, and J. A. Foley (2009). A safe operating space for humanity. *Nature 461*, 472–475.

Sarr, M., T. Goeschl, and T. Swanson (2008). The value of conserving genetic resources for R&D: A survey. *Ecological Economics 67*(2), 184–193.

Steffen, W., K. Richardson, J. Rockström, S. E. Cornell, I. Fetzer, E. M. Bennett, R. Biggs, S. R. Carpenter, W. de Vries, C. A. de Wit, C. Folke, D. Gerten, J. Heinke, G. M. Mace, L. M. Persson, V. Ramanathan, B. Reyers, and S. Sörlin (2015). Planetary boundaries: Guiding human development on a changing planet. *Science 347*(6223).

TEEB (2010). *The Eocnomics of Ecosystems and Biodiversity: Ecological and Economic Foundations.* London and Washington: Earthscan.

Tilman, D. (1999). The ecological consequences of biodiversity: A search for general principles. *Ecology 80*(5), 1455 – 1474.

UNEP (2014). *Global Biodiversity Outlook 4.* Montréal: United Nations Environment Programme, Secretariat of the Convention on Biological Diversity.

Weikard, H.-P. (2009). Cartel stability under an optimal sharing rule. *The Manchester School 77*(5), 575–593.

Winands, S. (2011). How does heterogeneity in ecosystems and wealth impact the stability of international biodiversity conservation agreements? Diploma thesis Bonn University / MSc. thesis Wageningen University.

Winands, S. (2012). Welchen Einfluss hat die Heterogenität von Ökosystemen und Wohlstand auf die Stabilität internationaler Biodiversitätsabkommen? In U. Feit and H. Korn (Eds.), *Treffpunkt Biologische Vielfalt 11*, BfN-Skripten 309, pp. 101–105. Bonn: Bundesamt für Naturschutz.

Chapter 2

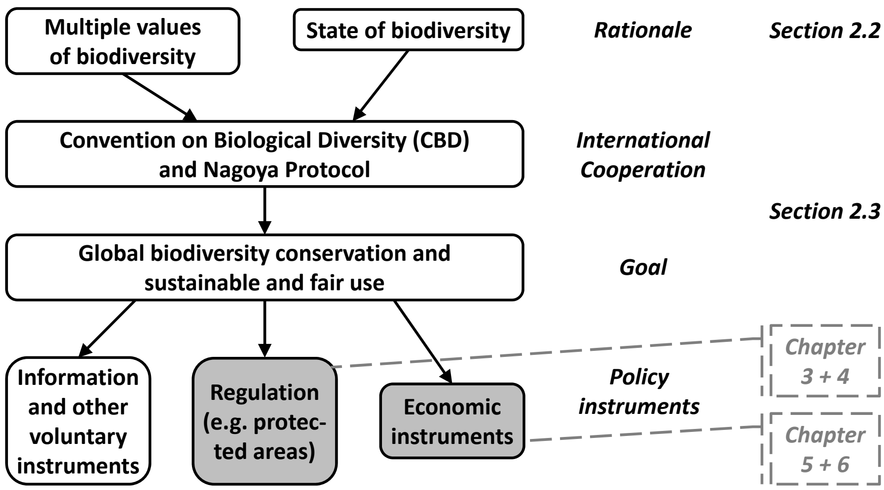
The Bigger Picture of Biodiversity and its Conservation and Sustainable and Fair Use

2.1 Introduction

Biological diversity is of paramount importance for *our common future*. The United Nations *'World Commission on Environment and Development'* (WCED)'s report (1987) of the same name drew attention to the importance of biological diversity for sustainable development. The WCED (1987, par. 27) coined the notion of sustainable development as "meet[ing] the needs of the present without compromising the ability of future generations to meet their own needs"–which carries over to the sustainable and fair use of biodiversity. In 1992 the groundbreaking *'United Nations Conference on Environment and Development'* (UNCED) followed, at which, inter alia, the United Nations *'Convention on Biological Diversity'*[1] (CBD) was opened for signature. Since then, the conservation and sustainable and fair use of biological diversity is firmly anchored in the international political agenda. In this chapter, I portray the bigger picture of biodiversity conservation and its sustainable use–of which I can only colour fractions in this thesis. Figure 2.1 guides through this chapter and the thesis: In Section 2.2, I introduce biodiversity and related terms and concepts. Moreover, I outline the rationale for biodiversity conservation and its sustainable and fair use by presenting the multiple values of biodiversity as well as the status and trends of global biodiversity. The resulting international cooperation is the focus of Section 2.3. I briefly describe the CBD and its *'Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising*

[1] United Nations (1992): Convention on Biological Diversity, 31 Int'l Leg. Mat. 818, Rio de Janeiro, 05.06.1992.

Figure 2.1: Chapter and thesis outline



Source: Own diagram, policy instrument classification based on OECD (2013)

from their Utilization'[2] and present the biodiversity goals and targets of the CBD's *'Strategic Plan for Biodiversity 2011-2020'*[3]. To achieve global biodiversity conservation goals different approaches and policy instruments can be employed (for an overview refer to, e.g., MEA (2005, p. 69 ff.), Pascual and Perrings (2007, p. 262), Helm and Hepburn (2012, p. 10 ff.)). Different instruments are apt to address different aspects of biodiversity. Hence, a mix of policy instruments is needed to capture the multiple biodiversity dimensions. OECD (2013) classifies policy instruments for biodiversity conservation and sustainable use into 'information and other voluntary instruments', 'regulation', and 'economic instruments'. The next chapters can be integrated into this picture. Chapters 3 and 4 focus on protected areas.[4] In-situ conservation in, for example, protected areas is an important regulative biodiversity policy instrument as it has not only the potential to preserve the status-quo biodiversity but also to contribute to the continuous evolution of biodiversity. Chapters 5 and 6 consider economic policy instruments.[5] In the following, I lay out the bigger

[2] United Nations (2010): Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity, Nagoya, 29.10.2010.

[3] UNEP/CBD/COP/DEC/X/2, Online: www.cbd.int/doc/decisions/cop-10/cop-10-dec-02-en.pdf, last 06.02.2015.

[4] In Chapters 3 and 4, I model biodiversity conservation as a game where the control variable is a country's conservation share of an ecosystem in terms of size.

[5] In Chapters 5 and 6, I discuss eco-regional cooperation and a global mechanism respectively as economic policy tools to internalise positive conservation externalities accruing to commercial users

picture of international cooperation for the conservation and sustainable and fair use of biodiversity as a foundation for analysing important aspects of it in detail in the next chapters.

2.2 The rationale for biodiversity conservation and sustainable and fair use

The rationale for biodiversity conservation and sustainable and fair use rests upon three interlinked arguments that are the focus of this section: First, biodiversity stabilises ecosystems, contributes to ecosystem functioning and thereby to ecosystem services and benefits (Section 2.2.1). Secondly, biodiversity, ecosystem functioning and ecosystem services have multiple and extensive values of immense size (Section 2.2.2). Thirdly, we have by far crossed planetary boundaries[6] with respect to biodiversity and continue to loose biodiversity at alarming rates (Section 2.2.3).

2.2.1 Biodiversity, ecosystem functioning, and ecosystem services

Biodiversity forms the basis for ecosystem services through the cascade visualised in Figure 2.2–subject to temporal dynamics and with heterogeneous interrelations along the local, regional and global scale. The demarcations and interlinkages between the elements biodiversity, ecosystem functioning, ecosystem functions, services and benefits have not been sufficiently substantiated by scientific research, however there seems to be a consensus about the cascade as such (Gómez-Baggethun and de Groot 2010, p. 109). In the following I introduce these terms and concepts as well as biological and genetic resources.

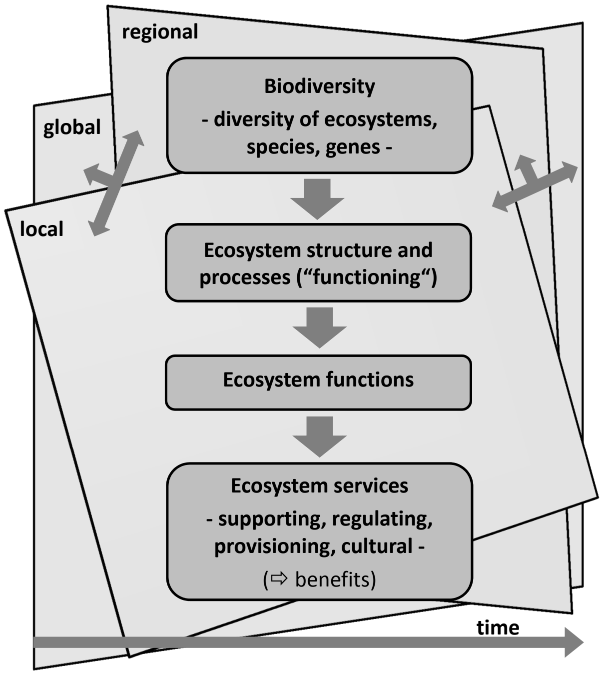
Biodiversity as a term dates back to the *'National Forum on BioDiversity'*[7] in Washington D.C. in 1986. It gained popularity through the book entitled *'Biodiversity'* by E. O. Wilson and F. M. Peters published in 1988 (Wilson 1997, p. 1). Since then references to biodiversity have increased rapidly in the scientific literature. Similarly, biodiversity gained importance in the political debate. In 1993 the United Nations *'Convention on Biological Diversity'* (CBD) entered into force. Two global influential studies followed: the *'Millennium Ecosystem Assessment'* (MEA 2005) and the study *'The Economics of Ecosystems and Biodiversity'* (TEEB 2010).

of genetic resources.

[6]Ref. Rockström et al. (2009), Steffen et al. (2015).

[7]The forum was organised by the *'National Academy of Science'* and the *'Smithsonian Institute'*.

Figure 2.2: Conceptual framework: The cascade from biodiversity to ecosystem services and benefits along temporal and intertwining spacial dimensions



Source: Own diagram, adapted from Gómez-Baggethun and de Groot (2010, p. 110), De Groot et al. (2002, Fig. 1, p. 394), MEA (2005, Fig. 1.4, p. 28), and TEEB (2010, Fig 1.4, p. 17).

Only a few years ago in 2012, the *'Intergovernmental Platform on Biodiversity and Ecosystem Services'* (IPBES)[8] was established.

Biological diversity or, in short, biodiversity is a multi-layered concept. It is characterised by multiple diversity dimensions at different spatial and temporal scales. Following the definition of the CBD (*Art. 2*), biological diversity "means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems". The CBD definition is applied broadly in the political and economic realm (Mace et al. 2012, p. 20). Also biologists use this definition as a general framework for the study of more detailed aspects of biodiversity (Meinard et al. 2014, p. 88). Common diversity scales to measure biodiversity are species or population richness, evenness, and difference (Purvis and Hector 2000, p. 212). Richness counts the number of

[8] Online: www.ipbes.net, last 06.02.2015.

species or populations in a geographic area. Evenness describes the size of each species relative to the size of the others for a given geographic area. Difference refers to the degree of similarity between different species or populations at geno- or phenotype level. Depending on the diversity measure chosen, different conservation priorities under restricted resources result (Solow et al. 1993).

From an economic perspective, biodiversity is a resource. It is an input of production and welfare functions–through the cascade pictured in Fig. 2.2. Biological diversity is in a broad sense a stock resource. Its present state determines its future state: reducing the diversity at a time t decreases the potential for diversification and thereby biological diversity at time $t + 1$. This relation is non-linear; the diversification potential differs in phylogenetic lineages (Purvis and Hector 2000, p. 214). With increasing diversity reduction, marginal productivity of biodiversity eventually converges to infinity. Hence, biodiversity is an essential resource.

Biodiversity is a global public good as it is non-rival and non-excludable on a global scale (Sandler 1993, p. 229).[9] Since long, biodiversity has been treated as '*common heritage of mankind*'[10] (Gepts 2004, p. 1295). But some scholars (e.g. ibid. (p. 1297); Lerch (1998, p. 289)) purport that this principle has been invalidated by the CBD. I argue, though, that biodiversity remains in the public domain. In the preamble of the CBD the international community "affirm[s] that the conservation of biological diversity is a common concern of humankind, [and] reaffirm[s] that states have sovereign rights over their own biological resources". Private property rights are assigned to biological resources. The global public good biological diversity, however, remains in the public domain and its conservation a common concern of humankind. Hence, the CBD acts as the global common property regime governing the public good biodiversity.

Ecosystem structures and processes characterise the functioning of an ecosystem. Biodiversity is closely intertwined with ecosystems as it underlies all ecosystem structures and processes (Mace et al. 2005, p. 79). The CBD (*Art. 2*) defines an ecosystem as "a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit". Biodiversity assures the permanent functioning of ecosystems, its resilience[11]; variability increases

[9] It thereby differs fundamentally in its economic nature from biological and genetic resources.

[10] The expression 'common heritage of mankind' was first used in the context of naval resources at the 1930 convention of the *'League of Nations'* and finally established at the 1972 *'World Heritage Convention'* (Lerch 1998, p. 288).

[11] Resilience describes the ability of an ecosystem to persist (Holling 1973).

ecosystem resilience (Holling (1973, p. 18), Folke et al. (1996, p. 1020)). Tilman (1999, p. 1470) concludes from theory and experiments that "diversity impacts the structure, dynamics, and functioning of ecosystems" together with the factors "composition, disturbance, nutrient supply dynamics, and climate", whereby a ranking according to importance is not possible at present. He finds that with rising biodiversity alien species invasions decrease, community temporal stability[12] increases, and population temporal stability decreases. Schwartz et al. (2000) conclude from an empirical literature review that there is a general positive relation between species diversity and ecosystem function, however no evidence for a linear relationship and thus no support for the hypothesis that rare species are *per se* important for ecosystem processes. Cardinale et al. (2006, p. 989) derive from a meta-analysis that "the average species loss does indeed affect the functioning of a wide variety of organisms and ecosystems, but the magnitude of these effects is ultimately determined by the identity of species that are going extinct". Folke et al. (1996) expound that a limited number of "keystone process species" are responsible for ecosystem functioning whereas a number of other species that occupy niches formed by the former guarantee ecosystem resilience. The MEA (2005, p. 24) ascertains that "changes in biotic interactions among species–predation, parasitism, competition, and facilitation–can lead to disproportionately large, irreversible, and often negative alterations of ecosystem processes". There still remains need for further detailed research on the biodiversity–ecosystem functioning link.

Ecosystem functions can be included as a step in the cascade (ref. Fig. 2.2) to facilitate the visualisation from ecosystem functioning to ecosystem services (see below). They are a subset of ecosystem structures and processes that give rise to ecosystem services (Gómez-Baggethun and de Groot 2010, p. 109). De Groot (1992, p. 7) defines ecosystem functions as "the *capacity* of natural processes and components to provide goods and services that satisfy human needs (directly and/or indirectly)" (emphasis added).[13] Ecosystem functions comprise biotic and abiotic functions (De Groot 1992, p. 16). They can be grouped into regulation, habitat, production and information functions (De Groot et al. 2002, p. 394). Examples

[12] Holling (1973, p. 17) defines stability as "the ability of a system to return to an equilibrium state after a temporary disturbance".

[13] De Groot (1992) uses the term ecosystem functions in the sense of ecosystem goods and services (ref. De Groot (1992, p. 13)). In later work, e.g. De Groot et al. (2002), he distinguishes between ecosystem functions and ecosystem services while still using the ecosystem function definition of De Groot (1992). In this thesis I use the term in the later understanding.

are respectively climate regulation, refugium function, raw materials, and genetic information (ibid., p. 396 f.). The focus lies on the *capacity* to provide ecosystem services. Functions such as climate regulation by, for example, forest ecosystems translate into regulating ecosystem services–in this case a climate comfortable for humans. Thereby ecosystem functions are the element connecting ecological and economic concepts (Gómez-Baggethun and de Groot 2010, p. 111).

The CBD uses the terms *biological resources* and *genetic resources* in a conceptual understanding of ecosystem functions. According to the definition of the CBD (*Art. 2*), *biological resources* comprise "genetic resources, organisms or parts thereof, populations, or any other biotic component of ecosystems with actual or potential use or value for humanity". Biological resources are flow goods originating from ecosystems. They are "conditionally-renewable" (Winands et al. (2013) id. Chapter 3): they reproduce themselves above certain ecosystem stock and biodiversity levels. Below these levels, their flow subsides–they are exhaustible–either because the stock generating their flow is run down or the base for the stock has been diminished too much. The preamble of the CBD assigns private property rights to states over their biological resources.

Genetic resources are or have been part of biological resources. The CBD (*Art. 2*) defines genetic resources as "genetic material of actual or potential value", whereby "genetic material means any material of plant, animal, microbial or other origin containing functional units of heredity". The CBD (*Art. 15.1*) assigns private property rights to states over their genetic resources. Besides the genetic material, genetic resources have a second dimension, genetic or natural information (Schei and Tvedt 2010, p. 18). The predominant, though not uncontested (e.g. ibid., p. 18), interpretation is that the CBD applies only to genetic material, not to genetic or natural information. *In-situ*, genetic resources are often distributed over several countries[14], which are all possible suppliers. Genetic resources also exist *ex-situ* in botanical or zoological gardens or genbanks. The economic nature of genetic resources depends on the dimension: genetic material is rival in consumption, genetic information non-rival (Sedjo 1992, p. 200f.). Exclusion is possible albeit difficult in case of genetic material, but almost impossible for genetic information. Thus, genetic material is a private good and genetic information a public good.

The ecosystem function 'pool of genetic resources' translates into an ecosystem service for, e.g., a pharmaceutical firm when searching for leads for pharmaceutical

[14]Based on data from the *'Global Biodiversity Information Facility'*, Oldham et al. (2013) show that species appearing in patents are often distributed across several countries.

products. With view to the later analysis–and as a small digression within this section–, I classify the following types of access to genetic resources:

(i) Access to physical genetic resources,

(ii) Access to genetic/natural information resources ...

(ii.a) ... contained in physical genetic resources,

(ii.b) ... not in the public domain,

(ii.c) ... in the public domain.

Physical genetic resources are accessed and exported for proliferation (i); for example plant seeds with observed healing properties or seeds of a bean variety with special properties that are not known in the customer's home country (e.g. colour). In addition, physical genetic resources are accessed as carrier of genetic information resources (ii.a); for example a pharmaceutical research institute that screens the genetic material for useful genetic information in the home country of the institute. These two types of access were the original focus of the CBD (cf. CBD, *Art. 2*). Besides, genetic information is accessed directly. This form of access is of increasing importance (Schei and Tvedt (2010, p. 18), Laird and Wynberg (2012)). Users can either access genetic information that has not yet been released into the public domain by local researchers (ii.b) or such that is already in the public domain (ii.c), that is, for example, available in genbanks. Genetic information is accessible free of charge and unrestricted online from the *'International Nucleotide Sequence Database Collaboration'* (INSDC), a cooperation between *GenBank* of the *'National Center for Biotechnology Information'* (NCBI) of the United States of America, the *'European Nucleotide Archive'*, and the *'DNA Data Bank of Japan'*.[15] INSDC patners daily exchange information. INSDC assigns an internationally authorized accession number and the names of all organisms with sequence data in INSDC are recorded in the NCBI taxonomy database (Nakamura et al. 2013). Currently ∼10% of all species described worldwide are included in the public sequence databases[16].

[15] Online: INSDC: www.insdc.org; GenBank: www.ncbi.nlm.nih.gov/genbank; European Nucleotide Archive: www.ebi.ac.uk/ena; DNA Data Bank of Japan: www.ddbj.nig.ac.jp; last 14.12.2014.

[16] Ref. NCBI taxonomy database online: www.ncbi.nlm.nih.gov/taxonomy, last 14.12.2014. In September 2013 GenBank, for example, contained sequences data for over 280 000 formally described species (Benson et al. 2014, p. D32). Benson et al. (2014) specify that GenBank obtains sequence data submissions from authors and sequencing centres as well as from the *'Patent and Trademark Office'* of the United States of America from issued patents.

Ecosystem services are specified by their contribution to human well-being (Bateman et al. 2011, p. 180) and thus an anthropocentric concept. The MEA (2005, p. 1) defines ecosystem services as "the benefits people obtain from ecosystems". Others (Boyd and Banzhaf (2007), Fisher et al. (2009)) argue that ecosystem services are not identical to benefits. According to Fisher et al. (2009, p. 645) ecosystem services "are the aspects of ecosystems utilized (actively or passively) to produce human well-being"–ecological phenomena. Benefits arise from ecosystem services in combination with other inputs: the ecosystem service 'clean water', for example, translates in combination with tools for water collection into the benefit 'drinking water' (ibid., p. 646).

The MEA (2005, p. 28) categorises ecosystem services into supporting, regulating, provisioning and cultural services. This classification is widely used (Fisher et al. 2009, p. 644) and the reason for employing it in this study instead of, e.g, the slightly deviating TEEB (2010) classification[17]. Supporting services are for example nutrient cycling and soil formation, provisioning services include food and fuel, regulating services cover inter alia climate and disease regulation, and cultural services are for example aesthetic and recreational services. Ecosystem services comprise a vast array of different types of services on the local, regional and global scale. Local rainforests, for example, supply non-timber products such as food and fibre (local provisioning ecosystem services), provide for the regional water and temperature circulation (regional regulating ecosystem services), and contribute to the global oxygen turnover (global regulating ecosystem service). In this thesis I define all ecosystem services from the perspective of nation states: all nationally appropriable ecosystem services are local services as, in principle, institutions exist for optimal conservation. National–viz. local–externalities can be internalised by nation states whereas there are no binding institutions at the international level.

Biodiversity is the base for ecosystem services–through the cascade pictured in Fig. 2.2. For example, genetic diversity (*biodiversity*) is the foundation for constant genetic transformations (*ecosystem functioning*); the latter provide genetic material and information (*ecosystem function*) which may provide leads for pharmaceutical research (*ecosystem service*) that can be used in the development of pharmaceutical products (*benefits*). Scientific research provides some insights into the relationship between biodiversity and ecosystem services. Tilman (1999, p. 1470) concludes from models and empirical experiments that primary plant productivity rises with

[17] TEEB (2010) differentiates between the four categories provisioning, regulating, habitat as well as cultural and amenity services. Within them, it identifies a total of 22 ecosystem service types.

increasing biodiversity. Hooper et al. (2012) evince from a meta-analysis that "in experiments, intermediate levels of species loss (21–40%) reduced plant production by 5–10%, comparable to previously documented effects of ultraviolet radiation and climate warming" and that at these levels "species loss generally had equal or greater effects on decomposition than did elevated CO_2 and nitrogen addition". The MEA (2005, p. 22) highlights that composition of species is more important than richness for the provision of ecosystem services. Balvanera et al. (2006, p. 1155) conclude from a quantitative meta-analysis that there is "clear evidence that biodiversity has positive effects on the provision of those [ecosystem] services" which they have examined. Supporting services are with high certainty dependent on biodiversity through ecosystem processes (MEA 2005, p. 25). The regulating service 'resistance to invasions', for example, is enhanced with medium certainty by the conservation of biodiversity in terms of "the number, types, and relative abundance of resident species" (ibid., p. 25), and the 'pest control services' strongly depends on biodiversity (ibid., p. 29).[18] Again, there is much need to advance and consolidate knowledge (TEEB 2010, p. 54 f.).

Ecosystem services can be conceived and modelled as flow resources from an ecosystem and–following the previous exposition–ultimately a biodiversity stock (cf. Mäler et al. (2009), Winands et al. (2013) id. Chapter 3). Bateman et al. (2011, p. 183) picture ecosystem services as a "flow from primary and intermediate through to final ecosystem services". Fisher et al. (2009) differentiate between intermediate and final services. Boyd and Banzhaf (2007) propose a definition of ecosystem services that only includes final services.

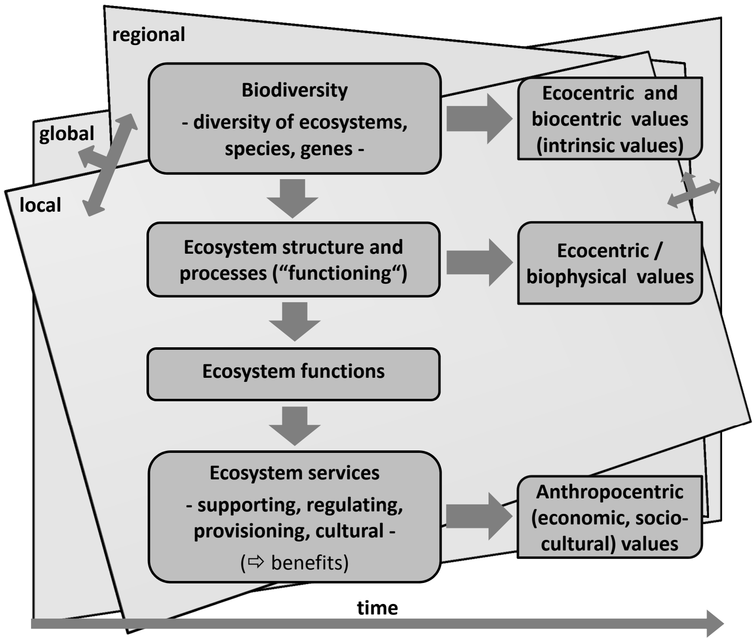
The economic nature of ecosystem services is broad. There are public goods such as climate regulation, common pool goods like fish stocks in the high sea, club goods such as religious connotations, as well as private goods such as food.

2.2.2 Multiple values of biodiversity

Biodiversity has multiple values. In the previous Section I introduced the cascade from biodiversity to ecosystem services and benefits. The focus of this section is the link to value concepts of biodiversity as visualised by Figure 2.3. Values ultimately reveal normative ethic convictions. In the extremes, biodiversity can be valuable on its own ground (intrinsic value) or only as a means to achieve human

[18] For further findings on the biodiversity–ecosystem service link refer to, e.g., Tilman (1999), MEA (2005), and TEEB (2010).

Figure 2.3: Extended conceptual framework: The cascade from biodiversity to ecosystem services and benefits along temporal and intertwining spacial dimensions linked to different value categories



Source: Own diagram, adapted from Gómez-Baggethun and de Groot (2010, p. 110), De Groot et al. (2002, Fig. 1, p. 394), MEA (2005, Fig. 1.4, p. 28), and TEEB (2010, Fig 1.4, p. 17).

welfare. Ecocentrism and biocentrism are related concepts of intrinsic value of nature. Whereas biocentrism ascribes absolute values to all living beings, ecocentrism is an even broader concept that also embraces non-living parts of ecosystems. Anthropocentrism on the other end of the spectrum attributes an instrumental value to biodiversity. An anthropocentric standpoint is likely to be the least disputed as a normative minimum consensus. Biophysical values refer to the value of biodiversity for the functioning of ecosystems. Although biophysical values are *prima facie* ecocentric values, they may fit as well in anthropocentric concepts (ref. "primary value" in Gren et al. (1994)). The preamble of the CBD regards intrinsic, biophysical and anthropocentric values: "Conscious of the intrinsic value of biological diversity and of the ecological, genetic, social, economic, scientific, educational, cultural, recreational and aesthetic values of biological diversity and its components. Conscious also of the importance of biological diversity for evolution and for maintaining life sustaining systems of the biosphere". Values of biodiversity can be addressed from different perspectives and classification types, that are difficult to align into one classification system; Chan et al. (2012) discuss seven dimensions of value besides "anthropocentric vs. biocentric". In the following, I introduce eco- and biocentric as well as anthropocentric values of biodiversity and ecosystem services.

Ecocentric and biocentric values are non-anthropocentric values of biodiversity that originate from ecocentrism respectively biocentrism, which are both physiocentric approaches to nature. Ecocentrism regards nature as a moral subject. As a consequence from an ecocentric world-view, "ethical human actions necessarily promote all life on earth by preserving intrinsic values such as diversity, stability, and beauty " (Mazzotta and Kline 1995, p. 246). Biocentrism attaches intrinsic values only to living beings. Biocentrists consider human beings as part of the planet's complex ecosystems where "the sound biological functioning of each being [is] dependent on the sound biological functioning of the others" (ibid., p. 245).

Emotional experiences connected to nature induce a conviction by some people that biodiversity has an intrinsic value. Literature and art provide testimony that humans have been experiencing surges of elation induced by biodiversity since centuries. Some religions including, and in particular, natural religions ascribe a divine facet to biodiversity. The Christian Nicholas of Cusa, for example, professes that "God is the enfolding of all things in that all things are in Him; and He is the unfolding of all things in that He is in all things" (De docta ignorantia, II, 3, 107)[19]. He reflects on diversity of species expressing God who is in himself inexpressible (Sermo CLXX, n. 8, 14-17). These biodiversity values are often 'protected values' that people are not willing to trade-off; if they are forced to do so, they feel miserable about their behaviour (Baron and Spranca 1997, p. 1). Intrinsic values of biodiversity may underlie attempts to value ecosystem services (Chan et al. 2012, p. 12) as well as conservation efforts (Mace et al. 2012, p. 24). Physiocentric attitudes may imply that protection of biodiversity is an obligation (Mazzotta and Kline 1995, p. 245).

Intrinsic values of biodiversity are different from anthropocentric non-use values "by placing natural resource values outside of human determination"–and thus cannot be valued using willingness-to-pay techniques (ibid., p. 245). Chan et al. (2012, p. 12) assert that "only the metaphorical shadow of these biocentric values can be captured as ecosystem services, e.g., in the form of existence and bequest values".

Biophysical values–or ecological values (De Groot et al. 2002)–of biodiversity link to ecosystem structure, processes, and functions. They are instrumental values–

[19]Translation online: http://urts99.uni-trier.de/cusanus/content/fw.php?werk=13& lid=22605& ids=& ln=hopkins, last 09.01.2015.

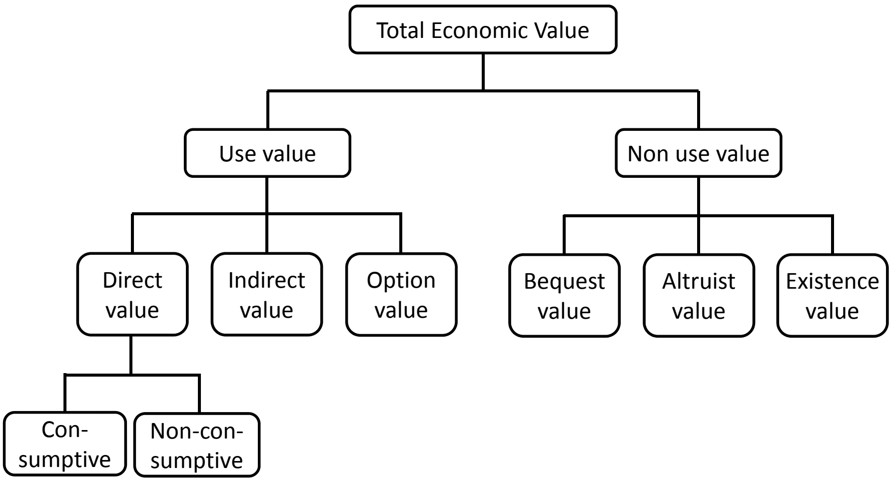
as opposed to the above discussed intrinsic values–within an ecocentric perspective. Whereas intrinsic values are not measurable, biophysical valuation methods exist. Gómez-Baggethun and de Groot (2010) introduce several of these methods and classify them into '*Surface or Material Accounting Methods*' and '*Energy Based Methods*'. According to De Groot et al. (2002, p. 403), the ecological value is "determined both by the integrity of the Regulation and Habitat Functions of the ecosystem and by ecosystem parameters such as complexity, diversity, and rarity". Folke et al. (1996, p. 1021) highlight that biodiversity has an insurance value in that it enables ecosystems to function under different environmental conditions. The values instrumental for ecosystem functioning can also be integrated into an anthropocentric value framework–as instrumental values for ecosystem services and thus humans. Baumgärtner (2007), for example, discusses the insurance value of biodiversity for the provision of ecosystem services.

Anthropocentric values of biodiversity refer to values humans ascribe to the benefits they obtain from ecosystem services. These values are linked to biodiversity through the cascade depicted in Figure 2.3. Thereby they are more indirect values of biodiversity than ecocentric values and hinge on strictly positive relationships between all elements of the biodiversity–ecosystem service chain. Anthropocentric values have different spatial scales, from local over regional to global, depending on the scale of the ecosystem service as well as on human valuation. For example, provision of food on a small island belonging to country A (local ecosystem service) is valued by the island's population (local value), but the existence of food on the island may also be valued by the mainland population of country A as they do not have to transport and possibly pay for food (regional value) as well as to distant relatives of the island's inhabitants living in a far-away country B that care about their kinsman (global value). Anthropocentric values are instrumental values in that the reference point is human well-being. This implies that they are measurable through their contribution to human well-being. It also means that they are specific to those who perceive the values. Moreover, values are specific to space and time (Fisher et al. 2011). Different anthropocentric value categories and related valuation methods exist that can be grouped into a socio-cultural and an economic framework. The challenge for decision-making is to integrate these values; meta-frameworks and multi-criteria analysis are tools to assist in this endeavour (e.g. Munda (2004); Gómez-Baggethun and de Groot (2010); Chan et al. (2012)).

The socio-cultural value framework regards social values and human preferences for biodiversity. These values are often not monetised. A ranking among alternatives allows trade-offs and can guide decision-making. Valuation techniques to obtain such ranking are group deliberations and joint analysis (Gómez-Baggethun and de Groot 2010, p. 115).

The economic value framework considers trade-offs between biodiversity conservation and land use by analysing the different values humans attach to biodiversity. The concept of the *'Total Economic Value'* (TEV) depicted in Figure 2.4 integrates the values of biodiversity from an economic perspective into one framework. The TEV consists of the broad value categories 'use value' and 'non use value'.

Figure 2.4: Total economic value



Source: Adapted from TEEB (2010, Fig 5.3, p. 195).

Use values comprise the value types 'direct value', 'indirect value' and 'option value'. Humans ascribe direct values to provisional services such as food and clean water ('consumptive use value') or cultural services like recreation ('non-consumptive use value'), indirect values to regulating services such as disease regulation, and option values to services they might potentially use in the future. People assign a high option value to biodiversity if they have a low discount rate and are risk averse, i.e. if they are willing to pay much in order to ensure that biodiversity provides specific services in the future. The category 'non use value' includes the value types 'bequest value', 'altruist value' and 'existence value'. Some people value biodiversity because it provides services to future generations ('bequest value') or to other, possibly unknown, fellow humans of the own generation ('altruist value'). The mere existence of biodiversity is also valued by some people ('existence value'). People ascribe different values and different value magnitudes to biodiversity and ecosystem services. The values of biodiversity a persons perceives depend on the social, cultural, and economic background. Maslow (1943) purports that only once basic needs, which he calls 'deficit needs', are fulfilled, nature can be regarded as a luxury good.

Importantly, economic valuation[20] is not attempting an ethical valuation statement. Economic valuation cannot express holistic viz. total values. It deals with marginal values. A total value of global biodiversity or world-wide ecosystem services can hardly be meaningfully calculated (cf. the critical discussions of the famous paper *'The Value of the World's Ecosystem Services and Natural Capital'* by Costanza et al. (1997), i.a. Heal et al. (2005, p. 188 f.); Simpson (2011, p. 6 f.), but also in Costanza et al. (1997, p. 258)). Valuing total biodiversity by using a willingness-to-pay approach cannot result in a value greater than the global gross domestic product (GDP) and by employing a willingness-to-accept approach it leads to infinity (Heal et al. 2005, p. 188). Moreover, there is high uncertainty over marginal benefit curves for large ranges of biodiversity levels and how to approach discounting (Bateman et al. 2011, p. 196, 202). In any case, total values are not relevant for most decision problems as they relate to small, locally confined changes. Economic valuation is best understood as a tool and one argument among many for the conservation of biodiversity and ecosystem services. It is first and foremost a conceptualisation to communicate biodiversity to people which do not have an background in ecology or biology. This is exactly the intention the global study '*The Economics of Ecosystems and Biodiversity*' (TEEB) pursues: to make the values of biodiversity and ecosystem services visible for decision making. Balmford et al. (2002, p. 950), for example, estimate conservatively that "the overall benefit:cost ratio of an effective global program for the conservation of remaining wild nature is at least 100:1". This language is not always adequate; for other audiences intrinsic, cultural or religious

[20] Economists attempt to capture the monetary units people assign to the values of biodiversity and ecosystem services with various methods: market valuation (market prices (prices only approximate values in competitive markets (Fisher et al. 2011, p.6))), indirect market valuation methods (avoided cost, replacement cost, mitigation and adaptation cost, production function approaches), revealed preference methods (travel cost, hedonic pricing), and stated preference methods (contingent valuation, choice modelling, group valuation) (e.g. Freeman (2003), TEEB (2010, p. 196 ff.)). Economic valuation suffers from several limitations. Firstly, revealing preferences for different levels of biodiversity and ecosystem services is not straightforward due to eliciting problems (Toman 1998, p. 59). Aggregating preferences and different value types is even more challenging. Secondly, marginal benefit curves of biodiversity and ecosystem services are unknown across large ranges. Huge ecological uncertainty prevails with regard to evolutionary processes and ecological systems, their interdependencies and thresholds–and only a small share of all existing species has been discovered (Purvis and Hector 2000, p. 213). Hence, economic valuation is "necessarily incomplete" (Helm and Hepburn 2012, p. 7).

values of biodiversity might be better communication channels.[21]

2.2.3 The status and trends of global biodiversity

The multidimensional and complex nature of biodiversity renders a comprehensive assessment of *the* state of biodiversity similarly complicated and necessarily multi-faceted. The global study *'Ecosystems and Human Well-being: Current State and Trends'* of the *'The Millennium Ecosystem Assessment Series'* provides a comprehensive global assessment of the status and trends of biodiversity at the scales of biogeographic realms, biomes, species, populations, and genes (Mace et al. 2005). In all eight biogeographic realms, at least 10% of the habitats have been destroyed, with the highest percentage of 54% for the Indo-Malayan realm (ibid., p. 83). The largest percentage of total endangered species of 25% is recorded in the Oceanic realm (ibid., p. 110). On the scale of biomes, 20-50% of the land size has been transformed in more than half of the biomes, whereby the tropical dry forests are the most diminished (ibid., p. 86). Tropical biomes (tropical moist forest, tropical grasslands and savannahs, tropical dry forests) are characterised by the highest overall species richness (ibid., p. 86), but the tropical moist forest also by the highest percentage of total endangered species (ibid., p. 87).

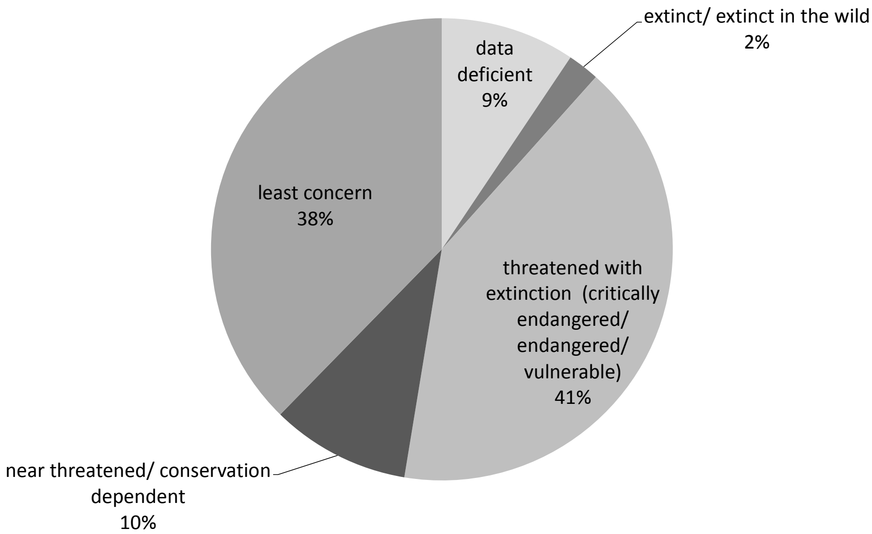
The status and trends of species (species richness viz. its decline) is measured most frequently to describe the situation of biodiversity. Still, even this assessment builds on vague figures. Only close to two million species out of an estimated three to thirty million species are formally described–whereby an upward deviation might be possible due to knowledge gaps in poorly researched groups (May 1992). Species richness is very unevenly distributed; for example, 44% of all vascular plant species and 35% of all vertebrate species belonging to the species groups mammals, birds, reptiles, and amphibians occur in only 1.4% of the planet's terrestrial surface (Myers et al. 2000). The '*Tropical Andes Hotspot*' is the leading of the 35 world biodiversity hotspots[22] (Mittermeier et al. (2004); Williams et al. (2011)). It has the highest estimated number of endemic plant and vertebrate species and the second largest remaining primary vegetation area (Mittermeier et al. 2004, p. 32 f.). The *'Red List'* of the year 2004 of the *'International Union for Conservation of Nature'* (IUCN)

[21] For some audiences economic values are even irritating and counterproductive. Moreover, there are outright critics of the concept of economic valuation (e.g. Kill 2014). A discussion about the "language"–intrinsic and ecological vs. economic values–might hinder the (common) goal of biodiversity conservation.

[22] Biodiversity hotspots are areas that host at least 0.5% of global plant species as endemic ones and that have diminished to 30% of its original size (Myers et al. 2000).

covers 38,047 species (2.5% of the world's described species) out of which 15,589 (41%) belong to the threatened with extinction categories[23] 'critically endangered', 'endangered', 'vulnerable', 844 (2%) to the categories 'extinct' or 'extinct in the wild', 3,700 (9.72%) to the category 'near threatened' or conservation dependent, 14,334 (38%) to 'least concern' category, and for 3,580 (10%) data is deficient (Baillie et al. (2004, p. 6); ref. Figure 2.5). Referencing the IUCN Red List 2004 category

Figure 2.5: Species classification according to risk of extinction (IUCN Red List 2004)



The percentages shown are referenced to the number of species covered by the IUCN Red List 2004. These are 2.5% of the world's described species.
Source: Own diagram based on data from Baillie et al. (2004, p. 6).

'species threatened with extinction' to all described species on earth, the species threatened with extinction make up just over 1% of the described species. Yet this category comprises 12% of all bird species, 23% of all mammal species, 32% of all amphibian species, and 34% of all gymnosperms (ibid., p. 6). Mace et al. (2005, p. 109) conclude that "the rate of species extinction is several orders of magnitude higher than the natural or background rate, even in birds, where the level of threat is the lowest among the assessed taxa. And the great majority of threatened species continue to decline."[24] Barnosky et al. (2011, p. 56) ascertain that further species extinctions in the 'critically endagered' category "would propel the world to a state

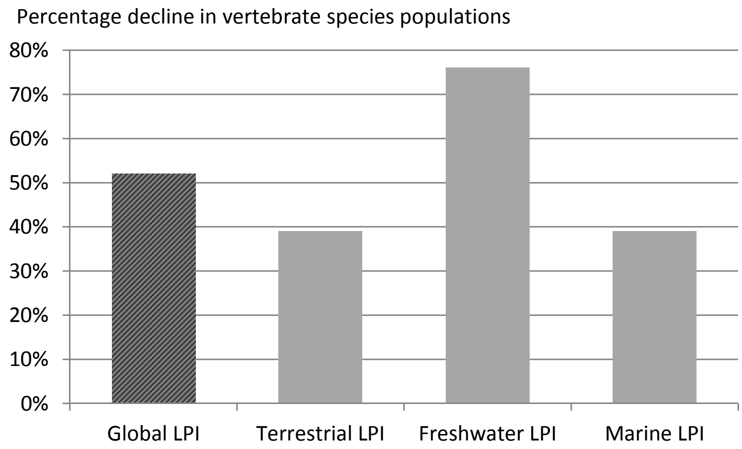
[23]For the IUCN Red List categories and criteria refer to IUCN (2012).

[24]The natural background extinction rate is 0.1 to 1 E/MSY (extinctions per million species per year). The current E/MSY of birds, mammals, and amphibians is 48 to 476 times higher (Mace et al. 2005, p. 105).

of mass extinction that has previously been seen only five times in about 540 million years" and that"additional losses of species in the 'endangered' and 'vulnerable' categories could accomplish the sixth mass extinction in just a few centuries".[25]

Populations extinctions are even much higher than species extinctions (Hughes et al. 1997, p. 691)–species are lost once all its constituting populations are lost. The *'Living Plant Index'* (LPI) of the *'World Wide Fund For Nature'* (WWF) measures trends in over 10,000 vertebrate species populations and provides the best available assessment of global population trends (Mace et al. 2005, p. 100). The LPI 2014 reveals a 52% decline of overall global vertebrate species populations between 1970 and 2010 (WWF 2014, p. 8) (ref. Fig. 2.6). The freshwater species populations

Figure 2.6: Decline in global vertebrate species populations between 1970 and 2010 (Living Plant Index 2014)



Source: Own diagram based on data from WWF (2014, p. 12).

declined by 76%, and the marine and terrestrial populations both by 39% (ibid., p. 12). The highest LPI decline occured in South America, followed by the Asia-Pacific region (ibid., p. 12). Even in terrestrial protected areas, populations declined, albeit half as fast (18% LPI decline) (ibid., p. 12).

For trends in genetic diversity, data is scarce. Fluctuating population sizes and endangered species populations tend to have less genetic diversity than their counterparts (Mace et al. 2005, p. 96, 99).

Steffen et al. (2015) (revision and update of Rockström et al. (2009)) find that

[25] A mass extinction occurs when over three quarters of species are lost within less than about two million years (Barnosky et al. 2011, p. 52).

four of nine 'planetary boundaries'[26] associated with Earth-system processes have been crossed: climate change, land-system change, and, furthest trespassed, introduction of novel entities (interference with the nitrogen cycle) and biosphere integrity (rate of biodiversity loss). The planetary boundaries describe the "safe operating space for humanity with respect to the Earth system" (Rockström et al. 2009, p. 472). Human activities contribute largely to biodiversity loss (MEA (2005, p. 96); Rockström et al. (2009, p. 474); Murphy and Romanuk (2014)). The most important driving factor for terrestrial ecosystems is widely recognised to be habitat loss through land-use change (Sala et al. (2000); Murphy and Romanuk (2014, p. 97)). Loss of habitat characteristics viz. 'quality' through habitat fragmentation, overexploitation, species invasions, climate change, nitrogen deposition, pollution, and diseases are further major drivers for biodiversity loss (MEA (2005, p. 96); Sala et al. (2000); Chapin et al. (2000, p. 234)). In freshwater ecosystems, biotic exchange in form of species introductions is the most pronounced driver of change (Sala et al. 2000). The fourth *'Global Biodiversity Outlook'* (GBO) of the CBD (UNEP (2014); Leadley et al. (2014)) paints a mixed picture of progress made over the last years in reducing the direct pressures on biodiversity and consequently also in the status of biodiversity.

2.3 International cooperation under the United Nations Convention on Biological Diversity

The recognition of the importance of biodiversity paired with its continuous decline motivates international cooperation for the conservation and sustainable and fair use of biodiversity under the CBD (Section 2.3.1) and its Nagoya Protocol (Section 2.3.2). Parties to the CBD adopted a *'Strategic Plan for Biodiversity 2011-2020'* to this end (Section 2.3.3).

2.3.1 The Convention on Biological Diversity

The United Nations *'Convention on Biological Diversity'*[27] (CBD) is the most comprehensive international agreement on biodiversity. It goes back to an *'Ad Hoc*

[26] The nine planetary boundaries originally defined by Rockström et al. (2009) are climate change, rate of biodiversity loss (terrestrial and marine) (= biosphere integrity (Steffen et al. 2015)), interference with the nitrogen and phosphorus cycles (= biogeochemical flows (Steffen et al. 2015)), stratospheric ozone depletion, ocean acidification, global freshwater use, change in land use, chemical pollution (= introduction of novel entities (Steffen et al. 2015)), and atmospheric aerosol loading.

[27] Ref. footnote 1.

Working Group of Experts on Biological Diversity', which was summoned by the *'United Nations Environment Programme'* (UNEP) in June 1987[28]–shortly after the release of the WCED (1987) report *'Our Common Future'*. It met in 1988 to discuss a potential international convention on biological diversity[29]. After intense preparatory work (cf. Boisson de Chazournes 2009) the CBD was opened for signature on 5 June 1992 at the *'United Nations Conference on Environment and Development'* (UNCED), the so-called *'Rio Conference'* or *'Earth Summit'*. The CBD entered into force on 29 December 1993 and by now counts 195 parties (including the European Union)[30]. The objectives of the CBD are "the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding" (CBD, *Art. 1*). Central provisions of the Convention pertain to the development of national biodiversity strategies and action plans (*Art. 6(a)*), the mainstreaming of biodiversity (*Art. 6(b)*), the identification and monitoring of the components of biological diversity (*Art. 7(a),(b)*), the identification of processes with significant adverse impacts on the conservation and sustainable use of biodiversity (*Art. 7(c)*), *in-situ* conservation including the establishment of protected areas (*Art. 8*), complementary *ex-situ* conservation (*Art. 9*), sustainable use of components of biological diversity (*Art. 10*), economically and socially sound measures that create incentives for biodiversity conservation and sustainable use (*Art. 11*), research and training (*Art. 12*), public education and awareness (*Art. 13*), and impact assessment and minimisation of adverse impacts (*Art. 14*). The Convention text includes specific provisions on access to genetic resources (*Art. 15*). Moreover, it covers access to and transfer of technology (*Art. 16*), exchange of information between parties (*Art. 17*), technical and scientific cooperation between parties (*Art. 18*), financial resources (*Art. 20*), and a financial mechanism (*Art. 21*). The Convention also contains provisions on the handling of biotechnology (*Art. 19*), based on which the *'Cartagena Protocol on Biosafety'*[31] was negotiated. It entered into force on 11 September 2003 and its objective is to "contribute to

[28] Governing Council of the United Nations Environment Programme decision 14/26 "Rationalization of international conventions on biological diversity", 17 June 1987.

[29] Ref. Report of the Ad Hoc Working Group of Experts on Biological Diversity on the Work of its First Session, UNEP/Bio.Div.1/3.

[30] Ref. online: www.cbd.int/information/parties.shtml, last 03.04.2015.

[31] United Nations (2000): Cartagena Protocol on Biosafety to the Convention on Biological Diversity, Montreal, 29.10.2000.

ensuring an adequate level of protection in the field of the safe transfer, handling and use of living modified organisms resulting from modern biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity" (Cartagena Protocol, *Art. 1*).

The *'Conference of the Parties'* (COP) is the CBD's governing body. At the COP, the CBD member states take decisions for the further implementation of the Convention. The last COP, the twelfth meeting, was held in the Republic of Korea in October 2014 and the next COP will take place in Mexico at the end of 2016. In-between the meetings of the COP, the *'Subsidiary Body on Scientific, Technical and Technological Advice'* (SBSTTA), the *'Subsidiary Body on Implementation'* (SBI) and other expert groups come together to prepare the COP and in particular to make recommendations for decisions to be taken by the COP. The Secretariat of the CBD is situated in Montreal, Canada. The *'Global Environmental Facility'* (GEF) acts as the financial mechanism of the Convention. Besides the *'Cartagena Protocol on Biosafety'*, a second protocol was adopted under the CBD: the *'Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization'* (ref. Section 2.3.2).

The COP initiated seven 'thematic programmes of work' and a number of 'cross-cutting issues' to advance the implementation of the CBD. The thematic programmes of work cover agricultural biodiversity, dry and sub-humid lands biodiversity, forest biodiversity, inland waters biodiversity, island biodiversity, marine and coastal biodiversity, and mountain biodiversity. Besides, the *'Strategic Plan for Biodiversity 2011-2020'* guides the implementation (ref. Section 2.3.3).

The historic context of the CBD, the Convention's objectives, and the *'Strategic Plan for Biodiversity 2011-2020'* show that sustainable development is integral to the convention. The CBD defines sustainable use as "the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations" (CBD, *Art. 2*). It is a "process-oriented sustainable development convention" (Boisson de Chazournes 2009, p. 3). Although the *'Declaration on the Responsibilities of the Present Generations Towards Future Generations'* of the *'United Nations Educational, Scientific and Cultural Organization'* (UNESCO) was adopted some years after the CBD, the CBD already complied with its provisions on the preservation of life on earth (*Art. 4*) that read "The present generations have the responsibility to bequeath to future generations an Earth which will not one day be irreversibly damaged by human activity. Each generation inheriting the Earth temporarily should take care to use natural resources reasonably and ensure that life is not prejudiced by harmful modifications of the ecosystems and that scientific and technological progress in all fields does not harm life on Earth."

The topic of sustainable and fair use of biodiversity is as important nowadays under the CBD as it has been in its founding years. In October 2014 the *'Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization'* entered into force. In the same month, the ministers participating in the high-level segment of the twelfth COP to the CBD adopted the *'Gangwon Declaration on Biodiversity for Sustainable Development'*[32] in the context of the ongoing process of developing a United Nations post-2015 development agenda and *'Sustainable Development Goals'*. Besides, the theme of the *'International Day for Biological Diversity 2015'* is "Biodiversity for Sustainable Development"[33].

2.3.2 The Nagoya Protocol

The *'Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization'*[34] (NP) is a Protocol under the CBD and addresses the third goal of the CBD. As indicated by the title of the Protocol, its objective is "the fair and equitable sharing of the benefits arising from the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding, thereby contributing to the conservation of biological diversity and the sustainable use of its components" (NP, *Art. 1*). The Nagoya Protocol applies to genetic resources covered by *Art. 15* of the CBD and related benefits as well as associated traditional knowledge and related benefits (NP, *Art. 3*). The Nagoya Protocol gives precedence to specialized international *'Access and Benefit-Sharing'* (ABS) instruments that are consistent with the objectives of the CBD and the NP (*Art. 4*). This is so far only the case for the *'International Treaty on Plant Genetic Resources for Food and Agriculture'* (ITPGRFA).

The precursor to the Nagoya Protocol are the *'Bonn Guidelines'*[35]. Shortly after

[32] Ref. online: www.cbd.int/hls-cop/gangwon-declaration-hls-cop12-en.pdf, last 03.04.2015.
[33] Ref. online: www.cbd.int/idb/default.shtml, last 03.04.2015.
[34] Ref. footnote 2.
[35] United Nations (2002): Bonn Guidelines on Access to Genetic Resources and Fair and Equitable

their adoption, the *'World Summit on Sustainable Development'* in Johannesburg in 2002 called on the CBD member states to negotiate an international regime on ABS of genetic resources under the CBD based on the Bonn Guidelines.[36] At its seventh meeting, the COP of the CBD mandated the *'Ad Hoc Open-ended Working Group on Access and Benefit-sharing'* to "elaborate and negotiate an international regime on access to genetic resources and benefit-sharing with the aim of adopting an instrument\instruments to effectively implement the provisions in Article 15 and Article 8(j) of the Convention and the three objectives of the Convention" (decision VII/19 D.1[37]). Six years later in 2010, delegates to the CBD's tenth COP adopted the Nagoya Protocol (decision X/1[38]) and established an interim governing body for the Protocol, the *'Open-ended Ad Hoc Intergovernmental Committee for the Nagoya Protocol'* (ICNP) (decision X/1, II). The ICNP met three times to prepare the first COP serving as the *'Meeting of the Parties'* to the Protocol (COP-MOP) prior to the entry into force of the Nagoya Protocol. 90 days after the 50^{th} ratification, the Nagoya Protocol entered into force on 12 October 2014 and the first COP-MOP took place immediately afterwards.

The Nagoya Protocol specifies obligations for member states regarding access to genetic resources (*Art. 6*) and to traditional knowledge associated with genetic resources (*Art. 7*) as well as to the fair and equitable benefit-sharing (*Art. 5*). A user has to obtain *'Prior Informed Consent'* (PIC) for the utilization of a genetic resource and the associated traditional knowledge from the country of origin. Then, both parties establish *'Mutually Agreed Terms'* (MAT) on ABS of the respective resources. The benefits from the utilization of genetic resources and associated traditional knowledge as well as from its subsequent applications and from a potential commercialization have to be shared fairly and equitably. To facilitate ABS, countries have to create legal certainty, clarity and transparency of their domestic ABS legislation. Domestic ABS legislation should also provide for the fair and equi-

Sharing of the Benefits Arising out of their Utilization. UNEP/CBD/COP/6/24.

[36] Ref. A/CONF.199/20, Resolution 2 'Plan of Implementation of the World Summit on Sustainable Development', Annex, Chapter IV, par. 44(o): "Negotiate within the framework of the Convention on Biological Diversity, bearing in mind the Bonn Guidelines, an international regime to promote and safeguard the fair and equitable sharing of benefits arising out of the utilization of genetic resources", online: http://daccess-ods.un.org/TMP/1725899.27911758.html, last 07.03.2015; as well as United Nations General Assembly resolution 57/260, 20 December 2002, A/RES/57/260, par. 8, online: www.un.org/en/ga/search/view_doc.asp?symbol=A/RES/57/260, last 07.03.2015.

[37] UNEP/CBD/COP/DEC/VII/19, D.1, online: www.cbd.int/doc/decisions/cop-07/cop-07-dec-19-en.pdf, last 07.03.2015.

[38] UNEP/CBD/COP/DEC/X/1, online: www.cbd.int/doc/decisions/COP-10/cop-10-dec-01-en.pdf, last 07.03.2015.

table sharing of benefits based on mutually agreed terms with indigenous and local communities holding genetic resources and associated traditional knowledge. The Nagoya Protocol requests the treaty parties to consider the need for a *'Global Multilateral Benefit-Sharing Mechanism'* (GMBSM) for transboundary genetic resources and traditional knowledge associated with genetic resources or for such genetic resources and traditional knowledge associated with genetic resources for which no PIC is possible (*Art. 10*). It explicitly encourages transboundary cooperation with regard to ABS (*Art. 11*).

The Nagoya Protocol includes regulations on tools to facilitate the implementation of ABS: model contractual clauses (*Art. 19*), codes of conduct, guidelines, and best practices and/or standards (*Art. 20*), awareness-rising (*Art. 21*) and capacity building (*Art. 22*), technology transfer, collaboration, and cooperation (*Art. 23*). The Nagoya Protocol calls upon member states to promote research that contributes to biodiversity conservation and its sustainable use (*Art. 8(a)*). Parties shall also consider health emergencies (*Art. 8(b)*) and the role of genetic resources for food security (*Art. 8(c)*) in the implementation of ABS.

Moreover, the Nagoya Protocol defines compliance obligations (*Art. 15 - 18, 30*). Member states have to ensure that genetic resources utilized within their territory have been obtained in compliance with the obligations under the Nagoya Protocol, notably PIC and MAT. They have to establish procedures for dealing with cases of non-compliance. Parties shall provide for access to justice. They shall cooperate in cases of compliance ambiguity and violation. Besides, parties have to take measures to monitor and to increase transparency regarding the utilization of genetic resources and associated traditional knowledge. At the first COP-MOP, the members to the Nagoya Protocol adopted cooperative procedures and institutional mechanisms to promote compliance with the Nagoya Protocol.[39]

The Nagoya Protocol provides for some institutional arrangements to facilitate the implementation of ABS. Parties have to specify a *'National Focal Point'* (NFP) for collaborating with the Secretariat and for providing official information on ABS provisions of their country (*Art. 13*). Parties can in addition create *'Competent National Authorities'* (CNAs) for granting access, otherwise the NFP is responsible for this task as well (ibid.). The Nagoya Protocol establishes an *'Access and Benefit-sharing Clearing-House'* (ABS CH) to share information on ABS and the parties' domestic implementation of the Protocol's provisions (*Art. 14*). The CBD

[39] UNEP/CBD/NP/COP-MOP/DEC/1/4, online: www.cbd.int/doc/decisions/NP-MOP-01/np-mop-01-dec-04-en.pdf, last 07.03.2015.

Secretariat is also the Secretariat for the Nagoya Protocol (*Art. 28*) and subsidiary bodies under the CBD can also serve under the Nagoya Protocol (*Art. 27*). Likewise, the financial mechanism for the Nagoya Protocol is the same as for the CBD, the GEF (*Art. 25*).

2.3.3 Biodiversity targets of the Convention on Biological Diversity

The *'Strategic Plan for Biodiversity'* of the CBD promotes the implementation of the Convention's three goals (ref. Section 2.3.1). The sixth COP adopted the first *'Strategic Plan for the Convention on Biological Diversity'* in 2002, ten years after the entry into force of the Convention (decision VI/26[40]). In this strategic plan the parties committed themselves "to a more effective and coherent implementation of the three objectives of the Convention, to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on earth" (ibid., Annex, par. 11). The aim to significantly reduce biodiversity loss by 2010 was also included in the *'Millennium Development Goals'* (MDGs)[41]. In 2010 the third edition of the GBO assessed the progress towards the 2010 biodiversity target and its 21 sub-targets (UNEP 2010). It attested the international community to have failed to meet the overall target as well as all sub-targets globally–although some have been partially or locally achieved (ibid., p. 17).

Following up on the lessons learned, the tenth COP endorsed the *'Strategic Plan for Biodiversity 2011-2020'* (decision X/2[42]). The vision of the current strategic plan is "Living in harmony with nature", whereby "by 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people" (ibid., II). Its mission is to

> *"take effective and urgent action to halt the loss of biodiversity in order to ensure that by 2020 ecosystems are resilient and continue to provide essential services, thereby securing the planet's variety of life, and contributing to human well-being, and poverty eradication. To ensure this, pressures on biodiversity are reduced, ecosystems are restored, biological resources are sustainably used and benefits arising out of utilization of genetic resources are shared in a fair*

[40] UNEP/CBD/COP/6/26, online: www.cbd.int/decision/cop/default.shtml?id=7200, last 07.03.2015.

[41] MDG 7c 'Reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss', ref. online: http://unstats.un.org/unsd/mdg/Host.aspx?Content=Indicators/OfficialList.htm, last 07.03.2015.

[42] UNEP/CBD/COP/DEC/X/2, online: www.cbd.int/doc/decisions/cop-10/cop-10-dec-02-en.pdf, last 07.03.2015.

> *and equitable manner; adequate financial resources are provided, capacities are enhanced, biodiversity issues and values mainstreamed, appropriate policies are effectively implemented, and decision-making is based on sound science and the precautionary approach" (ibid., III).*

To achieve its mission, the strategic plan sets out five strategic goals with twenty targets for 2015 and 2020, the *'Aichi Biodiversity Targets'* (ibid., IV). Strategic Goal A focuses at addressing "the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society". The third Aichi Target, for example, calls to eliminate, phase out or reform "by 2020, at the latest, incentives, including subsidies, harmful to biodiversity [...] in order to minimize or avoid negative impacts, and positive incentives for the conservation and sustainable use of biodiversity are developed and applied". Strategic Goal B envisions to "reduce the direct pressures on biodiversity and promote sustainable use", inter alia through the fifth Aichi Target, which states that "by 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced". Strategic Goal C aims "to improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity". Aichi Target eleven requests that "by 2020, at least 17 per cent of terrestrial and inland water areas, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes". Aichi Target twelve demands that "by 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained" and Aichi Target thirteen that by the same year "the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity". Strategic Goal D addresses the enhancement of benefits for everyone from biodiversity and ecosystem services and includes inter alia Aichi Target sixteen on the entering into force and implementation of the Nagoya Protocol. Strategic Goal E covers the "implementation through participatory planning, knowledge management and capacity building". It includes inter alia Aichi Target eighteen requesting that "by 2020, the traditional knowledge, innovations and practices of indigenous and local communities relevant for the conservation and sustainable use of biodiversity, and their customary use of biological resources, are respected, subject to national legislation and relevant international obligations, and fully integrated and reflected in the implementation of the Convention with the full and effective participation of indigenous and local communities, at all relevant levels". The strategic goals and the Aichi Biodiversity Targets should be achieved globally, but also serve as a framework for national targets.

Bibliography

Baillie, J., C. Hilton-Taylor, and S. Stuart (Eds.) (2004). *2004 IUCN Red List of Threatened Species. A Global Species Assessment.* Gland, Switzerland / Cambridge, UK: IUCN.

Balmford, A., A. Bruner, P. Cooper, R. Costanza, S. Farber, R. E. Green, M. Jenkins, P. Jefferiss, V. Jessamy, J. Madden, K. Munro, N. Myers, S. Naeem, J. Paavola, M. Rayment, S. Rosendo, J. Roughgarden, K. Trumper, and R. K. Turner (2002). Economic reasons for conserving wild nature. *Science 297*, 950–953.

Balvanera, P., A. B. Pfisterer, N. Buchmann, J.-S. He, T. Nakashizuka, D. Raffaelli, and B. Schmid (2006). Quantifying the evidence for biodiversity effects on ecosystem functioning and services. *Ecology Letters 9*, 1146–1156.

Barnosky, A. D., N. Matzke, S. Tomiya, G. O. U. Wogan, B. Swartz, T. B. Quental, C. Marshall, J. L. McGuire, E. L. Lindsey, K. C. Maguire, B. Mersey, and E. A. Ferrer (2011). Has the earth's sixth mass extinction already arrived? *Nature 471*, 51–57.

Baron, J. and M. Spranca (1997). Protected values. *Organizational Behavior and Human Decision Processes 70*(1), 1 – 16.

Bateman, I. J., G. M. Mace, C. Fezzi, G. Atkinson, and K. Turner (2011). Economic analysis for ecosystem service assessments. *Environmental and Resource Economics 48*(2), 177–218.

Baumgärtner, S. (2007). The insurance value of biodiversity in the provision of ecosystem services. *Natural Resource Modeling 20*(1), 87–127.

Benson, D. A., K. Clark, I. Karsch-Mizrachi, D. J. Lipman, J. Ostell, and E. W. Sayers (2014). Genbank. *Nucleic Acids Research 42*(Database issue), D32–D37.

Boisson de Chazournes, L. (2009). Convention on Biological Diversity and its Protocol on Biosafety. United Nations Audiovisual Library of International Law. Online http://legal.un.org/avl/ha/cpbcbd/cpbcbd.html (01.02.2015).

Boyd, J. and S. Banzhaf (2007). What are ecosystem services? The need for standardized environmental accounting units. *Ecological Economics 63*(2-3), 616–626.

Cardinale, B. J., D. S. Srivastava, J. E. Duffy, J. P. Wright, L. Downing, A., M. Sankaran, and C. Jouseau (2006). Effects of biodiversity on the functioning of trophic groups and ecosystems. *Nature 443*, 989–992.

Chan, K. M. A., T. Satterfield, and J. Goldstein (2012). Rethinking ecosystem services to better address and navigate cultural values. *Ecological Economics 74*, 8–18.

Chapin, F. S. I., E. S. Zavaleta, V. T. Eviner, R. L. Naylor, P. M. Vitousek, H. L. I. Reynolds, D. U. Hooper, S. Lavorel, O. E. SalaI, S. E. Hobbie, M. C. Mack, and S. Díaz (2000). Consequences of changing biodiversity. *Nature 405*, 234–242.

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. V. O'Neill, J. Paruelo, R. G. Raskin, P. Sutton, and M. van den Belt (1997). The value of the world's ecosystem services and natural capital. *Nature 387*(6630), 253 – 260.

De Groot, R. (1992). *Functions of Nature: Evaluation of Nature in Environmental Planning, Management and Decision Making.* Groningen: Wolters-Noordhoff.

De Groot, R. S., M. A. Wilson, and R. M. J. Boumans (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics 41*(3), 393–408.

Fisher, B., I. J. Bateman, and R. K. Turner (2011). Valuing ecosystem services: Benefits, values, space and time. *United Nations Enviornment Programme Ecosystem Services Economics (ESE) Working Paper Series 3*, 1–11.

Fisher, B., R. K. Turner, and P. Morling (2009). Defining and classifying ecosystem services for decision making. *Ecological Economics 68*(3), 643–653.

Folke, C., C. S. Holling, and C. Perrings (1996). Biological diversity, ecosystems, and the human scale. *Ecological Applications 6*(4), 1018–1024.

Freeman, A. (2003). *The Measurement of Environmental and Resource Values: Theory and Methods* (2 ed.). Washington: Resources for the Future.

Gepts, P. (2004). Who owns biodiversity, and how should the owners be compensated? *Plant Physiology 134*, 1295–1307.

Gómez-Baggethun, E. and R. de Groot (2010). Natural capital and ecosystem services: The ecological foundation of human society. In R. Hester and R. Harrison (Eds.), *Ecosystem Services*, Volume 30 of *Issues in Environmental Science and Technology*, pp. 118–145. Royal Society of Chemistry Cambridge.

Gren, I.-M., C. Folke, K. Turner, and I. Batemen (1994). Primary and secondary values of wetland ecosystems. *Environmental and Resource Economics 4*(1), 55–74.

Heal, G. M., E. B. Barbier, K. J. Boyle, A. P. Covich, S. P. Gloss, C. H. Hershner, J. P. Hoehn, C. M. Pringle, S. Polasky, K. Segerson, and S.-F. K. (2005). *Valuing Ecosystem Services. Toward better environmental decision-making.* Washington: The National Academies Press.

Helm, D. and C. Hepburn (2012). The economic analysis of biodiversity: An assessment. *Oxford Review of Economic Policy 28*(1), 1–21.

Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics 4*(4), 1–23.

Hooper, D. U., E. C. Adair, B. J. Cardinale, J. E. K. Byrnes, B. A. Hungate, K. L. Matulich, A. Gonzalez, J. E. Duffy, L. Gamfeldt, and M. I. O'Connor (2012). A global synthesis reveals biodiversity loss as a major driver of ecosystem change. *Nature 486*, 105–108.

Hughes, J. B., G. C. Daily, and P. R. Ehrlich (1997). Population diversity: its extent and extinction. *Science 278*, 689–692.

IUCN (2000/2012). IUCN Red List Categories and Criteria. Version 3.1 Second edition, As approved by the 51st meeting of the IUCN Council Gland, Switzerland.

Kill, J. (2014). *Economic Valuation of Nature. The Price to Pay for Conservation? A critical exploration.* Brussels: Rosa Luxemburg Foundation.

Laird, S. and R. Wynberg (2012). *Bioscience at a Crossroads: Implementing the Nagoya Protocol on Access and Benefit Sharing in a Time of Scientific, Technological and Industry Change.* Montreal: Secretariat of the Convention on Biological Diversity.

Leadley, P. W., C. B. Krug, R. Alkemade, H. M. Pereira, U. R. Sumaila, M. Walpole, A. Marques, T. Newbold, L. S. L. Teh, J. van Kolck, C. Bellard, S. R. Januchowski-Hartley, and P. J. Mumby (2014). Progress towards the Aichi Biodiversity Targets: An assessment of biodiversity trends, policy scenarios and key actions. Technical Series 78, Secretariat of the Convention on Biological Diversity, Montreal.

Lerch, A. (1998). Property rights and biodiversity. *European Journal of Law and Economics 6*, 285–304.

Mace, G., H. Masundire, and J. Baillie (2005). Biodiversity. In R. Hassan, R. Scholes, and N. Ash (Eds.), *Ecosystems and Human Well-being: Current State and Trends, Volume 1*, The Millennium Ecosystem Assessment Series, Chapter 4, pp. 77–122. Washington, DC: Island Press.

Mace, G. M., K. Norris, and A. H. Fitter (2012). Biodiversity and ecosystem services: A multilayered relationship. *Trends in Ecology and Evolution 27*(1), 19–26.

Mäler, K.-G., S. Aniyar, and Å. Jansson (2009). Accounting for ecosystems. *Environmental and Resource Economics 42*, 39 – 51.

Maslow, A. (1943). A theory of human motivation. *Psychological review 50*, 370 – 396.

May, R. M. (1992). How many species inhabit the earth? *Scientific American 267*(4), 42–48.

Mazzotta, M. J. and J. Kline (1995). Environmental philosophy and the concept of nonuse value. *Land Economics 71*(2), 244–249.

MEA (2005). *Ecosystems and Human Well-being: Biodiversity Synthesis.* Millennium Ecosystem Assessment. Washington, DC: World Resources Institute.

Meinard, Y., S. Coq, and B. Schmid (2014). A constructivist approach toward a general definition of biodiversity. *Ethics, Policy & Environment 17*(1), 88–104.

Mittermeier, R. A., G. P. Robles, M. Hoffmann, J. D. Pilgrim, T. Brooks, C. G. Mittermeier, J. Lamoreux, and G. A. B. da Fonseca (2004). *Hotspots revisited: Earth's biologically richest and most endangered ecoregions.* Mexico City: CEMEX.

Munda, G. (2004). Social multi-criteria evaluation: Methodological foundations and operational consequences. *European Journal of Operational Research 158*(3), 662 – 677.

Murphy, G. E. P. and T. N. Romanuk (2014). A meta-analysis of declines in local species richness from human disturbances. *Ecology and Evolution 4*(1), 91–103.

Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. B. da Fonseca, and J. Kent (2000). Biodiversity hotspots for conservation priorities. *Nature 403*, 853–858.

Nakamura, Y., G. Cochrane, and I. Karsch-Mizrachi (2013). The international nucleotide sequence database collaboration. *Nucleic Acids Research 41*(Database issue), D21–D24.

OECD (2013). *Scaling-up Finance Mechanisms for Biodiversity.* OECD Publishing.

Oldham, P., S. Hall, and O. Forero (2013). Biological diversity in the patent system. *PLoS One 8*(11), e78737.

Pascual, U. and C. Perrings (2007). Developing incentives and economic mechanisms for in situ biodiversity conservation in agricultural landscapes. *Agriculture, Ecosystems and Environment 121*, 256–268.

Purvis, A. and A. Hector (2000). Getting the measure of biodiversity. *Nature 405*, 212–219.

Rockström, J., W. Steffen, K. Noone, A. Persson, F. S. Chapin, E. F. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. J. Schellnhuber, B. Nykvist, C. A. de Wit, T. Hughes, S. van der Leeuw, H. Rodhe, S. Sörlin, P. K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Karlberg, R. W. Corell, V. J. Fabry, J. Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen, and J. A. Foley (2009). A safe operating space for humanity. *Nature 461*, 472–475.

Sala, O. E., F. Stuart Chapin, III, J. J. Armesto, E. Berlow, J. Bloomfield, R. Dirzo, E. Huber-Sanwald, L. F. Huenneke, R. B. Jackson, A. Kinzig, R. Leemans, D. M. Lodge, H. A. Mooney, M. Oesterheld, N. L. Poff, M. T. Sykes, B. H. Walker,

M. Walker, and D. H. Wall (2000). Global biodiversity scenarios for the year 2100. *Science 287*(5459), 1770–1774.

Sandler (1993). Tropical deforestation: Markets and market failures. *Land Economics 69*(3), 225–233.

Schei, P. J. and M. W. Tvedt (2010). "Genetic Resources" in the CBD: The wording, the past, the present and the future. Submission to the Executive Secretary of the Convention on Biological Diversity, UNEP/CBD/WG-ABS/9/INF/1.

Schwartz, M. W., C. A. Brigham, J. D. Hoeksema, K. G. Lyons, M. H. Mills, and P. J. Mantgem (2000). Linking biodiversity to ecosystem functioning: Implications for conservation ecology. *Oecologia 122*(3), 297–305.

Sedjo, R. A. (1992). Property rights, genetic resources, and biotechnological change. *The Journal of Law and Economics 35*(1), 199–213.

Simpson, R. D. (2011). The "ecosystem service framework": A critical assessment. *The United Nations Environment Programme Ecosystem Services Economics (ESE) Working Paper Series 5*, 1–20.

Solow, A., S. Polasky, and J. Broadus (1993). On the measurement of biological diversity. *Journal of Environmental Economics and Management 24*, 60–68.

Steffen, W., K. Richardson, J. Rockström, S. E. Cornell, I. Fetzer, E. M. Bennett, R. Biggs, S. R. Carpenter, W. de Vries, C. A. de Wit, C. Folke, D. Gerten, J. Heinke, G. M. Mace, L. M. Persson, V. Ramanathan, B. Reyers, and S. Sörlin (2015). Planetary boundaries: Guiding human development on a changing planet. *Science 347*(6223).

TEEB (2010). *The Eocnomics of Ecosystems and Biodiversity: Ecological and Economic Foundations.* London and Washington: Earthscan.

Tilman, D. (1999). The ecological consequences of biodiversity: A search for general principles. *Ecology 80*(5), 1455 – 1474.

Toman, M. (1998). Why not to calculate the value of the world's ecosystem services and natural capital. *Ecological Economics 25*(1), 57–60.

UNEP (2010). *Global Biodiversity Outlook 3.* Montréal: United Nations Environment Programme, Secretariat of the Convention on Biological Diversity.

UNEP (2014). *Global Biodiversity Outlook 4.* Montréal: United Nations Environment Programme, Secretariat of the Convention on Biological Diversity.

WCED (1987). *Our Common Future.* World Commission on Environment and Development. Oxford: Oxford University Press.

Williams, K. J., A. Ford, D. F. Rosauer, N. De Silva, R. Mittermeier, C. Bruce, F. W. Larsen, and C. Margules (2011). Forests of East Australia: The 35th biodiversity hotspot. In F. E. Zachos and J. C. Habel (Eds.), *Biodiversity Hotspots. Distribution and Protection of Conservation Priority Areas*, Berlin/Mannheim, pp. 295–310. Springer.

Wilson, E. O. (1997). *Biodiversity II: Understanding and Protecting Our Biological Resources*, Chapter Introduction, pp. 1–3. Joseph Henry Press.

Winands, S., K. Holm-Müller, and H.-P. Weikard (2013). The biodiversity conservation game with heterogeneous countries. *Ecological Economics 89*, 14–23.

WWF (2014). *Living Planet Report 2014: Species and spaces, people and place.* Gland, Switzerland: World Wide Fund For Nature.

Part I

Modelling Cooperation for Biodiversity Conservation

Chapter 3

The Biodiversity Conservation Game with Heterogeneous Countries

Abstract: Biodiversity is an essential resource, which we classify as conditionally-renewable. In order to achieve conservation and sustainable use of biodiversity virtually all nation states signed the United Nations *'Convention on Biological Diversity'*. In this chapter we investigate how the heterogeneity of countries in regard to ecosystems and wealth influences the stability of international biodiversity conservation agreements both without and with transfers. We further examine the effect of different degrees of ecosystem substitutability. We model a coalition formation game with players that have a continuous conservation choice. The conservation benefit is dependent on wealth and ecosystem quality. Aggregation of global benefits respects differences in ecosystem substitutability. In case of transfers, a fund redistributes coalition benefits according to a sharing rule. The main finding is that in the absence of transfers, compared to the homogeneous situation, heterogeneity in ecosystems and wealth reduces the size of a stable coalition. The destabilising effect is stronger the higher the ecosystem substitutability. Optimal transfers facilitate a large stable coalition.

3.1 Introduction

Biodiversity is an *essential resource* as its marginal benefits approach infinity with increasing depletion. Indeed, biodiversity is the backbone of human life. The need for

Chapter 3 has been published as: *Winands, S., K. Holm-Müller, and H.-P. Weikard (2013). The biodiversity conservation game with heterogeneous countries. Ecological Economics 89, 14-23.* A first analysis can be found in Winands (2011), which has partly been published in Winands (2012).

its (partial) conservation enjoys a wide consensus among individuals and countries worldwide. Unfortunately, goodwill and the rising costs associated with increasing depletion are insufficient for conservation. As many services of biodiversity exhibit characteristics of global public goods, international cooperation is needed to prevent suboptimal conservation levels. The challenge and aspiration of such international environmental agreements (IEAs) are to be self-enforcing in the absence of a worldwide government while assuring real cooperation. The *'Convention on Biological Diversity'*[1] (CBD) is an IEA that achieves (nearly) full cooperation and codifies the sovereignty of nation states over their biological resources.[2] A common pitfall for agreements, which also applies to the CBD, is to codify more or less an outcome which is unilaterally beneficial. The game theoretic model result of Barrett's (1994) Biodiversity Supergame seems to confirm that the CBD is unable to improve much upon global welfare compared to the non-cooperative scenario. We argue, however, that Barrett's disillusioning result originates from his restrictive model assumptions. From Weikard (2009, p. 578) we know that "Barrett's results do not generalize to cases where players differ with respect to their marginal benefits of the public good". Beyond doubt, countries do not benefit equally from biodiversity conservation.

Our main objective is to contribute to the game theoretic modelling and thereby enhance the understanding of cooperation incentives and coalition stability in international biodiversity conservation cooperation. Specifically, we investigate how heterogeneity in ecosystems[3] and wealth impact the stability of international biodiversity conservation agreements among differing participants. We model competitive land use between biodiversity conservation and other activities such as agriculture, but do not consider the specific case of biological diversity of agriculturally used crops and their governance regimes (Droege and Soete 2001). Our Biodiversity Game is an international biodiversity conservation game with heterogeneous players and benefit sharing. Some form of fund, which functions as the financial mechanism, redistributes coalition benefits according to a specific sharing rule. We solve the Biodiversity Game sequentially in three stages. In the analysis, we examine a "real world

[1] United Nations (1992): Convention on Biological Diversity, 31 Int'l Leg. Mat. 818, Rio de Janeiro, 05.06.1992.

[2] Biological resources are defined by the Convention on Biological Diversity (CBD, Art. 2) as "genetic resources, organisms or parts thereof, populations, or any other biotic component of ecosystems with actual or potential use or value for humanity", and biological diversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems".

[3] For simplification, we focus on the *ecosystem level* (omitting the levels *species* and *genetic diversity*).

scenario" as base scenario, reproduce a "Barrett scenario", and subsequently vary parameters to better understand the impact of biodiversity quality, ecosystem substitutability and countries' wealth. Formally, we mainly differ from Barrett's (1994) Biodiversity Supergame by assuming non-identical countries (different ecosystems and wealth), explicitly considering local benefits, assuming an ecosystem resilience threshold, and most notably by respecting the imperfect substitutability between biodiversity services. To our knowledge, the consideration of imperfect ecosystem substitutability or even imperfect complementarity is unique in stability analyses of biodiversity conservation agreements.

The chapter proceeds as follows: In Section 2 we discuss the key model characteristics of heterogeneity in the attributes 'ecosystems' and 'wealth'. In Section 3 we present the model, first the rationale of the general Biodiversity Game, and then formally the stages of the Biodiversity Game using a general specification. Next in Section 4, we provide a numerical appraisal of the Biodiversity Game for specific functional forms and parameters, together with a sensitivity analysis and discussion of the results. With Section 5 we conclude.

3.2 Model characteristics: heterogeneity in attributes

We consider a set $N = \{1, 2, ..., n\}$ of countries with n equal to the number of internationally recognised countries that participate in the Biodiversity Game. These countries are heterogeneous in the two dimensions 'wealth' and 'biodiversity richness', other aspects being identical. Coalition formation is influenced on the supply side by differences in ecosystems (Section 3.2.1) and on the demand side by wealth heterogeneity (Section 3.2.2).

3.2.1 Heterogeneity in ecosystems

In this subsection we focus on the supply side differences of the biodiversity conservation game. Supply of biodiversity conservation is influenced by the general reproduction dynamics of biodiversity and differences in biodiversity richness between countries, both natural and human-induced such as forest clearing.

The reproduction dynamics of biodiversity are decisive for economic exploitation and conservation decisions. Biodiversity is a stock resource, as its present use determines its future availability. Biological resources naturally reproduce themselves. Nevertheless, they are exhaustible under certain circumstances: the reproduction is contingent on human exploitation levels and certain environmental conditions such as soil, air, solar and climate characteristics. We classify biological resources as '*conditionally-renewable*'. If a certain critical minimum resource share (here ecosystem size in hectare) is conserved, they are renewable; otherwise, they become extinct.

We discuss differences in the countries' biodiversity richness in terms of ecosystem heterogeneity. An ecosystem of some country i belongs to a particular ecosystem type e with $e \in \{1, ..., m\}$. An ecosystem type e provides a distinct set of ecosystem services. The *'Millennium Ecosystem Assessment'* (MEA) assigns these services to the four broad service categories: supporting, provisioning, regulating and cultural services (MEA 2005, p. 19), similar to those used by Barbier et al. (1994, p. 45). Generally these biodiversity services arise from *biological resources*. *Biological variability* in turn ensures their elastic and robust provision (cf. Purvis and Hector 2000, p. 216). These services, because valued by humans, translate into benefits. An ecosystem type e is characterised by its *quality* q_e in terms of biological diversity, and its *productivity* y_e for other purposes than conservation, where q_e and y_e are exogenously given parameters of the model. q_e influences local and global benefits obtained from biodiversity services and y_e affects local benefits from non-conservation uses. Opportunity costs per hectare of conserved land arise, depending on the ecosystem's location, from various potential uses; we employ agricultural use as representative use under which we subsume all other uses. The ecosystems with the highest parameter values for q_e are biodiversity hotspots. Globally 35 biodiversity hotspots have been identified (Mittermeier et al. (2004); Williams et al. (2011))–areas hosting at least 0.5 % of global plant species: these hotspot areas, despite covering only 1.4 % of the global land area, comprise 44 % of global vascular plant species and 35 % of all vertebrate species (mammals, birds, reptiles, amphibians).

As the services of different ecosystems are not identical, substitution of ecosystems through other ecosystems or other goods is limited. Tropical rainforests for example cannot be perfectly substituted by boreal forests. Substitution through other goods is especially limited in case of life-support functions. Perfect artificial substitutes of biodiversity services are not available.

3.2.2 Heterogeneity in wealth

In this subsection we address the demand side differences of the biodiversity conservation game. In our model demand side differences stem from wealth discrepancies between countries. Wealthy countries are assumed to have both a high gross domestic product and an advanced technological development.

Wealth heterogeneity influences the demand side through differences in valuing biodiversity. A country's demand for biodiversity largely influences its degree of cooperation in global biodiversity conservation. It is a function of the inhabitants' demand viz. preference for biodiversity conservation, which in turn is dependent on their need of biodiversity. Individuals value biodiversity services on the basis of their use–to satisfy, among others, physiological needs (use value). Moreover, they consider today's unknown future demand, the potential future value (option value). The option value as an insurance value addresses inter alia safety needs and as a quasi-option value information gains for irreversible decisions (Weikard 2003). We assume a positive option value as the de facto loss of biodiversity is irreversible and the future costs of such loss are highly uncertain.

Besides the risk preference, wealth influences the valuation. Wealthy countries will attach, for example, higher recreational values to biodiversity. Pimm (1997, p. 231) reports that an assumption of Robert Costanza and his colleagues in their seminal research on 'the value of the world's ecosystem services and natural capital' is that the cultural values rich countries ascribe to their coasts are 100 times higher than those of poor countries. Lavoie (2004, p. 639) considers the "principle of subordination of needs" to apply especially to "moral choices or public goods such as the environment". There is evidence for lexicographic preferences in biodiversity valuation (Gowdy and Mayumi 2001, p. 228). Only once all fundamental need categories are fulfilled, a person will perceive and value nature and its biological variability as a luxury good. Many individuals tend to develop environmental concerns and a pronounced sense of responsibility for nature, once they are freed from basic living concerns. Similarly, biological variability increases benefits for variety-loving consumers. Arguably, income viz. wealth is the main determinant of the hierarchy of needs (Lavoie 2004, p. 646), and thus of the value ascribed to a certain biodiversity service.

Wealth heterogeneity influences the demand side also through differences in the countries' exploitation possibilities of biodiversity. Wealthier countries tend to have more human resources and to invest more in research and development.

We use parameter ω_i to capture the wealth dependent differences in valuing biodiversity and exploitation possibilities of biodiversity; it increases with rising wealth and is a multiplier of local and global benefits in the benefit function.

3.3 The Model

In this section we derive a formal game theoretic model, labelled Biodiversity Game. It is a three-stage game in which $N = \{1, 2, ..., n\}$ countries first individually decide whether to sign a biodiversity treaty or not, secondly the signatories mutually agree on how much to conserve jointly, and thirdly the non-signatories individually settle on a conservation choice. The Biodiversity Game thereby determines for each country i the optimal ecosystem protection (or conservation) share $P_{e,i}$ of an ecosystem type e under each coalition K. It then examines which sets of $P_{e,i}$'s belong to a stable coalition.

The section proceeds as follows: In Section 3.3.1 we outline the countries' options in making a biodiversity conservation choice. Next, in Section 3.3.2 we describe the countries' conservation pay-offs and present the biodiversity conservation outcome. Finally, we establish the stage game of biodiversity conservation in Section 3.3.3.

3.3.1 Continuous biodiversity conservation choice

Countries decide about the usage of their ecosystems' status-quo size, each of which we normalise to 1. They can either choose *protection* $P_{e,i}$ or *use*[4] $U_{e,i}$ of an ecosystem of type e: $P_{e,i} + U_{e,i} = 1$, where P_i depicts the vector $P_i = (P_{1,i}, P_{2,i}, ..., P_{m,i})$, P the vector $P = (P_1, P_2, ..., P_n)$, U_i the vector $U_i = (U_{1,i}, U_{2,i}, ..., U_{m,i})$, and U the vector $U_i = (U_1, ..., U_n)$. The conservation share of an ecosystem $P_{e,i}$ in terms of size, e.g. hectares, is the control variable of the Biodiversity Game. Conservation $P_{e,i} = 1 - U_{e,i}$ is a continuous choice $P_{e,i} \in [0, 1]$. For simplicity we assume that all countries are identical in size, which allows us to compare $P_{e,i}$'s of different countries.

The exhaustion of country i's ecosystem e is a reduction of that ecosystem's size below a threshold $P_{e,i,Min}$, where the ecosystem loses its specific functionality (cf. Folke et al. 1996). The ecosystem is only resilient[5] above this threshold. Determining the correct $P_{e,i,Min}$ requires perfect information on ecosystem behaviour, interdependencies with other systems, thresholds and feedback loops. Ecological uncertainty may hence justify an insurance margin. As biodiversity is essential for human survival, extinction of all ecosystems leads to infinite marginal utility–i.e.

[4] Agricultural production generates biotic resources which are harvested. For modelling simplicity, we do not differentiate between U and the harvested biotic resources which are produced on the land U.

[5] Resilience describes the ability of an ecosystem to retain its structure (organisation and function) following a disruption (e.g. Holling 1973).

humankind is willing to pay an arbitrarily high amount to prevent extinction. By anticipating future extinction for $P_{e,i} < P_{e,i,Min}$ in the benefit function, conservation shares equal to $P_{e,i,Min}$ must already lead to infinite marginal benefits in the static benefit function (see Figure 3.1).[6]

3.3.2 Biodiversity conservation pay-offs and outcome

Biodiversity services have local, regional and global dimensions. Local rainforests, for example, provide for a significant share of the global oxygen turnover (global benefit) and contribute to the regional water and temperature circulation, thus preventing droughts (regional benefit).

We define all biodiversity services a nation state can appropriate as local benefits $b^l_{e,i}(P_{e,i}, q_e, \omega_i)$. Otherwise we consider the benefit to be global. This categorisation is justified, because nation states are the level of consideration in the Biodiversity Game, and because sovereign states exist, which are endorsed with the power to regulate access. Countries have an incentive to supply appropriable services through costly conservation measures, because they alone reap the benefits from these measures. Local benefits $b^l_{e,i}(P_{e,i}, q_e, \omega_i)$ from biodiversity for an ecosystem type e depend on the control variable *conserved ecosystem share* $P_{e,i}$, and the parameters biodiversity *quality* q_e and *wealth* ω_i. The function $B^l_i(P_i)$ denotes the total $b^l_{e,i}(P_{e,i}, q_e, \omega_i)$ of a country i additively aggregated over all ecosystem types e.

The function $b^g_{e,i}(P_e, q_e, \omega_i)$ describes the benefits from services a country cannot appropriate. Non-appropriable services belong to the categories public goods and common pool resources. Non-exclusion implies that countries benefit from the services generated by those countries, who have engaged in costly conservation measures. Hence, there is too little incentive for biodiversity conservation. This leads to an under-supply of biodiversity services in the absence of international cooperation. Global benefits $b^g_{e,i}(P_e)$ arise from biodiversity for each ecosystem type e being the sum of all countries' ecosystems of type e. For example, global benefits from the ecosystem type 'rainforest' are the aggregated benefits generated from the rainforest of each country that hosts the ecosystem rainforest. Global benefits $b^g_{e,i}(P_e, q_e, \omega_i)$ depend on the control variable *conserved ecosystem share* P_e, and the parameters *biodiversity quality* q_e and *wealth* ω_i. $B^g_i(P)$ denotes the total $b^g_{e,i}(P_e, q_e, \omega_i)$ of country i additively aggregated over all ecosystem types e. Total benefits from biodiversity services comprise both local and global benefits. Here, the benefits represent

[6] This presupposes that humans weigh the future with a discount factor greater than zero, i.e. they are not perfectly myopic.

discounted present values for a certain time horizon.

The agriculturally used land U generates local benefits from logging and harvesting for each ecosystem e in country i. These are opportunity costs of biodiversity conservation, $z_{e,i}(U_{e,i}, y_e)$. They have the properties 'easy exclusion' and 'high subtractability', and are thus private goods. Opportunity costs $z_{e,i}(U_{e,i}, y_e)$ depend on the variable *agriculturally used land share* $U_{e,i}$ and the parameter *soil quality* y_e. Opportunity conservation costs are ecosystem and country specific. $Z_i(U_i)$ denotes the sum of $z_{e,i}(U_{e,i}, y_e)$ over all ecosystem types e of country i. They represent discounted present values for a certain time horizon. Note that the conservation costs in this model only cover opportunity costs of conservation due to forgone logging and harvest of primary production factors. The small costs arising from conservation efforts (wild nature largely cares best for itself) such as potential fencing of a protected area are negligible.[7]

The following equation describes the i-th country's pay-off:

$$\pi_i(P_i, P_{j \in N \setminus \{i\}}) = B_i^l(P_i) + B_i^g(P) + Z_i(1 - P_i) \ , \tag{3.1}$$

where 1 is the vector (1,1,...,1) and $U_i = 1 - P_i$. Countries obtain local benefits from their own, appropriable services; global benefits from services not appropriable by any country; and benefits from agriculturally used land within their country. The aggregate pay-off is the sum of the individual pay-offs of a country i and other countries $j \in N \setminus \{i\}$:

$$\pi_N(P) = \sum_{i \in N} [\pi_i(P_i, P_{j \in N \setminus \{i\}})] \ . \tag{3.2}$$

The global biodiversity conservation outcome depends on the countries' maximisation behaviour. Without cooperation, countries realise a Nash-equilibrium by unilaterally solving the following maximisation problem for a given $P_{j \in N \setminus \{i\}}$:

$$\max_{P_i} \ \pi_i(P_i, P_{j \in N \setminus \{i\}}) \ . \tag{3.3}$$

[7] Inamdar et al. (1999) give estimates of opportunity costs of protected areas and management investment.

The social optimum is achieved by full cooperation according to

$$\max_{P} \sum_{i \in N} \pi_i(P_i, P_{j \in N \setminus \{i\}}) \ . \tag{3.4}$$

The social optimum can be reached entailing a Pareto improvement if the model includes transfers. Often however, a coalition achieves only partial cooperation. The coalition size, its composition and the strategies of signatories to the coalition and non-signatories are determined by solving the stage game (Section 3.3.3).

3.3.3 The stage game of biodiversity conservation

The general modelling approach of the Biodiversity Game follows established environmental game theoretic models. In the international environmental agreements literature, problems are generally analysed by a two-stage game (e.g Barrett (2003); Hoel (1992)). The Biodiversity Game is analogously solved by backward induction, however played in three stages[8]. In contrast to the pollution-game it is not an aggregate effort game as ecosystems are imperfect substitutes whereas pollution of different countries is considered a perfect substitute. In addition, the Biodiversity Game contains a threshold $P_{e,i,Min}$ below which the ecosystem loses its functionality–$P_{e,i}$ equal to $P_{e,i,Min}$ yielding infinite marginal benefits.

The first stage of the game requires $N = \{1, 2, ..., n\}$ countries, with $n \geq 2$, to take the binary decision of treaty signature under individual rationality. K denotes the set of treaty members. Thereby $K = N$ is full cooperation, the grand biodiversity conservation coalition. In the second stage, all signatory countries mutually settle on a joint total conservation choice, whereby protection shares can differ between signatory countries. We model the coalition as a single player. It decides on a protection level $0 < P_{e,i} \leq 1$. In stage three, the non-signatories individually choose their protection level. The countries thus engage in a Stackelberg competition. Sequential moves seem plausible as the biodiversity-conserving coalition, by definition, aims to be a first mover in biodiversity conservation. The coalition is the quantity leader and the non-signatories are quantity-followers.

Solving the three-stage game by means of backward induction gives a subgame-

[8]In the pollution game (e.g. Barrett 2003), stages two and three can be amalgamated: the dominant strategy for non-signatories is always Pollute, i.e. no influence is exerted by the previous two stages on the behaviour of non-signatories. In the Biodiversity Game however 'no conservation' will not be a dominant strategy due to the characteristics of the benefit function (non-linear, includes local benefits). Thereby it seems probable that some conservation will be undertaken by the non-signatories.

perfect equilibrium. Both the coalition and the non-signatories maximise their pay-off. Non-signatories behave individually rationally, signatories by contrast reason collectively. The coalition being the Stackelberg leader considers the non-signatories' pay-off maximisation problem to make an optimal conservation choice. Thus, we solve the profit-maximisation problem of the non-signatories (step three) first. An interior solution results for a concave benefit and a convex cost function. The interior solution is determined by:

$$\begin{aligned} 0 &= \frac{\partial \pi_i(P_i, P_{j\in N\setminus\{\{i\}\cup K\}}, P_k^K)}{\partial P_{e,i}} \\ &= \frac{\partial B_i^l(P_i)}{\partial P_{e,i}} + \frac{\partial B_i^g(P_i, P_{j\in N\setminus\{\{i\}\cup K\}}, P_k^K)}{\partial P_{e,i}} + \frac{\partial Z_i(1-P_i)}{\partial P_{e,i}} \quad \forall i \in N\setminus K \text{ and } \forall e. \end{aligned} \tag{3.5}$$

Non-signatories take into account the other players' conservation choice, i.e. of other non-signatories $j \in N \setminus \{\{i\} \cup K\}$ and coalition members k, but as given parameters $P_{j\in N\setminus\{\{i\}\cup K\}}$ and P_k^K, the conservation vector for all signatories for each ecosystem. As the non-signatories react to the coalition's conservation choice, their pay-off maximisation problem is reformulated into the reaction function:

$$P_{e,i\in N\setminus K} = r_{e,i\in N\setminus K}(P_{j\in N\setminus\{\{i\}\cup K\}}, P_k^K) \ . \tag{3.6}$$

The reaction function $r_{e,i\in N\setminus K}(P_{j\in N\setminus\{\{i\}\cup K\}}, P_k^K)$ determines the conservation choice of the non-signatories $P_{e,i\in N\setminus K}$.

Stage two establishes the optimal strategy of the coalition. Signatories maximise their aggregate pay-off $\sum_{i\in K} \pi_i$ subject to the reaction function (Eq. 3.6):

$$\max \sum_{i\in K} \pi_i(P_i, P_{j\in K\setminus\{i\}}, r_{j\in N\setminus K}(P_{j\in N\setminus\{\{i\}\cup K\}}, P_k^K)) \ , \tag{3.7}$$

where the set $j \in K \setminus \{i\}$ refers to other coalition members. The interior solution is determined by:

$$
\begin{aligned}
0 &= \sum_{i\in K} \frac{\partial \pi_i(P_i, P_{j\in K\setminus\{i\}}, r_{j\in N\setminus K}(P_{j\in N\setminus\{\{i\}\cup K\}}, P_k^K))}{\partial P_{e,i}} \\
&= \sum_{i\in K} \left(\frac{\partial B_i^l(P_i)}{\partial P_{e,i}} + \frac{\partial B_i^g(P_i, P_{j\in K\setminus\{i\}}, r_{j\in N\setminus K}(P_{j\in N\setminus\{\{i\}\cup K\}}, P_k^K))}{\partial P_{e,i}} \right. \\
&\quad \left. + \frac{\partial Z_i(1-P_i)}{\partial P_{e,i}} \right) \forall e, \qquad (3.8)
\end{aligned}
$$

where the reaction function $r_{j\in N\setminus K}(P_{j\in N\setminus\{\{i\}\cup K\}}, P_k^K)$ gives the conservation level for all ecosystems: $r_{j\in N\setminus K}(P_{j\in N\setminus\{\{i\}\cup K\}}, P_k^K) = [r_{1,j\in N\setminus K}(P_{j\in N\setminus\{\{i\}\cup K\}}, P_k^K), r_{2,j\in N\setminus K}(P_{j\in N\setminus\{\{i\}\cup K\}}, P_k^K), ..., r_{m,j\in N\setminus K}(P_{j\in N\setminus\{\{i\}\cup K\}}, P_k^K)]$. The coalition, as a Stackelberg leader, likewise takes into account the non-signatories' conservation choice $P_{e,i\in N\setminus K}$. However, for the coalition the non-signatories' choice is not a given parameter, but a consequence of its own conservation choice. Maximising the coalition pay-off subject to the reaction function (Eq. 3.6) expresses this relationship. The maximisation outcome is the coalition's optimal conservation choice. Substituting the coalition's optimal conservation choice into the reaction function (Eq. 3.6) gives the non-signatories' optimal conservation choice. A unique equilibrium conservation vector P_N^K associated with a total pay-off $\pi_N^K = \pi_k^K + \pi_{\bar{k}}^K$ for all signatories and non-signatories belongs to every possible coalition, where $\pi_k^K = \sum_{i\in K} \pi_i$ is the coalitions' total pay-off and $\pi_{\bar{k}}^K = \sum_{i\notin K} \pi_i$ the non-signatories' total pay-off. Both pay-offs depend on the coalition actually formed. Non-signatories' pay-off increases with increasing coalition size due to the partially global character of benefits $b_{e,i}^g(P_e)$. The coalition can redistribute its aggregate pay-off π_k^K to its members so that:

$$
\sum_{i\in K} \varphi_i^K = \pi_k^K, \qquad (3.9)
$$

where φ_i^K denotes a coalition member's pay-off after redistribution. This distribution constitutes a per-member-partition function, which assigns pay-offs to coalition members subject to a sharing-rule. The sharing rule applied within the coalition depends on the inter-country symmetry and countries' claims[9]. Weikard (2009) has shown that coalition stability requires that signatories receive at least their "outside

[9] In case of symmetric countries without prior claims, the individual pay-offs are also symmetric:

$$
\pi_{i\in K} = \frac{\pi_k}{k}.
$$

Thus no transfers are needed.

option". Note that we assume an efficient protection and pay-off distribution within the coalition by special treaty mechanisms (and do not explicitly define any sharing rule).

At stage one we analyse the stability of the obtained coalition. The conservation vector P_N^K is a stable equilibrium if it satisfies both internal and external stability. In the stability analysis we consider the pay-offs of individual coalition members and of non-signatories, which are provided by the per-member-partition-function: in the stable equilibrium no signatory is better off by leaving the coalition (internal stability), and no non-signatory by acceding to the coalition (external stability). This requires the pay-offs of signatories (Eq. 4.3) and non-signatories (Eq. 4.4) to satisfy:

$$\varphi_i^K \geq \pi_i^{K \setminus \{i\}} \qquad \forall i \in K \tag{3.10}$$

$$\pi_i^K \geq \varphi_i^{K \cup i} \qquad \forall i \in N \setminus K \ . \tag{3.11}$$

3.4 Numerical appraisal

In this section we apply the formal model to a concrete parametrization in order to obtain a numerical evaluation of the Biodiversity Game. Countries in the Biodiversity Game differ in the two dimensions 'wealth', with $\omega_i \in [0, 10]$, and 'biodiversity richness', with *quality* $q_i \in [0, 1]$ and *productivity* $y_i \in [0, 10]$, other aspects being identical. They thereby belong to one of four distinct country types:

(i) countries with biodiversity hotspots, which are poor (shorthand HP),

(ii) countries with biodiversity hotspots, which are rich (shorthand HR),

(iii) countries without biodiversity hotspots, which are rich (shorthand LR),

(iv) countries without biodiversity hotspots, which are poor (shorthand LP).

The different groups of countries are typified by one representative country, thus $N = 4$. To illustrate, the HP country reflects countries such as Bolivia (*'Tropical Andes Hotspot'*) or Liberia (*'Guinean Forest of West Africa Hotspot'*), the HR country countries such as Australia (*'Queensland Wet Tropics Hotspot'* and *'Southwest Australia Hotspot'*) or New Zealand (*'New Zealand Hotspot'*), the LR country countries such as Norway or Germany, and the LP country countries such as Mali or Mongolia. Each representative country consists of exactly one ecosystem and no country is identical in type. In Section 3.4.1 we describe the model specification and implementation. Next, in Section 3.4.2 we present the model results together with a sensitivity analysis. Finally, we discuss the results in Section 3.4.3.

3.4.1 Model application

Solving the Biodiversity Game is a non-linear optimisation problem. We solve it by backward induction as described in Section 3.3.3. It demands a solution to the economic question of how much land should be optimally conserved by each of four different profit maximising countries while allowing for cooperation. We solve the maximisation problem of the Stackelberg leader (Eq. 3.7) with GAMS, the General Algebraic Modelling System (Brooke et al. 2010), subject to the analytically derived first order conditions.

In game stages three and two we calculate an optimal conservation result for every coalition and the corresponding pay-offs for every country. The calculation demands a specification of the benefit and cost functions together with their first derivatives. A root function describes local benefits from biodiversity conservation $b_i^l(P_i)$:

$$b_i^l(P_i) = \omega_i q_i \frac{1}{v}(P_i - P_{i,Min})^{\theta} \ , \tag{3.12}$$

where $0 < \theta < 1$ and v is a scale parameter; it allows to downscale the local benefits without changing the global benefits (cancelled via multiplication with v in global benefit function), in order to elucidate the cooperation incentives more clearly. We choose the root exponent θ to equal 1/3 in order to influence the curvature such that the Nash-players' solution space lies in the interval [0:1]. A crucial assumption is that countries do not want an ecosystem to become extinct. As the size of the ecosystem P_i approaches a certain minimum level $P_{i,Min}$, marginal benefits $\partial b_i^l(P_i)/\partial P_i$ will approach infinity.

A country-specific *'Constant Elasticity of Substitution'* (CES) benefit function aggregates the non-appropriable benefits generated by the ecosystems of all countries to global biodiversity conservation benefits of the respective country. The CES function allows one to consider varying degrees of substitutability between ecosystems (see Section 3.2.1). It takes the general form of

$$b_i^g(P_i, P_{j\in N\setminus\{i\}}) = \omega_i[\alpha_A(vb_A^l)^{\rho} + \alpha_B(vb_B^l)^{\rho} + \alpha_C(vb_C^l)^{\rho} + \alpha_D(vb_D^l)^{\rho}]^{1/\rho}, \tag{3.13}$$

where ω_i influences the magnitude of a country's global benefits, α is a share parameter, ρ the substitution parameter, and $HP = A, HR = B, LR = C$, and $LP = D$ for better readability. We stipulate equal benefit shares originating from each country, $\alpha_A = \alpha_B = \alpha_C = \alpha_D = 0.25$, which sum up to one. The parameter ρ indicates how easily one ecosystem can compensate for the services generated by another ecosystem, i.e. it integrates the elasticity of substitution σ: $\rho = (\sigma - 1)/\sigma$. In the later analysis we consider perfect substitutability ($\rho = 1.0$), imperfect substitutability ($\rho = 0.2$), and imperfect complementarity ($\rho = -1.0$). For simplicity, we assume the quality of an ecosystem to be decisive for both local and global benefits, i.e. that there is a correlation between the two types of benefits.

Land use benefits rise for simplicity proportionally with an increase in land used for agricultural production in the model application; a linear function represents the local opportunity cost from local land use benefits $z_i(1 - P_i)$:

$$z_i(1 - P_i) = y_i^{\vartheta}(1 - P_i) \ . \tag{3.14}$$

We attenuate the pronounced effect of y_i on the level of marginal costs by setting $\vartheta = 1/2$ to account for decreasing marginal returns to land use in our model application.

In game stage one we examine coalition stability[10]. First, we analyse stability of a coalition without pay-off relocation: we compare the pay-offs of individual coalition members, which are provided by the per-member-partition-function, with their outside-option (internal stability); and contrast the pay-offs of non-signatories with the pay-offs they would receive if they acceded to the coalition (external stability). For example, the coalition ABD is stable without transfers, if the following conditions hold:

$$\pi_A^{ABD} \geq \pi_A^{BD}, \quad \pi_B^{ABD} \geq \pi_B^{AD}, \quad \pi_C^{ABD} \geq \pi_C^{ABCD}, \quad \text{and} \quad \pi_D^{ABD} \geq \pi_D^{AB} \ . \tag{3.15}$$

Allowing for transfers generally increases the chance for a coalition to be stable. Intra-coalition pay-off reallocation eases the stability requirements. Any coalition stable without transfers is also internally stable when there is a transfer scheme in place. For a coalition otherwise not internally stable, we inquire whether every non-profiting coalition member can be compensated by the coalition members, which profit from the given coalition. This is possible if the compensating coalition members are not worse off than under the coalition without the non-profiting members.

[10] A detailed exposition of the stability analysis is available in Supplementary Material S.3.1.

Thereby, they compensate the non-profiting members at most by the difference between their pay-off under the given coalition and the pay-off under the coalition without the non-profiting coalition members. If the sum of the transfers from all profiting coalition members exceeds the loss endured by the non-profiting coalition members, the coalition is internally stable. In other words, the coalition pay-off must exceed the sum of the outside option pay-offs (optimal sharing, cf. Weikard (2009, p. 577)). To give an example, assume that the described coalition ABD is not internally stable without transfers, because country A has an incentive to leave the coalition. The coalition ABD is internally stable with transfers if the subsequent condition holds:

$$\begin{aligned} & (\pi_B^{ABD} - \pi_B^{BD}) + (\pi_D^{ABD} - \pi_D^{BD}) \geq (\pi_A^{BD} - \pi_A^{ABD}) \\ \Longleftrightarrow \quad & \pi_A^{ABD} + \pi_B^{ABD} + \pi_D^{ABD} \geq \pi_A^{BD} + \pi_B^{BD} + \pi_D^{BD} \ . \end{aligned} \tag{3.16}$$

The coalition pay-off with country A being a coalition member must be greater than the pay-off these countries realise in case country A is a non-signatory. It is possible to examine external stability indirectly by proving that the coalition is not internally stable with any additional member joining from the set of non-members (for a formal proof refer to Weikard (2009, p. 581)).

3.4.2 Model results

In this subsection we present the results of our *numerical model application*. We first describe the results[11] of a "Real World Scenario" that will serve as the base scenario in the sensitivity analysis (see Section 3.4.3). Subsequently, we reproduce the assumptions of Barrett's (1994) Biodiversity Supergame as close as possible in a "Barrett Scenario". Table 3.1 shows the stable coalitions of the two scenarios.

Table 3.1: Stable coalitions of the "Real World Scenario" and the "Barrett Scenario"

Scenario	$\rho = 1.0$		$\rho = 0.2$		$\rho = -1.0$	
	without transfers	*with transfers*	*without transfers*	*with transfers*	*without transfers*	*with transfers*
Real World Scenario	HR+LR	Grand coalition	HR+LR	Grand coalition	HR+LR	Grand coalition
Barrett Scenario	LR+LR	Grand coalition	LR+LR	Grand coalition	Grand coalition	Grand coalition

[11] Detailed model results are available in Supplementary Material S.3.2.

3.4.2.1 "Real World Scenario" results.

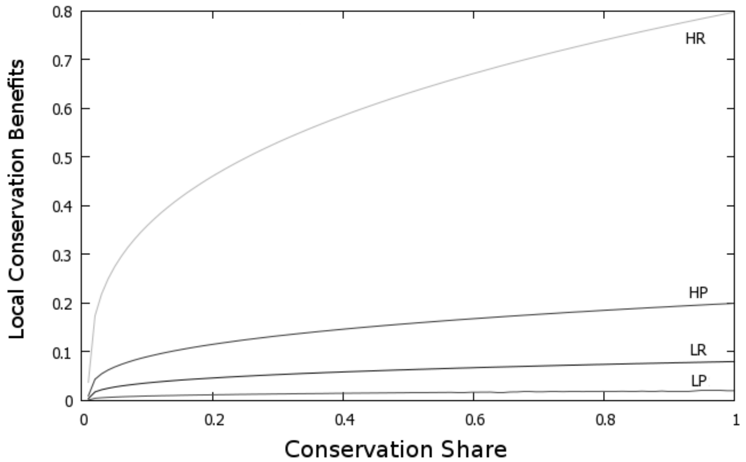
The real world (base scenario) is characterised by strong heterogeneity between countries in terms of ecosystems and wealth. Table 3.2 presents the parameter values of this scenario for the four countries HP, HR, LR, and LP; $P_{i,Min} = 0.01$ represents a threshold below which the ecosystem becomes extinct.

Table 3.2: Parameter values of the base scenario "Real World Scenario"

Parameter	$\mathbf{q_i}$		$\mathbf{y_i}$		$\omega_\mathbf{i}$		**v**	$\mathbf{P_{i,Min}}$
	q_A, q_B	q_C, q_D	y_A, y_B	y_C, y_D	ω_A, ω_D	ω_B, ω_C		
Value	1.0	0.1	6	3	2.0	8.0	10	0.01

Fig. 3.1 illustrates the extent of the countries' heterogeneity with the local benefit functions.

Figure 3.1: Local benefits from biodiversity conservation $b_i^l(P_i)$



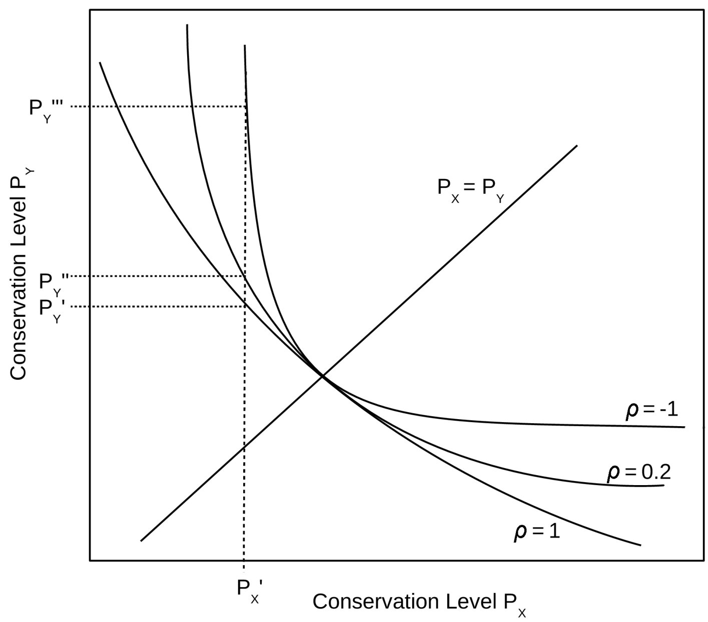
Applying the stability conditions of Section 3.3.3 we find: A coalition of country HR and country LR is stable without transfers in the "Real world scenario". Coalition stability can be explained by Heckscher-Ohlin comparative advantages relating to endowments: The coalition HR+LR is stable due to the presence of both a comparative advantage on the supply side (biodiversity quality) and a relative stronger one on the demand side (biodiversity benefits):

	HP	HR	LR	LP
comp. advantage supply side:	x –	x –	– –	– –
comp. advantage demand side:	– –	– **x**	– **x**	– –

Country HR benefits from both comparative advantages, country HP from a comparative advantage on the supply side, and country LR from one on the demand side. The stable coalition of the "Real world scenario" comprises the two countries with the strongest comparative advantages. With transfers full cooperation is stable. The coalition formation is independent of the degree of substitutability.

The total pay-off declines for a reduction in substitutability under the Nash-equilibrium and the grand coalition. The higher the substitutability the better countries can exploit the comparative advantages on the demand (biodiversity benefits) and supply side (biodiversity quality). Figure 3.2 shows that for achieving the

Figure 3.2: Benefit isoquants with respect to conservation level



same global benefit level, countries have to conserve more the less substitutable the ecosystems (except for $P_x = P_y$).

The total Nash conservation share declines for a decrease in substitutability, because for a $\rho < 1.0$, received global benefits due to own conservation are underproportional to private local benefits of this conservation. The total grand coalition conservation share, though, is highest under imperfect substitutability, lower under perfect substitutability and lowest under imperfect complementarity. Two different effects, which both reduce conservation in low quality countries, cause this result: a *comparative advantage effect* and a *complementarity effect*. First, the better the substitutability, the higher the comparative advantage with respect to biodiversity quality, and the less conservation is conducted in low quality countries. As one unit of conservation yields higher benefits in high quality countries, and as global benefits are the sum of local benefits, conservation efforts will be shifted to hotspot countries. The land in low quality countries is used predominantly agriculturally (comparative advantage effect). Secondly, the worse the substitutability, the more conservation needs to be done in low-quality countries where conservation is less efficient (complementarity effect). This reduces the comparative advantage and impacts on the conservation-harvest trade-off. Harvest becomes more attractive for all countries. Conservation is especially traded off against harvest benefits in low q-countries. For medium degrees of ecosystem substitutability (imperfect substitutability), both dynamics are relatively weak so that full conservation is realised.

3.4.2.2 "Barrett Scenario" results.

In the Barrett Scenario we assume parameter values for q_i, y_i, ω_i, v, $P_{i,Min}$, and ρ which approach the scenario as far as possible to Barrett's (1994) Biodiversity Supergame. Table 3.3 presents these parameter values.

Table 3.3: Parameter values of the "Barrett Scenario"

Parameter	$\mathbf{q_i}$		$\mathbf{y_i}$		$\boldsymbol{\omega_i}$		**v**	$\mathbf{P_{i,Min}}$	ρ
	q_A, q_B	q_C, q_D	y_A, y_B	y_C, y_D	ω_A, ω_B	ω_C, ω_D			
Value	1.0	0.001	0.6	0.267	2.0	8.0	120	0	1.0

Barrett models no cross-heterogeneity of ecosystems and wealth: in the Biodiversity Supergame, biodiversity hotspots are correlated with poverty and poor-quality ecosystems with wealth. Thus, not four but only two country types exist: HP and LR. Developed countries LR do not engage in conservation themselves, but pay developing countries HP for their conservation measures. In order to reduce the conservation activities of developed countries as far as possible, the biodiversity quality takes the value $q_{LR} = 0.001$ and the soil quality $y_{LR} = 0.267$. Barrett considers only global conservation benefits explicitly. Therefore, we scale down local benefits to $v = 120$ in the "Barrett Scenario". As ecosystems are identical and conservation efforts completely substitutable in developing countries, only $\rho = 1.0$ results are of interest in this scenario. Barrett considers no resilience threshold of ecosystems; therefore $P_{i,Min} = 0$.

The model results are as follows: The small coalition of the two countries LR is stable without transfers, and the grand coalition with transfers. The total pay-off under coalition LR+LR amounts to 40.1% of the pay-off under the grand coalition ($\sum_{i \in N} \pi_i^{CD} / \sum_{i \in N} \pi_i^{ABCD}$). This is a relatively low share compared to other analysed scenarios. Transfers are thus crucial in the "Barrett Scenario". In the Nash equilibrium countries conserve close to nothing ($\sum_{i \in N} P_i^{Nash} = 0.0004$), whereas in the social optimum half of the land is protected. The resulting welfare enhancing potential of the grand coalition with respect to the Nash equilibrium is 249.7% ($\sum_{i \in N} \pi_i^{ABCD} / \sum_{i \in N} \pi_i^{Nash}$). Clearly, these results do not match those reached by Barrett in the Biodiversity Supergame. Barrett (1994, p. 120) concludes that "Where the agreement can sustain the full cooperative outcome, global net benefits will be only slightly larger than in the non-cooperative outcome." The local benefit root function of our model application largely contributes to the positive results: it ensures that countries engage in some degree of conservation. We discuss the stability of the grand coalition in Section 3.4.3.

3.4.3 Parameter analysis and discussion

Parameter variations impact coalition formation, as well as total pay-off and total conservation share. In Appendix 3.A we provide the parameter values of different model runs. Table 3.4 gives an overview of the results in the form of general trends in parameter impact. Based on these trends, in this subsection we assess the existence of comparative advantages on both (a) the supply side with respect to biodiversity quality (parameter q_i and y_i) and on (b) the demand side with respect to biodiversity benefits (parameter ω_i), (c) the influence of the ecosystem substitution elasticity ρ, (d) the influence of the ecosystem resilience threshold $P_{i,Min}$, (e) the influence of the magnitude of local benefits (parameter v), and (f) the robustness of the stability of the grand coalition with transfers.

(a) The comparative advantage on the supply side. Analysis of the coevolving quality parameters q_i and y_i (parallel variation) under constant ω_i. In a world without transfers and with perfect ecosystem substitutability, partial cooperation between the countries HP and HR is stable for medium and large heterogeneity in biodiversity quality (the grand coalition is stable for small degrees of heterogeneity). The HP-HR-coalition is–with ω_i being set equal–essentially a coalition of two hotspot countries H. The quality of their biodiversity is higher and higher quality translates into higher conservation benefits. As countries only undertake

Table 3.4: General trends in parameter impact. *The number of arrows indicates the relative strength of the trend. For * no ranking is possible, because at least one of the total conservation shares has reached a corner solution.*

Parameter	ρ	**♯ Coalition members without transfers**	**total Nash pay-off**	**total social optimum pay-off**	**total Nash conservation share**	**total social optimum conservation share**
hetero-geneity in $q_i \uparrow$	ρ **1.0**	↓	↑	↑	↑	↓
	ρ **0.2**	constant	↓	↓	↓	constant
	ρ **-1.0**	constant	↓↓	↓↓	↓↓	↓↓
hetero-geneity in $\omega_i \uparrow$	ρ **1.0**	↓↓↓	↑	↑	↑	↓
	ρ **0.2**	↓↓	↓	↓	↓	constant
	ρ **-1.0**	↓	↓↓	↓↓	↓↓	↓↓
v ↑	ρ **1.0**	↓↓↓	↑↑↑	↑	↑	↑ *
	ρ **0.2**	↓↓	↑↑	↑↑↑	↑↑↑	↑ *
	ρ **-1.0**	↓	↑	↑↑	↑↑	↑ *
$\mathbf{P_{i,Min}} \uparrow$	ρ **1.0**	constant	↓	↓↓↓	↑	↑ *
	ρ **0.2**	constant	↓	↓↓	↑	↑ *
	ρ **-1.0**	constant	↓	↓	↑	↑ *

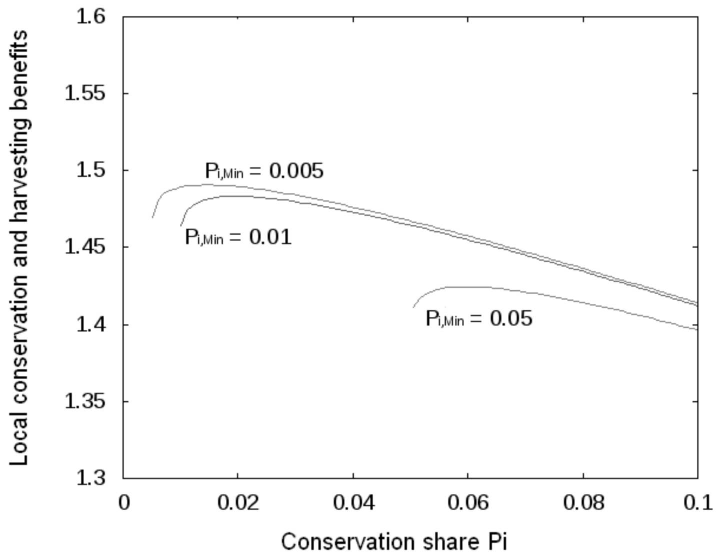
conservation measures when conservation of land is more profitable than its use, the formation of a hotspot country coalition confirms the existence of a Heckscher-Ohlin comparative advantage with respect to biodiversity quality. This comparative advantage rises with increasing quality heterogeneity: the total pay-off under the coalition between HP and HR approaches the total pay-off under the social optimum for increasing heterogeneity. The importance of this comparative advantage becomes evident in a world with transfers: Low quality countries join the coalition, because they are now also able to exploit the comparative advantage on the supply side by paying hotspot countries for conservation measures. With transfers, full cooperation is always stable. The comparative advantage with respect to biodiversity quality is highest under perfect ecosystem substitutability and decreases with reduced ecosystem substitutability: With reducing ecosystem substitutability replacing conservation of one ecosystem by conservation of another ecosystem becomes increasingly limited, i.e. the minimum conservation share of each ecosystem is more and more imperative. When the value of ρ in the CES function decreases, the lowest local benefits increasingly dominate the global benefits. Restrictions in the substitution possibility demand a minimum conservation share of each ecosystem, if benefits are not to decrease substantially. Higher quality does not translate linearly, but rather under-proportionally, into higher global conservation benefits.

(b) The comparative advantage on the demand side. Ceteris paribus analysis of the wealth parameter ω_i. In a world without transfers and with perfect substitutability, the initial full cooperation under equally-rich countries breaks down with increasing wealth inequality and is replaced by partial cooperation between the countries HR and LR. This coalition is–as biodiversity richness is identical–essentially a coalition of wealthy countries R, which benefit more from one unit of conservation than poor countries. The direction of the impacts and dynamics of the comparative advantage on the demand side is identical with the previously analysed comparative advantage on the supply side. However, the magnitude of the decrease of the comparative advantage on the demand side with declining ecosystem substitutability is less pronounced than on the supply side, because the parameter ω_i is additionally a factor of a countries' global benefit function. This multiplication of global benefits by ω_i also results in a stronger impact of heterogeneity in wealth on coalition formation. In contrast to the results from the analysis of heterogeneity on the supply side, already a slight increase in wealth heterogeneity leads to the coalition of HR and LR countries being the only stable one in a world without transfers and perfect substitutability; under imperfect substitutability and imperfect complementarity, the grand coalition is longer stable without transfers. With transfers the grand coalition is always stable.

(c) The influence of the ecosystem substitution elasticity. Analysis of the parameter ρ. The more the ecosystem substitutability decreases (perfect to imperfect substitutability to imperfect complementarity), the higher is the chance for a stable grand coalition both with and without transfers. For imperfect complementarity, the conservation effort of every country is crucial and the free-riding potential reduced. The game transforms more and more from an aggregate efforts game into a weakest link game (cf. Barrett 2007, p. 3 ff.). We discussed the impact of the ecosystem substitution elasticity on the comparative advantages on the supply and demand side already under (a, b).

(d) The influence of the ecosystem resilience threshold. The impact of the parameter $P_{i,Min}$ on coalition stability is marginal for the considered variations ($P_{i,Min}$ values 0.005, 0.01 and 0.05). Still, an increase in $P_{i,Min}$ affects the total pay-off (decreases) and the total conservation share (increases). A larger compulsory minimum stock size leads to a larger total grand coalition conservation share–even in case $P_{i,Min}$ is not binding. For $P_{i,Min} = 0.01$ and even for $P_{i,Min} = 0.005$ the grand coalition already conserves a share greater than 0.05 of every ecosystem (i.e. every country in this case) for all three values of ρ. The reason for the fact that an increasing $P_{i,Min}$ leads even to a further increase in the conservation share of biodiverse land (and lowers the total pay-off), is that the local benefit root function shifts to the right as can be seen in Figure 3.3. The conservation potential of the social op-

Figure 3.3: Local conservation and harvesting benefits $b_i^l(P_i) + z_i(P)$ for different $P_{i,Min}$ values



timum decreases with increasing compulsory $P_{i,Min}$, because the Nash-equilibrium conservation share more than doubles from $P_{i,Min} = 0.01$ to $P_{i,Min} = 0.05$, whereas the grand coalition conservation share does not increase much. Nash conserves close to $P_{i,Min}$. Therefore the realised conservation share under Nash-equilibrium is very sensitive to an increase in $P_{i,Min}$. The grand coalition on the contrary conserves in a range where marginal benefits are low (and hence not sensitive).

(e) The influence of local benefits. The sensitivity analysis of v confirms the intuition that the higher the local benefits, the higher the individual interest to engage in conservation (unilateral action). If local benefits are low, the coalition of country HR and country LR is stable without transfers. In case of high local benefits, the coalition of HR is stable without transfers. Unilateral action is plausible for a wealthy country with high biodiversity richness; it engages in conservation as a first mover. With transfers the grand coalition is always stable. The total pay-off and the total conservation share decrease in v (increase in $b_i^l(P_i)$) for all coalitions under all substitution elasticities. The importance of local benefits for biodiversity conservation coalitions is most evident from the magnitude of the conservation and welfare enhancing potential of the social optimum. Both are extremely high for low local benefits, because for small local benefits countries have no incentive to engage in conservation unilaterally. The free riding problem is stronger. It follows rather obviously that the total pay-off under the largest stable coalition without transfers is much smaller than the total pay-off under the grand coalition if the local benefits are small.

(f) The implications of relaxing the assumptions of the numerical model appraisal. The most striking result of the model computation is that the grand coalition is always stable with transfers. This outcome has to be qualified: full cooperation is sensitive towards the number of players. The restriction of $N = 4$ is a limitation of the model application. Enlarging the number of players by one additional player might possibly already destabilise the grand coalition. When the fifth player accedes, the cooperation gain of the remaining four players rises. However, their outside option and thereby their free-riding incentive also grow, as the free-rider benefits from positive global benefit spillovers are generated by the coalitions' conservation effort. The relative development of the cooperation gain with respect to the outside options is important for the stability of the grand coalition. This relative development depends on the number and type of players that join the game. If the cooperation gain grows faster than the outside options, full cooperation is stable. If not, partial cooperation will be stable. In reality, a prisoners' dilemma will be present within each country type and thereby on both the donor and the provider side. This prisoners' dilemma, however, is absent in case of $N = 4$, because only one country belongs to one country type.

A further limitation in the model application is the restriction of one ecosystem per country. The implication of countries hosting numerous ecosystems for coalition stability depends on the ecosystem substitutability. Imperfect substitutable ecosystems–the most realistic case–have a stabilising effect on coalition formation.

The third major confinement derives from the very structure of the model: the Stackelberg assumption. The first mover advantage increases–as the welfare increasing potential of the grand coalition with respect to the Nash-equilibrium demonstrates–with the degree of substitutability. The first mover advantage might barely stabilise a coalition, which in a Nash-game, would not be stable anymore—especially in a world with well substitutable ecosystems.

Despite the qualification of the full cooperation observation, a major conclusion can be drawn: transfers are crucial for effective biodiversity conservation IEAs.

The effect of transfers will be equally visible in a game with $N > 4$ or a Nash-game setting. Transfers will in any case be able to sustain an improved partial cooperation. With $N > 4$ transfers tend to be the more effective, the higher the cross-heterogeneity in ecosystems and wealth. For sufficient degrees of heterogeneity countries can realise gains from trade with transfers.

3.5 Conclusions

With this chapter we enhance the understanding of how heterogeneity in ecosystems and wealth impact the stability of international biodiversity conservation agreements. The model refinements provide new insights into coalition formation: This chapter evinces with the numerical application that heterogeneity in the form of different, imperfectly substitutable ecosystems and wealth asymmetry is decisive for the stability of biodiversity conservation agreements. Heterogeneity in ecosystems generates a Heckscher-Ohlin comparative advantage with respect to biodiversity quality on the supply side, and heterogeneity in wealth one with respect to biodiversity benefits on the demand side.

The main result from the numerical model application for four players is that the grand coalition is always stable with transfers. The effect of transfers will be equally visible in a game with $N > 4$ or a Nash-game setting. Transfers might not be able to sustain full cooperation, but an improved partial cooperation. Even in the “Barrett Scenario” the importance of transfers is evident. The reason for the merit of transfers is a joint provision effect of local and global biodiversity benefits, which lowers the costs of winning over additional coalition members. Global benefits are spillovers of local biodiversity conservation. A coalition does not need to offer a transfer amounting to the equivalent of the forgone opportunity cost of conservation, because the free rider will receive own local benefits from conservation. A free rider profits from higher own local benefits, from increased global benefits, and from the transfers, when acceding to a coalition. Transfers are not only crucial for the stability and effectiveness of an IEA, but also offer the opportunity to achieve a Pareto improvement if they are well designed. Unfortunately, in reality transfers are often not well designed because they are difficult to deal with. The outside-option rule is a first best allocation, but suffers from practical problems. Transfers are hard to agree on even if the outside-option-rule for transfer allocation is applied, because of imperfect information on the outside options of other countries. Therefore, we also investigate coalition formation without transfers.

Heterogeneity in ecosystems and wealth destabilises the grand coalition without transfers. The pay-off difference between the stable coalition and the social optimum is largest at the point, where heterogeneity is so high that the grand coalition breaks, and only a partial coalition can be maintained. With further rising heterogeneity this difference diminishes again. The destabilising effect of ecosystem and wealth heterogeneity is stronger the better the ecosystem substitutability. High local benefits have a decreasing effect on the size of the stable coalition without transfers, as they increase the incentive for unilateral action.

The continuous action space of the Biodiversity Game is an important reason for our promising conservation results, because it allows countries to observe the ecosystem resilience threshold and conserve some (however little) of their biodiversity. These conclusions are striking because they are the first to show the importance of asymmetric countries and different, imperfectly substitutable ecosystems with a resilience threshold in a biodiversity conservation game.

The model application presented in this chapter, however, still suffers from some limitations: the restriction of the number of players to four, the stipulation of one ecosystem per country, and the assumption of a linear relationship between local and global benefits. Nonetheless, this chapter portrays a biodiversity conservation game with higher empirical relevance than previous models.

Our findings highlight that poverty reduction can contribute to effective global biodiversity conservation. This results from the fact that wealthier countries assign higher values to biodiversity services, and that coalition formation is eased in a world with low wealth heterogeneity between countries. Reduced heterogeneity in wealth and biodiversity quality stabilises the grand coalition. As redistribution of ecosystem quality is impossible, redistribution of wealth can be one measure to increase the size of a stable coalition. If the latter is not possible and heterogeneity remains high, transfers become imperative. This result resonates with Gatti et al.'s (2011, p. 625) finding in a cooperative bargaining setting, that transfers "based upon the essential characteristics between the parties" and thereby addressing fairness concerns are crucial for long-term stability. Transfers that are perceived as legitimate are important for the long-term effectiveness of a multilateral fund (Rosendal and Andresen 2011).

The CBD is a milestone in the endeavour to conserve biodiversity on a global scale–despite its small conservation impact. It has to be honoured as the first international environmental agreement (IEA), which addresses biological resources in the aggregate, achieves (nearly) full cooperation, and codifies the sovereignty of nation states over their biological resources. Instead of an *'Access and Benefit-Sharing'* (ABS) mechanism, we employ some form of fund in our Biodiversity Game, which functions as financial mechanism and redistributes coalition benefits according to a specific sharing rule. ABS increases the locally appropriable benefits from biodiversity conservation, but Kamau et al. (2010, p. 248) attest that the ABS-mechanism performs poorly in regard to implementation and functioning. The way it works today, only part of the potentially appropriable benefits of biodiversity are captured. Moreover, biodiversity is a mixed good that comprises service goods on the entire continuum of private to public goods. All biodiversity benefits that are not appropriable by a nation state need other, more comprising means of funding. With the *'Global Environment Facility'* (GEF) a fledgling institution of a multilateral fund for biodiversity conservation already exists. Our model provides a good tool to further investigate the possible role of a multilateral trust that allocates transfers such that the social optimum is stable.

Moreover further research is needed to consider more complex game structures with sub-coalitions and different coalition designs. In 1996 the megadiverse countries of the Andean Community passed community law on ABS (Decisión 391 on a *'Common Regime on Access to Genetic Resources'*[12]) and in 2002 the *'Group of Like-Minded Megadiverse Countries'* formed in Mexico to facilitate intensified communication. Understanding the incentives for and design of these coalitions of megadiverse countries is necessary to improve the conservation outcome of the current ABS mechanism or find institutional solutions beyond bilateral ABS trade.

Appendix

3.A Parameter values of the analysis runs

3.A.1 Ecosystem quality parameters q_i and y_i:

The co-evolving quality parameters q_i and y_i are varied simultaneously. $\sum_{i \in N} q_i$ and $\sum_{i \in N} y_i$ are constant and equal to the respective sums of the base scenario. All

[12] Comision del Acuerdo Cartagena (1996): Decisión 391: Régimen Común sobre Acceso a los Recursos Genéticos, Gaceta Oficial del Acuerdo de Cartagena, Año XII, Numero 213, Lima, 17.06.1996.

other parameters remain unchanged and the wealth parameter ω_i takes the value 5. Each parameter variation is conducted for all three values of ρ.

Table A.1: Parameter values for q_i and y_i in the different analysis runs

Analysis run	$\mathbf{q_A, q_B}$	$\mathbf{q_C, q_D}$	$\mathbf{y_A, y_B}$	$\mathbf{y_C, y_D}$
Quality 1	0.55	0.55	0.45	0.45
Quality 2	0.625	0.475	0.475	0.425
Quality 3	0.7	0.4	0.5	0.4
Quality 4	0.775	0.325	0.525	0.375
Quality 5	0.85	0.25	0.55	0.35
Quality 6	0.925	0.175	0.575	0.325
Quality 7	1.0	0.1	0.6	0.3

3.A.2 Wealth parameter ω_i:

Parameter ω_i varies, whereby $\sum_{i \in N} \omega_i$ is constant and equal to the sum of the base scenario. All other parameters remain unchanged and the biodiversity quality ($q_i = 0.55$ and $y_i = 0.45$) is equal for all countries. Every analysis run is conducted for all three values of ρ.

Table A.2: Parameter values for ω_i in the different analysis runs

Analysis run	$\omega_{\mathbf{A}}, \omega_{\mathbf{D}}$	$\omega_{\mathbf{B}}, \omega_{\mathbf{C}}$
Wealth 1	5	5
Wealth 2	4	6
Wealth 3	3.5	6.5
Wealth 4	3	7
Wealth 5	2	8
Wealth 6	1	9

3.A.3 Local benefit parameter v:

Parameter v takes three different values in case of high local benefits depending on the degree of ecosystem substitutability, because the point where the first country reaches a Nash-conservation-share of 100% varies significantly.

Table A.3: Parameter values for v in the different analysis runs

Analysis run	$\mathbf{b_i^l(P_i)}$	**v**		
		$\rho = 1.0$	$\rho = 0.2$	$\rho = -1.0$
Local benefits 1	High	3.29	1.51	1.10
Local benefits 2	Base	10		
Local benefits 3	Low	120		

Bibliography

Barbier, E. B., J. Burgess, and C. Folke (1994). *Paradise lost? The Ecological Economics of Biodiversity*. London: Earthscan Publications Limited.

Barrett, S. (1994). The biodiversity supergame. *Environmental and Resource Economics 4*(1), 111–122.

Barrett, S. (2003). *Environment and Statecraft: The Strategy of Environmental Treaty-Making*. New York: Oxford University Press.

Barrett, S. (2007). *Why Cooperate? The Incentive to Supply Global Public Goods*. New York: Oxford University Press.

Brooke, A., D. Kendrick, A. Meeraus, and R. Raman (2010). *GAMS. A User's Guide*. Washington, DC: GAMS Development Corporation.

Droege, S. and B. Soete (2001). Trade-related intellectual property rights, north-south trade, and biological diversity. *Environmental and Resource Economics 19*, 149–163.

Folke, C., C. S. Holling, and C. Perrings (1996). Biological diversity, ecosystems, and the human scale. *Ecological Applications 6*(4), 1018–1024.

Gatti, R., T. Goeschl, B. Groom, and T. Swanson (2011). The biodiversity bargaining problem. *Environmental and Resource Economics 48*, 609–628.

Gowdy, J. M. and K. Mayumi (2001). Reformulating the foundations of consumer choice theory and environmental valuation. *Ecological Economics 39*(2), 223–237.

Hoel, M. (1992). International environmental conventions: The case of uniform reductions of emissions. *Environmental and Resource Economics 2*(2), 141–159.

Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics 4*(4), 1–23.

Inamdar, A., H. de Jode, K. Lindsay, and S. Cobb (1999). Capitalizing on nature: Protected area management. *Science 283*, 1856–1857.

Kamau, E., B. Fedder, and G. Winter (2010). The Nagoya Protocol on Access to Genetic Resources and Benefit Sharing: What is new and what are the implications for provider and user countries and the scientific community? *Law, Environment and Development Journal 6*(3), 246–262.

Lavoie, M. (2004). Post Keynesian consumer theory: Potential synergies with consumer research and economic psychology. *Journal of Economic Psychology 25*(5), 639–649.

MEA (2005). *Ecosystems and Human Well-being: Biodiversity Synthesis.* Millennium Ecosystem Assessment. Washington, DC: World Resources Institute.

Mittermeier, R. A., G. P. Robles, M. Hoffmann, J. D. Pilgrim, T. Brooks, C. G. Mittermeier, J. Lamoreux, and G. A. B. da Fonseca (2004). *Hotspots revisited: Earth's biologically richest and most endangered ecoregions.* Mexico City: CEMEX.

Pimm, S. L. (1997). The value of everything. *Nature 387*, 231–232.

Purvis, A. and A. Hector (2000). Getting the measure of biodiversity. *Nature 405*, 212–219.

Rosendal, G. K. and S. Andresen (2011). Institutional design for improved forest governance through REDD: Lessons from the global environment facility. *Ecological Economics 70*(11), 1908–1915.

Weikard, H.-P. (2003). On the quasi-option value of biodiversity and conservation. In J. Wesseler, H.-P. Weikard, and R. D. Weaver (Eds.), *Risk and Uncertainty in Environmental and Resource Economics*, Chapter 3, pp. 23–37. Cheltenham: Edward Elgar.

Weikard, H.-P. (2009). Cartel stability under an optimal sharing rule. *The Manchester School 77*(5), 575–593.

Williams, K. J., A. Ford, D. F. Rosauer, N. De Silva, R. Mittermeier, C. Bruce, F. W. Larsen, and C. Margules (2011). Forests of East Australia: The 35th biodiversity hotspot. In F. E. Zachos and J. C. Habel (Eds.), *Biodiversity Hotspots. Distribution and Protection of Conservation Priority Areas*, Berlin/Mannheim, pp. 295–310. Springer.

Winands, S. (2011). How does heterogeneity in ecosystems and wealth impact the stability of international biodiversity conservation agreements? Diploma thesis Bonn University / MSc. thesis Wageningen University.

Winands, S. (2012). Welchen Einfluss hat die Heterogenität von Ökosystemen und Wohlstand auf die Stabilität internationaler Biodiversitätsabkommen? In U. Feit and H. Korn (Eds.), *Treffpunkt Biologische Vielfalt 11*, BfN-Skripten 309, pp. 101–105. Bonn: Bundesamt für Naturschutz.

Chapter 4

Are Benefit-Sharing Rules Based on the Game-Theoretic Paradigm Applicable to International Environmental Agreements? The Case of the Biodiversity Game.

Abstract: The objective of this chapter is to derive and assess benefit-sharing rules for the case of biodiversity conservation cooperation and thereby contribute to a discussion on the applicability of standard game-theoretic benefit-sharing rules for international environmental agreements. To this end I transfer established optimal sharing rules for general coalition formation games to a biodiversity game. I argue, though, that ecological uncertainty and economic valuation problems render their application currently untenable. To assess this tentative hypothesis and further explore the topic I conduct empirical-qualitative research. Expert interviews confirm the need for an alternative approach. Based on the empirical results and a discussion of technical feasibility and political economy aspects I derive an alternative benefit-sharing rule. It distributes expected assessable benefits according to environmental conservation and egalitarian criteria of allocation-based equity. I show how this rule can be incorporated in the standard game-theoretic framework once countries have gained sufficient information to form expectations about biodiversity benefits.

4.1 Introduction

Biodiversity is essential for human existence. Yet, protecting it on a global scale and thereby securing the basis for the continued provision of local to global ecosystem services is challenging. International biodiversity conservation relies on cooperation that needs to be in the self-interest of every member country to be stable. Game theory can provide important findings for the design of biodiversity conventions as well as other international environmental agreements (IEAs). It postulates rational utility maximising players. In this chapter I study the case of the biodiversity conservation game to discuss whether benefit-sharing[1] rules following the game-theoretic paradigm are (currently) applicable to IEAs.

Sharing benefits from biodiversity between members of a biodiversity conservation coalition is of growing relevance for global policy making. The international community cooperates under the United Nations *'Convention on Biological Diversity'* (CBD)[2] to conserve and sustainably use biodiversity and share the benefits arising out of the utilization of genetic resources. The major financial mechanism to facilitate achieving these goals is the *'Global Environment Facility'* (GEF), a trust fund to which countries make voluntary contributions. Another global multilateral mechanism that relates to genetic resources is being discussed under the *'Nagoya Protocol'*[3] to the CBD. The *'Global Crop Diversity Trust'*, the financing body of the *'International Treaty on Plant Genetic Resources for Food and Agriculture'* (ITPGRFA), also distributes benefits between its members.

A multilateral biodiversity fund–or as well a biodiversity cartel–can be modelled as a biodiversity conservation game where countries' pay-offs are dependent on the other countries' conservation decisions. A country's conservation generates local, regional and global benefits and is thereby also beneficial to other countries; the biodiversity conservation game is a game with positive externalities. It can be analysed with a non-cooperative game theoretic model (e.g. Barrett (1994), Winands et al. (2013) id. Chapter 3). The game's positive externalities–positive spillovers

[1] Global biodiversity conservation cooperation is phrased in terms of benefit-sharing following the debates on *'Access and Benefit-Sharing'* (ABS) of genetic resources under the United Nations *'Convention on Biological Diversity'* (CBD). It could also be conceptualised as a cost-sharing game. Considering two stylised countries, one poor country with low levels of biodiversity A and one rich country with high levels of biodiversity B: A shares the benefits of biodiversity conservation in B, which A perceives in terms of e.g. direct (recreational), option, bequest, altruist, and intrinsic values (TEEB 2010, p. 194 ff.), through supporting conservation efforts viz. costs in B.

[2] United Nations (1992): Convention on Biological Diversity, 31 Int'l Leg. Mat. 818, Rio de Janeiro, 05.06.1992.

[3] United Nations (2010): Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity, Nagoya, 29.10.2010. The Nagoya Protocol requests the treaty parties in *Art. 10* to consider the need for a *'Global Multilateral Benefit-Sharing Mechanism'* (GMBSM) for transboundary genetic resources and traditional knowledge associated with genetic resources or for such genetic resources and traditional knowledge associated with genetic resources for which no prior informed consent is possible.

from cooperation to protect biodiversity–generate free-riding incentives which imply that full cooperation may not always be realised. The intra-coalition pay-off distribution, first introduced by Thrall and Lucas (1963), is tailored to such game as it assigns pay-offs to all coalitions and non-member states. A per-member partition function allocates pay-offs to all signatories and non-signatories. The coalition stability depends much on the intra-coalition pay-off partition.

My objective in this chapter is to derive and assess benefit-sharing rules for the biodiversity conservation game that are relevant for international decision-making and governance. I consider the case of biodiversity cooperation as *pars pro toto* for IEAs; in contrast to climate change, biodiversity conservation negotiations are not confined to the ministerial level and stakeholders are approachable–i.a. for the expert interviews that are part of this research. For *general* coalition formation games, established sharing rules are the benefit surplus sharing rule (e.g. Carraro et al. 2006) and the *'optimal sharing'* rule based on the outside option (Weikard 2009). Eyckmans et al. (2012) use the latter concept also for the valuation function of their *'Proportional Surplus Sharing Scheme'*. I transfer these per-member partition functions to the biodiversity conservation game. My presumption, though, is that the information requirements for game-theoretic per-member partition functions are too demanding in case of biodiversity cooperation. I consider even the application of rules based on expected benefits currently untenable due to lacking ecological information and economic valuation problems. To assess my presumptions and appraise the game-theoretic rules, I conduct semi-structured expert interviews with decision makers from countries, which host large parts of global biodiversity and are thereby crucial members of a biodiversity benefit-sharing cooperation. The empirical-qualitative research confirms the need for an alternative approach. Based on the interview results and technical feasibility and political economy considerations I derive an alternative rule. It distributes expected assessable benefits according to environmental conservation and egalitarian criteria of allocation-based equity. I outline how this rule can be integrated in the standard game-theoretic model once countries have sufficient information to assess (or form expectations on) their own and others' status-quo pay-offs and the coalition pay-off, their own and others' pay-off under every possible coalition structure. Sharing rules are usually the product of purely theoretical work; I differ in basing them on empirical-qualitative research.

The chapter proceeds as follows: I introduce the biodiversity conservation game and basic definitions in Section 4.2. In Section 4.3 I transfer established per-member partition functions to the biodiversity conservation game and discuss their applicability. Next, I provide insights from qualitative expert interviews in Section 4.4. In Section 4.5 I discuss technical and political-economy requirements for an alternative benefit-sharing rule and show how it can be incorporated in the game-theoretic model. With Section 4.6 I conclude.

4.2 The game-theoretic model

The conceptual framework of the further analysis of benefit-sharing rules for biodiversity conservation games is a game theoretic model with heterogeneous countries developed by Winands et al. (2013) (id. Chapter 3).[4] I present the model setting in Section 4.2.1, the partition function and the per-member partition function in Section 4.2.2, and coalition stability in Section 4.2.3.

4.2.1 The setting

The biodiversity game by Winands et al. (2013) (id. Chapter 3) is a three stage non-cooperative coalition formation game, whereby a coalition is characterised by joint welfare maximisation. $N = \{1, 2, ..., n\}$ countries, with $n \geq 2$, decide about joining a biodiversity conservation coalition K. K is a subset of N that consists at least of two countries, whereby $K = N$ is the grand coalition and $K = \emptyset$ the Nash-equilibrium structure without coalition formation. Subsequently the signatories jointly agree on the coalition's ecosystem protection share. Then each non-signatory chooses its own share. The game is solved by backward induction.

A country i can choose between protection P_i and land use U_i of its total area A_i, whereby $P_i + U_i = A_i$. Protection is a continuous choice $P_i \in [0, 1]$. Countries are pay-off maximising agents. They are heterogeneous in biodiversity richness and wealth. A country can appropriate local conservation benefits; aggregated over all its ecosystems, they are denoted by $B_i^l(P_i)$. An ecosystem gives also rise to global ecosystem services, which are not directly appropriable by the country hosting the ecosystem. A country's share of total global benefits aggregated over all ecosystems of all countries is given by $B_i^g(P)$. Besides, agriculturally used land U_i generates local benefits from logging and harvesting. A country's aggregated land use benefits are $Z_i(A_i - P_i)$. Hence, the i-th country's pay-off reads:

[4] It differs from Barrett's (1994) *'Biodiversity Supergame'* in that it considers four types of countries varying in ecosystems and wealth, explicitly includes local benefits, and regards imperfect substitutability between biodiversity services.

$$\pi_i(P_i, P_{j\in N\setminus\{i\}}) = B_i^l(P_i) + B_i^g(P) + Z_i(A_i - P_i) \ , \tag{4.1}$$

where $P = (P_1, P_2, ..., P_n)$.

4.2.2 The partition function and per-member partition function

The coalition K's and the non-signatories' pay-offs depend on the coalition formed. A partition function allocates these pay-offs for all coalition structures:

Definition 1. *Partition function: A partition function assigns the pay-offs to the coalition K and its associated respective non-signatories under each coalition structure of the set $\Xi = \{K_1, K_2, ...K_o\}$.*

A country's pay-offs are dependent on all countries protection decisions through global benefits (ref. Eq. 4.1). The per-member partition function, by some scholars also called valuation function, ψ_i^K assigns a pay-off to *all* countries–signatories and non-signatories.

Definition 2. *Per-member partition function: A per-member partition function ψ_i^K assigns the i'th country a pay-off under a coalition $K \in \Xi$ for all countries in and outside the coalition.*

A coalition member receives a certain share of the aggregate biodiversity coalition pay-off π^K after redistribution φ_i^K. The coalition pay-off can be shared in various ways either spontaneously or according to a pre-defined rule. The shares have to add exactly up to the total pay-off:

Definition 3. *Efficiency property:*

$$\sum_{i\in K} \varphi_i^K = \sum_{i\in K} \pi_i^K =: \pi^K. \tag{4.2}$$

4.2.3 Coalition stability

A coalition structure K belongs to the set of stable coalition structures if no signatory of the coalition structure profits from leaving the coalition and if no non-signatory of the coalition structure gains from acceding to the coalition; the coalition must be internally and externally stable (D'Aspremont et al. 1983).

Definition 4. *Stability: A biodiversity coalition K is stable if it is internally (Eq. 4.3) and externally stable (Eq. 4.4):*

$$\varphi_i^K \geq \pi_i^{K\setminus\{i\}} \qquad \forall i \in K \tag{4.3}$$

$$\pi_i^K \geq \varphi_i^{K\cup i} \qquad \forall i \in N \setminus K \ . \tag{4.4}$$

4.3 Application and appraisal of established per-member partition functions

In this section I present the state of the art benefit-sharing rules in the game theoretic literature on non-cooperative games. All sharing rules have to satisfy the efficiency property (Def. 3). I transfer the formal representation of outcome-based benefit surplus sharing rules (Section 4.3.1) and outside-option sharing rules (Section 4.3.2) to the biodiversity game so that they respect its benefit structure. In Section 4.3.3 I discuss why they might currently, however, not be feasible.

4.3.1 Benefit surplus sharing rule

Outcome-based surplus sharing rules (e.g. Carraro et al. (2006), Weikard et al. (2006)) distribute the total gain from cooperation S^K among the coalition members. The coalition surplus is the difference between the sum of the signatories' benefits and the sum of their pay-offs in the business-as-usual structure without coalition formation. For the biodiversity conservation game I define this surplus in Eq. 4.5.

Definition 5. *Coalition surplus:*

$$\begin{aligned} S^K = &\sum_{i\in K}[B_i^l(P_i^K) + B_i^g(P^K) + Z_i(A_i - P_i^K)] - \\ &\sum_{i\in K}[B_i^l(P_i^{\emptyset}) + B_i^g(P^{\emptyset}) + Z_i(A_i - P_i^{\emptyset})] \quad . \end{aligned} \tag{4.5}$$

I apply the surplus sharing per-member partition function (first derived by Chander and Tulkens (1997) for cooperative games) to the biodiversity game in Eq. 4.6. It is noteworthy for the argument in Section 4.3.3 that the surplus sharing rule is based on the assumption that the surplus under each coalition structure is public knowledge.

Definition 6. *Surplus sharing per-member partition function $\psi_i^{K,S}$ under certainty about the surplus:*

$$\psi_i^{K,S} = \begin{cases} \pi_i^{\emptyset} + \lambda_i^K * S^K & \forall i \in K \\ \pi_i^K & \forall i \in N \setminus K \ , \end{cases} \tag{4.6}$$

where λ_i^K is the weight according to which coalition members share the surplus.

To exemplify, I present two surplus sharing rules for the biodiversity game that are likely to be technically feasible, a protected area based surplus sharing per-member partition function $\psi^{K,SPA}$ (Eq. 4.7) and a biodiversity weighed protected area based surplus sharing per-member partition function $\psi_i^{K,SBPA}$ (Eq. 4.8). Whereas the former uses the factor 'absolute size of a country's protected area' to determine how much each coalition member obtains, the latter additionally respects the quality of the protected area in terms of biodiversity richness (i.e. size of protected ecosystems where very diverse ecosystems count more).

$$\psi_i^{K,SPA} = \begin{cases} \pi_i^{\emptyset} + \frac{\frac{P_i}{A_i}}{\sum_{i \in K} \frac{P_i}{A_i}} * S^K & \forall i \in K \\ \pi_i^K & \forall i \in N \setminus K \ , \end{cases} \tag{4.7}$$

$$\psi_i^{K,SBPA} = \begin{cases} \pi_i^{\emptyset} + \frac{q_i}{\sum_{i \in K} q_i} * \frac{\frac{P_i}{A_i}}{\sum_{i \in K} \frac{P_i}{A_i}} * S^K & \forall i \in K \\ \pi_i^K & \forall i \in N \setminus K \ , \end{cases} \tag{4.8}$$

where q_i denotes an aggregated parameter of country i's biodiversity richness.

In line with Def. 4, the coalition structure K in a biodiversity game with the surplus sharing per-member partition function $\psi_i^{K,S}$ is stable if the following internal and external stability equations hold:

$$\lambda_i^K * S^K \geq B_i^g(P^{K \setminus \{i\}}) \qquad \forall i \in K \tag{4.9}$$

$$B_i^g(P^K) \geq \lambda_i^{K \cup \{i\}} * S^{K \cup \{i\}} \qquad \forall i \in N \setminus K \ . \tag{4.10}$$

Hence, when employing a benefit surplus sharing rule, the stability of a coalition structure K depends strongly on the choice of the sharing weight. This is not the case for the outside option based benefit-sharing rule (Section 4.3.2).

4.3.2 Outside option based benefit-sharing rule

Weikard (2009) developed a general optimal sharing rule, which is based on the countries' outside options, for coalition formation games with asymmetric players and a supperadditive pay-off function. It requires that every coalition member receives at least his outside option, the opportunity costs of joining the coalition. Eyckmans et al. (2012) build on the outside option rule with their *'Proportional Surplus Sharing Scheme'* (PSSS), which is particularly suited for coalition formation games with positive externalities. The *'Proportional Surplus Sharing Valuation Function'* (PSSVF) respects the outside options, explicitly distributes the coalition pay-off in excess of the sum of the members' outside option pay-offs, and assigns a pay-off to all signatories and non-signatories. I present the PSSVF in the notation of the biodiversity game in Eq. 4.11. For the reasoning in Section 4.3.3 it is noteworthy that Eyckmans et al. (2012) develop the PSSVF assuming that the countries' outside options are public knowledge.

Definition 7. *Per-member partition function* $\psi_i^{K,PSSVF}$ *under certainty about the outside options:*

$$\psi_i^{K,PSSVF} = \begin{cases} \pi_i^{K\setminus\{i\}} + \lambda_i^K * \sigma^K & \forall i \in K \\ \pi_i^K & \forall i \in N \setminus K \ , \end{cases} \tag{4.11}$$

where σ^K *is the coalition benefit in excess of all members' outside options,* $\sigma^K = \pi^K - \sum_{i \in K} \pi_i^{K\setminus\{i\}}$*, and* λ_i^K *the weight according to which the former is shared (Eyckmans et al. 2012, Def. 6).*

The weight parameter λ_i^K of the PSSVF remains general in Eyckmans et al. (2012)–some positive weights which add up to one for each coalition. A biodiversity game specific choice of the weight parameter adapts the PSSVF to the biodiversity conservation game. To exemplify I introduce two weights which correspond to the rules applied for the surplus sharing in Section 4.3.1, a weight based on the countries' total size of protected ecosystems ($\lambda_i^{K,PA}$, Eq. 4.12) and one based on countries' total size of protected ecosystems weighed by ecosystem quality ($\lambda_i^{K,BPA}$, Eq. 4.13).

$$\lambda_i^{K,PA} = \frac{\frac{P_i}{A_i}}{\sum_{i \in K} \frac{P_i}{A_i}} \tag{4.12}$$

$$\lambda_i^{K,BPA} = \frac{q_i}{\sum_{i \in K} q_i} * \frac{\frac{P_i}{A_i}}{\sum_{i \in K} \frac{P_i}{A_i}} \tag{4.13}$$

Weikard (2009, Theorem 1) proves for the case of sharing rules which satisfy each country's outside option ('claim rights condition') that internal stability does not depend on the rule the coalition applies to share the benefits in excess of the sum of the members' outside options. Eyckmans et al. (2012, Prop. 1) prove that there exists a stable coalition structure for every PSSVF in a partition function game. This result is independent of the weight parameter as long as the weights are positive and all coalition members' weights add up to one (ref. also Carraro et al. 2006, p. 390). Hence, weight choices are purely of political nature.

4.3.3 Application obstacle: Information uncertainty about biodiversity benefits

The outside option rule is, in theory, optimal to achieve the stable welfare maximising coalition in a general coalition formation game. My presumption, though, is that it is not feasible in the case of biodiversity. Its fundamental assumption of perfect knowledge about countries' pay-offs under different coalition structures π_i^K is too far from reality to be a valid model generalisation due to, inter alia, fundamental ecological uncertainties. Moreover, I presume that lacking scientific information and economic valuation problems render even the application of rules based on expected benefits currently untenable. In the following I substantiate this argument.

Far-reaching knowledge constraints with regard to benefits from biodiversity obstruct the use of the discussed sharing rules. To estimate or even calculate benefit predictions countries would have to have considerable knowledge on their portfolio of biodiversity and its market value. We face uncertainty, though, about the existence of biological and genetic resources, ecosystem behaviour, reproduction, thresholds, feedback loops and system interdependencies. Sources of uncertainty can be 'variability' (ontological, nature of reality) and 'limited knowledge' (epistemological, nature of knowledge), whereby the latter partly arises from the former (Van Asselt and Rotmans 2002, p. 78ff.). Whereas some sources of uncertainty are fundamental, research may reduce limited knowledge. For example, constantly new discoveries of biological resources are made; Purvis and Hector (2000, p. 213) give an idea of the dimension: "An average day sees the formal description of around 300 new species across the whole range of life, and there is no slowdown in sight." Whether uncertainty helps or hampers stability of IEAs is an open question in the game theoretic literature (Kolstad (2007); Finus and Pintassilgo (2013)).

In addition, the economic valuation of biological and genetic resources is challenging. A market hardly exists for genetic resources; with only few effective genetic resource trade regimes (*'Access and Benefit-Sharing'* (ABS) regimes) in place (Kamau et al. 2010, p. 248), there is no functioning market nor an established market price. Moreover, most agreements and especially their benefit stipulations are confidential (Ten Kate and Laird 1999, p. 63). Asymmetric information about the research process and the contribution of genetic resources to a final product (Ten Kate and Laird 2000, p. 244) hamper a provider country forming an idea about potential benefits further. In addition, complementarities, inter alia between genetic resources and (traditional and local) knowledge (Pastor and Sigüeñas 2008, p. 15), create negative cross-price elasticities, where benefits are dependent not only on the resource itself but also on the existence of e.g. associated traditional knowledge.[5] The theoretical potential of genetic resource trade to raise substantial financial funds is subject to scientific debate (Barrett and Lybbert (2000), Costello and Ward (2006)). Besides marketed private goods and services, biological and genetic resources provide non-marketed ones on the whole continuum of private to public goods. The value of non-marketed goods and services is even more difficult to estimate (ref., e.g., Freeman (2003) for an overview of non-market valuation methods and their shortcomings). De Groot et al. (2012, p. 55), for example, find for the tropical forest biome a considerable range of value estimates of the total set of ecosystem services varying between a total minimum value of 1,581 Int.$/ha/year and a total maximum value of 20,851 Int.$/ha/year with a mean value of 5,264 Int.$/ha/year, all at 2007 price levels (based on 96 estimates from the *'Ecosystem Service Valuation Database'*[6]). For the same biome, Pearce (2001, p. 291) presents differences in the valuation of various ecosystem services. The value of carbon storage and sequestration, for example, varies much and depends heavily on the existence and functioning of a carbon market, whereby a price of 10 US-$/tC may result in more than 2500 US-$/ha for closed primary forest and fluctuate accordingly with changing carbon prices. Hence, coalition benefits can be divided into assessable π_a^K (e.g. genetic resource ABS contracts) and difficult or non-assessable ones π_n^K, i.e. $\pi^K = \pi_a^K + \pi_n^K$.

Ecological uncertainty and economic valuation problems thus render it impossible for countries to calculate their status-quo pay-offs π_i, let alone the other countries'

[5] Dependencies on traditional knowledge can be captured by the model through local benefits that are dependent on the knowledge available to use biological resources. I thank an anonymous reviewer for this suggestion.

[6] For details on the database ref. Van der Ploeg et al. (2010).

status-quo pay-offs $\pi_j \; \forall j \in N\backslash\{i\}$. It follows evidently that countries are neither aware of the coalition pay-off S^K under every possible coalition structure nor of their own pay-off π_i^K under every possible coalition structure nor of the other countries' pay-offs $\pi_j^K \; \forall j \in N\backslash\{i\}$ under every possible coalition structure–which would be necessary for the outcome-based surplus sharing rule (Eq. 4.6) and the PSSVF outside option based benefit-sharing rule (Eq. 4.11). For such knowledge a country would have to be able to calculate the monetary implication of differences in coalition membership (itself or another country joins or leaves the coalition) or of changes in the benefit-sharing rule on its benefits.

In any case, countries would use their *perceived* viz. expected benefits to apply the outcome-based surplus sharing rule or the PSSVF outside option based benefit-sharing rule. Eq. 4.6 and Eq. 4.11 under uncertainty read respectively:

Definition 8. *Expected value of the surplus sharing per-member partition function $\psi_i^{K,S}$ under uncertainty about biodiversity benefits:*

$$\mathbb{E}_i[\psi_i^{K,S}] = \begin{cases} \mathbb{E}_i[\pi_i^{\emptyset}] + \lambda_i^K * \mathbb{E}_i[S^K] & \forall i \in K \\ \mathbb{E}_i[\pi_i^K] & \forall i \in N \setminus K \ , \end{cases} \tag{4.14}$$

Definition 9. *Expected value of the per-member partition function $\psi_i^{K,PSSVF}$ under uncertainty about biodiversity benefits:*

$$\mathbb{E}_i[\psi_i^{K,PSSVF}] = \begin{cases} \mathbb{E}_i[\pi_i^{K\setminus\{i\}}] + \lambda_i^K * \mathbb{E}_i[\sigma^K] & \forall i \in K \\ \mathbb{E}_i[\pi_i^K] & \forall i \in N \setminus K \ , \end{cases} \tag{4.15}$$

Once countries gain sufficient information to be able to determine their status-quo benefits (the equation's element soonest to be observable), $\mathbb{E}_i[\pi_i^{\emptyset}]$ in Eq. (4.14) becomes $\pi_i^{\emptyset}$ and the surplus sharing per-member partition function turns out to be preferable to the PSSVF. Even more so, when potential coalition members are able to establish a joint, and through deliberations improved, estimate of the coalition surplus, i.e. when $\mathbb{E}_i[S^K] = \mathbb{E}_K[S^K] \;\; \forall i \in K$, Eq. 4.14 becomes:

$$\mathbb{E}_i[\psi_i^{K,S}] = \begin{cases} \pi_i^{\emptyset} + \lambda_i^K * \mathbb{E}_K[S^K] & \forall i \in K \\ \mathbb{E}_i[\pi_i^K] & \forall i \in N \setminus K \ , \end{cases} \tag{4.16}$$

and thereby involves less uncertainty than Eq. 4.15. The question therefore is how much information countries have and whether they are likely to form expectations based an them, i.e. to embark on the difficult task of estimating, if not guessing, their benefits from various coalition structures, $\mathbb{E}_i[\pi_i^K]$. And–if they do so–whether they are able to produce estimates they are convinced of to the extend that they will base decisions on them.

In addition, asymmetric information about the other countries' expected biodiversity benefits further complicates the issue. Countries face the challenge to convey their expected benefits credibly while at the same time the benefit-sharing rules discussed create incentives for (some) countries not to reveal their expected benefits correctly, such that $\mathbb{E}_i[\pi_j^K] \neq \mathbb{E}_j[\pi_j^K]$. Jakob and Lessmann (2012) develop signalling strategies to stabilise mutually desirable cooperation under asymmetric information for climate change mitigation games. However, they assume perfect information about own benefits–and a strong cooperation spirit among countries. In the case of biodiversity cooperation, countries are left with their own benefit expectations, which in the light of the described range of uncertainties are likely to be vague. In such a situation, countries might be susceptible to be guided by a subjective under- or over-appreciation of their objectively expectable biodiversity richness $\mathbb{E}_{obj}[\pi_i^K]$, whereby $\mathbb{E}_i[\pi_i^K] \neq \mathbb{E}_{obj}[\pi_i^K]$. As a consequence the stability of a coalition–if initially stable at all–is fragile and likely to break up or restructure once countries realise that $\mathbb{E}_i[\pi_j^K] \neq \mathbb{E}_j[\pi_j^K]$ and that $\mathbb{E}_i[\pi_i^K] \neq \mathbb{E}_{obj}[\pi_i^K]$. High transaction costs in re-negotiating might lead to a break-up rather than a restructuring.

These arguments motivate the tentative hypothesis that decision makers are currently likely to decide about their countries' membership in a multilateral biodiversity conservation fund or a biodiversity cartel based on *expected assessable* coalition benefits, $\mathbb{E}_K[\pi_a^K]$, whereby I assume that a joint estimate by coalition members is possible. Moreover, I presume that countries consider the *fairness* of the sharing rule for these benefits. I expect the international and domestic policy considerations, social aspects, as well as environmental concerns to play a major role. Besides, biodiversity might have an intrinsic value for some decision makers that prevents them to consider nature in (purely) monetary terms. If the tentative hypothesis and its rationale were true, the game theoretic assumption of players comparing their payoffs under different coalition structures is not an acceptable model abstraction. The calculation of benefit-sharing rules based on the outside option would give no valid real-world prediction on coalition stability and conservation outcome. To assess the argument and further explore the topic I conducted empirical-qualitative research.

4.4 Insights from empirical-qualitative research

Given the lack of empirical research applicable to study the adequacy of game-theoretic benefit-sharing rules, I conducted empirical-qualitative research to evaluate the assumptions from Section 4.3.3 and further explore the subject. A fortunate coincidence for this research is the fact that the need for and modalities of a *'Global Multilateral Benefit-Sharing Mechanism'* (GMBSM) are currently debated intensively under the *'Nagoya Protocol'* (NP) of the CBD (ref. NP, *Art. 10*). Users of genetic resources would contribute to this still theoretical mechanism and contributions would be earmarked for conservation and sustainable use of biodiversity. Studying the case of genetic resources is illustrative for other types of biodiversity benefit-sharing agreements as it considers benefit sharing with regard to one element of biodiversity: genetic diversity, one of the three components of biodiversity and arguably the most interesting one to consider for the derivation of benefit-sharing rules as it is the most complex diversity dimension; it describes both the tangible (genetic resource as material (ref. CBD, *Art. 2*)) and intangible components (genetic resource as information). In Section 4.4.1 I describe the data collection and analysis. In Section 4.4.2 I present the results.

4.4.1 Data collection and analysis

I conducted fourteen explorative expert interviews in November 2013 with sixteen experts from eight biodiversity rich *'Latin American and Caribbean'* (LAC) biodiversity rich countries in the context of a workshop on ABS[7]. The experts were competent stakeholders[8] in the ABS process of the CBD and its NP. The interviews were conducted in the preferred language of the interviewee as semi-structured interviews with a pretested topic guideline[9] (twelve Spanish, two English). I asked open questions related to (i) a country's past experiences and satisfaction with ABS, (ii) how easy or difficult it is to estimate (potential) monetary benefits from genetic resource trade, (iii) the country's attitude towards a GMBSM and comprehensive global ABS (iv) how benefits from genetic resources should be distributed by a biodiversity conservation fund among countries, and (v) how important benefits and costs

[7]The Science-Policy Workshop on Access and Benefit-Sharing for non-commercial academic research in LAC was facilitated by the International Council for Science, DIVERSITAS, the Swiss Academy of Sciences, the International Union of Biological Sciences, Bonn University, and the Ministry of Environment of Peru.

[8]Inter alia ABS national focal points in the ministries.

[9]Ref. Supplementary Material S.4.1.

are for negotiating international agreements on genetic resource trade. The experts had considerable flexibility in answering and directing the interlocution. The open interview concept allowed me to ask specific detailed questions in response to the experts' statements and thereby explore the topic thoroughly. All but two interviews were recorded (for one notes were taken and the other was a written submission) and interview protocols were drafted after each interview to increase the quality of the analysis. The interview statements are particularly authentic as the GMBSM is a real option which is currently being discussed internationally[10].

I transcribed the interview statements verbatim with only very few and brief exceptions in case of repetitions or obvious digressions. For the interviews recorded in Spanish the transcription included a translation into English. The recordings were played several times to verify the transcript's accuracy. Content analysis and interpretation are suitable methods to analyse verbal, qualitative data. I followed an inductive analysis approach (similar to Mayring (2010)). First, I studied the textual data line by line and coded it by highlighting relevant passages in different colours (codings). Next, I assorted the codings to question headers. Then, I transferred the codings to meta-documents that contain all codes from different interviews which have the same header. I analysed relevant code compilations in detail while the others served to generate background knowledge as situative context information. To ensure internal validity as far as possible in the qualitative analysis, the soundness of the analysis was appraised by assessing potential differences in interpretation nuances. External validity was achieved through a representative choice of experts, a 'theoretical sample' (Bortz and Döring 2006, p. 335): The interviewees were pre-selected by the organizers of a workshop on ABS who have inside knowledge about relevant stakeholders in the ABS process. The final selection focused on policy makers–whereas the workshop had two target groups, researchers and policy makers–and aimed to achieve a coverage of different country backgrounds.

4.4.2 Results

The results from the expert interviews have to be appraised in the context of ABS of *genetic* resources. Countries' preferences and decision making with regard to benefit sharing of genetic resources, though, will share marked parallels to the case

[10]Prior to the interviews, the GMBSM had already been discussed at the second and third meeting of the *'Open-ended Ad Hoc Intergovernmental Committee for the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization'* (ICNP): ICNP-2: www.cbd.int/doc/?meeting=icnp-02; ICNP-3: www.cbd.int/doc/?meeting=ICNP-03, last accessed 03.01.2014.

of a more general sharing of biodiversity benefits as explained in the introduction to this Section. In the following I present the results.

Past experiences and satisfaction with ABS. The interview results show that the experience with monetary benefit sharing is very limited. Peru has signed no commercial ABS contract, Colombia one, Bolivia two to three out of ten solicitations, and Cuba a few. In Mexico the first commercial permit was being processed and in Ecuador the first commercial contract negotiated at the time of the interview. Costa Rica issued between thirty and forty permits for investigation with commercial potential, but no explicitly commercial contract has been signed. Brazil concluded 98 commercial contracts in the period 2004-2013. More progress has been made with non-commercial research contracts. Consequentially, the countries received few monetary benefits[11]. Bolivia obtained payments from one contract, Brazil and Cuba[12] from some, and Costa Rica from non-commercial contracts. The other four countries have not obtained any monetary benefits. The governments' expectations of monetary benefits have not been met.[13] According to the experts, monetary benefits are more important than non-monetary ones for two of the eight countries, non-monetary for one, and equally important for four.

Benefit estimation feasibility. Several experts mentioned that due to the lack of practical experience, it is very complicated to estimate the monetary benefits a country can obtain from genetic resource trade. Only one expert from Costa Rica stated that the Costa Rican *'National Biodiversity Institute'* (INBio) is confident about negotiating commercial contracts with monetary benefits; the capacity has increased because they have gained some negotiation experience. This was also mentioned by one expert from Brazil for her[14] country.

Attitude towards global multilateral benefit sharing. The experts' attitude towards global benefit sharing ranged from being opposed over being sceptical or unsure to being open for the idea and positive about it. As a detailed exposition of the statements would be beyond the scope of this chapter, I limit the presentation to the comments on multilateral benefit sharing that are related to the benefit-sharing

[11] For clarification, these can be payments from international as well as national users.

[12] According to the Cuban expert the case of Cuba is special as research departments of companies and universities are publicly financed and thus most of the benefits flow back to the state.

[13] Six out of eight countries, one no information, one no high benefit expectations at the beginning.

[14] We refer to all experts in the female gender for anonymity reasons.

rule. An expert from Peru was sceptical about a multilateral benefit-sharing fund because she feared that achieving a just and equitable distribution would be too complicated and thus "in the end, at the producer of these genetic resources very little would arrive"–and "because of transaction costs", her colleague added. She elaborated that "if the objective is conservation and sustainability of these resources, those who carry out the conservation have to receive the benefits." Another Peruvian expert mentioned that if resources are not related to traditional knowledge, where one has to consider the local communities in designing a fund, "the fund would be ideal". An Ecuadorian expert favoured regional benefit-sharing programs whose funds are used for "strengthening of institutions in topics of technology transfer and higher involvement of indigenous communities so that the defence of traditional knowledge can be stronger".

Benefit-sharing rules. A Colombian expert explained that due to the little solicitations with commercial aims, they are "not yet thinking of the benefits; so these criteria, they are not yet established". This seemed to be the case for a number of experts I interviewed. An Ecuadorian expert stressed the need to start discussing benefit sharing between countries, although this would be much more complex than the distribution of benefits within one country, which she already considered to be very complex. A Peruvian expert stated that the benefit distribution should be fair in the sense that it respects the countries' conservation efforts. However, a Bolivian and a Mexican expert had doubts about a rule that distributes benefits according to countries' conservation efforts. The Mexican expert stated that such idea would not be bad, but cautioned, "we would need to take care when deciding how to measure it: having protected areas does not necessarily mean that those areas are actually being conserved or that those areas have the most diversity in the country." The Bolivian expert considered such rule to be less attractive for the Latin American countries than an equitable rule. She stated that the distribution of benefits has to be based on equity principles, on the solidarity and sovereignty of countries.[15] A Cuban expert, however, could not imagine a fund that equally distributes money, but rather payments for conservation projects. She and the Mexican expert stressed that the benefits from a fund should only be used for conservation projects and that there should be clear rules for selecting and evaluating these projects. The Cuban expert

[15] To illustrate, the she gave an example, "which could work and which is not very far from imagining, there are five million dollars for an access to genetic resources, an economic projection, which is perhaps made mutually,–five million, if we are five countries, we would get one million".

added that this selection should be based on equality of conditions. An expert from Ecuador was also of the opinion that the fund should invest in projects. She stated that “we have to regard it [the benefit-sharing payments] differently, in a sustainable manner. If we look at it from a financial point of view (...) this might even generate corruption.” The experts from Costa Rica, Peru, Bolivia, Mexico and Ecuador all stated that the communities have to be consulted and their needs considered. One Peruvian expert said that initial payments are important and that they could at first be determined based on the project budget and should then be readjusted as the project progresses. She explained that the determination of a payment has to take into account in-kind transfers already made by the project. Furthermore, she stressed that a mechanism has to allow every state to negotiate. Four experts from four different countries stated that the benefit-sharing rule(s) should be negotiated case by case rather than be based on a global agreement. A Bolivian expert pointed out that “in many cases, in which it [the value of the genetic resource] is not understood, it can probably be started by negotiating genetic resources in a generic manner–but I believe it is case by case.” She argued that a case by case negotiation is needed to respect the different geographic, social, environmental and ecological characteristics of the origin of the genetic resources. A Colombian expert explained that “the distribution of benefits will be case by case depending on the solicitation, on what will be made, where he will work and with whom”.

Importance of monetary factors in negotiations. The picture of the importance of economic versus political, social, and environmental aspects in international negotiations about the design of an IEA is very mixed. Four experts considered them more or less equally important, two regarded the monetary aspects to be more significant, whereas two purported that only non-monetary aspects are relevant in international negotiations. Two other experts explained that it depends on the respondent; one opined that politicians tend to see the economic arguments and researchers the other factors, while the other believed that negotiators are more idealistic while the communities demand monetary benefits.

In conclusion, the results show that the experts, who were all political stakeholders in the ABS processes of LAC countries, could so far only gain little experience with commercial benefit-sharing contracts. Consequentially they feel rather unsure in dealing with monetary benefits–to estimate them and to negotiate them. Monetary benefits tend to be important, but not necessarily more than non-monetary benefits. Likewise, in international negotiations about a benefit-sharing rule economic benefits and costs are only one aspect countries consider besides political, social and environmental ones. The use of benefits for conservation projects, for example, would imply too much conservation from a rational utility maximising perspective as increasing conservation costs reduce the overall benefits. The results thus confirm that benefit-sharing rules that consider rational utility maximisers who are at least aware of expected biodiversity benefits are currently not a feasible model abstraction.

4.5 An alternative appraoch to benefit-sharing rules

In this Section I outline an alternative approach to benefit-sharing rules which takes the current real-world constraints of ecological and biological uncertainties, limited information on biodiversity benefits, unease to form benefit expectations, and asymmetric information about expected benefits into account. A benefit-sharing rule can currently only be based on *expected assessable coalition benefits* $\mathbb{E}_K[\pi_a^K]$ (ref. Section 4.3.3). Benefit-sharing determinants $f_i(\cdot)$ specify the weight λ_i according to which the expected assessable coalition pay-off is distributed among the coalition members:

$$\pi_i = \lambda_i(f_i^1, f_i^2, ..., f_i^N) * \mathbb{E}_K[\pi_a^K] \quad \forall i \in K, \ \frac{\partial \lambda_i}{\partial f_i^j} \geq 0 \ , \ \sum \lambda_i = 1 \ . \qquad (4.17)$$

In the following, I develop a benefit-sharing determinant that is relevant for international decision-making and governance and that can also be incorporated into the established game-theoretic rules. In Section 4.5.1 I discuss requirements for its technical operability and political economy feasibility based on which I propose a tentative determinant in Section 4.5.2.

4.5.1 Technical and political economy feasibility requirements

Benefit-sharing determinants $f_i(\cdot)$ have to meet technical and political economy requirements to be employable in practice–not only in the case of IEAs. For technical operability the determinants need to be adequate and measurable. Their data ideally satisfies the following criteria:

(i) Data observability

(ii) Reasonable data collection cost

(iii) Formal accuracy of collected data

(iv) Data validity

(v) Data comparability between countries

'Data observability' (i) refers to whether the data is theoretically measurable. The criteria 'reasonable data collection cost' (ii) considers whether the data is affordable or whether data acquisition costs are prohibitively high. 'Formal accuracy of collected data' (iii) requires that no measurement errors are made. The criteria 'data validity' (iv) ensures that the data measures what it is supposed to measure, so that the benefit-sharing determinant leads to the intended benefit distribution. This includes the possibility that a measurement method may have certain flaws as long as they are acknowledged and accepted by all stakeholders. 'Data comparability between countries' (v) points to the necessity that measurements are taken in a standardised manner. An example of a technically feasible determinant is the total size of conserved ecosystems of a country i, P_i. The data is observable (i) and available at negligible cost (ii), because the creation of protected areas includes their measurement. The formal accuracy of the data is also likely as the measurements are usually made using the *'Global Positioning System'* (GPS) (iii). Actual data validity depends on the enforcement of the areas' protection state (iv). It is likely to require special consideration given the variation in the enforcement of protected areas by countries' executives (ref. the respective statement made by a Mexican expert, Section 4.4.2). The data measurements are presumably comparable between countries as most conservation sites are classified according to or inspired by the protected area criteria[16] of the *'International Union for Conservation of Nature'* (IUCN) (v). Moreover, the determinant is directly related to biodiversity conservation efforts and thus arguably adequate for a sharing rule for biodiversity benefits. Following the same line of argument, further possibly technically feasible determinants $f(\cdot)$ for the benefit-sharing weight, which fulfil the criteria (i) to (v) to a certain degree, are:

(1) Size of protected ecosystems of a country i relative to the size of protected ecosystems of all countries:
$f_i^1\left(\frac{P_i}{\sum_{i\in K} P_i}\right), \quad f'(\cdot) > 0;$

(2) Number of endemic species x of a country i relative to the number of endemic species of all countries (data in e.g. Groombridge and Jenkins (2002)):

[16] Online: www.iucn.org/about/work/programmes/gpap_home/gpap_quality/gpap_pacategories/, last 15.05.2014.

$$f_i^2\left(\frac{x_i}{\sum_{i\in K} x_i}\right), \quad f'(\cdot) > 0;$$

(3) Number of endangered species y of a country i relative to the number of endangered species of all countries (IUCN Red List of Threatened Species: "endangered" and "critically endangered"):

$$f_i^3\left(\frac{y_i}{\sum_{i\in K} y_i}\right), \quad f'(\cdot) > 0;$$

(4) Population size of a country i relative to the population size of all countries:

$$f_i^4\left(\frac{\Omega_i}{\sum_{i\in K} \Omega_i}\right), \quad f'(\cdot) > 0;$$

(5) Size of a country i's area A relative to the total size of all countries' areas:

$$f_i^5\left(\frac{A_i}{\sum_{i\in K} A_i}\right), \quad f'(\cdot) > 0;$$

(6) Equal shares for all provider countries:

$$f_i^6 = \frac{1}{K}, \quad f'(\cdot) = 0.$$

Determinants (4) to (6) are not directly related to biodiversity whilst still being adequate; adequacy can be justified by countries' preferences–for example preferences for the most simple and transparent parameter. This highlights the importance of political economy aspects.

The results from the expert interviews show that for the interviewed political stakeholders environmental considerations are important in the context of benefit sharing of genetic resources. Several experts stated that the benefits from genetic resource trade should be earmarked for conservation projects (ref. Section 4.4.2). This is more broadly also reflected by the popularity of the concept of *'Good Living'*, which depicts a deep respect for nature in several Latin American countries (Gudynas 2011, p. 231). The results from the expert interviews show that the interviewed policy makers pay attention to fairness concerns such as the acknowledgement of conservation efforts, the consideration of indigenous and local communities, as well as other social aspects. The perception of receiving a fair and equitable benefit share seems to be crucial for a self-enforcing coalition. Distributional justice can result from allocation-based, outcome-based, and process-based equity criteria (Rose et al. 1998). Allocation-based equity refers to the fairness of the benefit-distribution determinants. A very important criteria is that the allocation rule respects the countries' 'sovereignty'. Other criteria are ecological and egalitarian criteria, which were also voiced prominently by the experts (ref. Section 4.4.2) and include those discussed above. Outcome-based equity considers whether the achieved benefit distribution is just; it is a teleological-consequentialist ethical concept, to which i.a. the outside-option rule belongs[17]. However, outcome-based equity was not in the focus of the experts' statements. Process-based equity refers to rule-based ethical considerations and thus deontological ethics. This includes for example the criteria fairness of the international negotiations, which was mentioned by several experts, in particular in the context of including indigenous and local communities in deliberations about a benefit-sharing rule. Thus equity considerations are very important in decisions on whether to participate in a biodiversity coalition or not.

4.5.2 A tentative determinant for the benefit shares

The previous considerations of technical feasibility and political economy aspects together with the results from the expert interviews prepare the ground for my proposal of a determinant f_i^* for the weight λ_i according to which the expected assessable coalition pay-off is distributed among the coalition members. I consider the determinant "size of protected ecosystems of a country i relative to the size of protected ecosystems in all other countries, weighed by a country's biodiversity richness and population density" to be adequate:

$$f_i^* \left(\frac{\frac{P_i}{A_i}}{\sum_{i \in K} \frac{P_i}{A_i}} * \frac{q_i}{\sum_{i \in K} q_i} * \frac{\frac{\Omega_i}{A_i}}{\sum_{i \in K} \frac{\Omega_i}{A_i}} \right), \quad f'(\cdot) > 0. \tag{4.18}$$

The parameter values for P_i, q_i, and Ω_i are taken at a certain reference date prior the point of coalition formation.[18] I substantiate my proposal in the following.

The tentative determinant f_i^* (Eq. 4.18) is, arguably, suitable as it embraces the political economy considerations of the previous section and those voiced during the expert interviews. The interviews revealed the importance of environmental and fairness concerns. f_i^* consists of two allocation-based equity criteria, an 'environmental conservation' and an 'egalitarian' component. It implies that protection in countries with a high biodiversity richness and a high population density counts more. The reason for the former is the higher contribution to global biodiversity benefits. The rationale for the latter are opportunity costs rising with population density; more land is needed for food, housing, public infrastructure, and recreation. Outcome-based equity concerns were not expressed dominantly by the experts. The tentative

[17] The outside-option corresponds to Rose et al.'s (1998, p. 30) 'compensation' criteria.

[18] It is crucial that the reference date is prior to coalition formation. Taking the observed share of protected area during coalition formation would lead to strategic interactions as it is the strategy variable in the underlying basic biodiversity game (ref. Eq. 4.1).

determinant viz. sharing rule has to withstand practical scrutiny and should be regarded as a substantiated proposal. It may feed into discussions about a multilateral benefit-sharing fund. Thereby process-based equity, which cannot exist at this stage, may evolve through inclusive, open and fair deliberations.

Besides being adequate, f_i^* needs to fulfil the technical feasibility criteria (i) to (v) (ref. Section 4.5.1). The data on protected areas is available in the *'World Database on Protected Areas'* (WDPA)[19]. It is publicly accessible as *'terrestrial and marine areas protected, percentage of terrestrial area and territorial waters'*[20]. The data on a country's biodiversity richness can easily be obtained from, e.g., Groombridge and Jenkins's (2002) *'World Atlas of Biodiversity'* (Diversity Index DI as mean of richness and endemism) or the *'Global Environment Facility'*s (GEF) benefits index for biodiversity[21]. The *'World Development Indicator'* (WDI) of the World Bank[22] supplies free online data on population density in terms of *'people per square kilometre of land area'*. Thereby all required data can be obtained from public databases (i) at low cost (ii) and high degree of accuracy (iii). Data validity (iv) is likely for the data on population density, whereas biodiversity richness is more likely to vary slightly with indicator choice and the validity of the data on protected areas is, as discussed previously, dependent on a state's enforcement of the protection status. Countries might be willing to accept these potential deviations and agree to use standardised official data (e.g. from UN, GEF, World Bank, etc.) nevertheless– if not, a governance indicator could be included to capture the latter concern. To illustrate, I provide an numerical example for several LAC and *'European Union'* (EU) countries in Fig. 4.1. Brazil and Ecuador, for example, will appropriate a high benefit share. Brazil profits from the highest biodiversity richness, which even outweighs its relative low population density. Ecuador is biodiversity rich although not as much as Brazil according to the indicator and benefits strongly from its relative high land surface with protected areas. For Bolivia the tentative

[19]The WDPA is provided by the *'United Nations World Conservation Monitoring Centre'* (UNEP-WCMC) and the IUCN *'World Commission on Protected Areas'* and contains all protected areas for which the location and extent is known. It is the most comprehensive global dataset for protected areas and was used for the 2013 *'Millennium Development Goals'* (MDGs) Report and for reports towards the achievement of the CBD *'Aichi Targets'*. Online: www.protectedplanet.net, last 04.04.2014.

[20]Ref. www.wdpa.org/resources/statistics/2013_MDG_National_stats_Indicator_7_6.xlsx, last 04.04.2014. It can also be accessed through the *'World Development Indicator'* (WDI) databank of the World Bank: http://data.worldbank.org/indicator/ER.PTD.TOTL.ZS, last 04.03.2015.

[21]Ref. http://www.thegef.org/gef/GEF-4_benefits_index, last 04.03.2015. It can also be accessed through the WDI databank: http://data.worldbank.org/indicator/ER.BDV.TOTL.XQ, last 04.03.2015.

[22]Ref. http://data.worldbank.org/indicator/EN.POP.DNST, last 04.04.2014.

determinant is not favourable as the country has a very low population density paired with medium levels of both protected areas and biodiversity richness. Biodiversity richness is low for the EU countries reducing their share of benefits. Germany raises its otherwise even lower determinant's value slightly by a good performance in the extent of protected areas.

Figure 4.1: Numerical application example: Tentative determinant for the benefit shares

Country	$\frac{P_i / A_i}{\sum_{i \in K} P_i / A_i}$ (Source: WDI / WDPA)	$\frac{q_i}{\sum_{i \in K} q_i}$ (Source: WDI / GEF)	$\frac{\Omega_i / A_i}{\sum_{i \in K} \Omega_i / A_i}$ (Source: WDI / FAO, World Bank)	f_i^*	$\lambda_i = \frac{f_i^*}{\sum_{i \in K} f_i^*}$
LAC countries					
Bolivia	0.064	0.037	0.006	1.4E-05	0.007
Brasil	0.090	0.295	0.015	3.9E-04	0.197
Colombia	0.070	0.152	0.026	2.8E-04	0.142
Costa Rica	0.061	0.029	0.057	1.0E-04	0.051
Cuba	0.015	0.037	0.069	3.9E-05	0.020
Ecuador	0.131	0.086	0.038	4.3E-04	0.218
Mexico	0.040	0.202	0.038	3.1E-04	0.158
Peru	0.045	0.098	0.014	6.4E-05	0.033
EU countries					
France	0.059	0.016	0.076	7.0E-05	0.036
Germany	0.146	0.002	0.152	4.2E-05	0.021
Italy	0.055	0.011	0.129	8.0E-05	0.041
Poland	0.075	0.002	0.081	9.4E-06	0.005
Romania	0.027	0.002	0.058	3.0E-06	0.002
Spain	0.026	0.020	0.060	3.2E-05	0.016
Sweden	0.035	0.001	0.015	4.4E-07	0.000
United Kingdom	0.062	0.010	0.165	1.1E-04	0.055
Sum	1.0	1.0	1.0	2.0E-03	1.0

The cells are coloured to indicate the relative contribution of the determinant's dimensions to the level of a countries determinant f_i^* as well as the performance of a country compared to other countries in one determinant's dimension and the determinant itself.
Source: Own compilation with data from the WDI 2008 data series "Terrestrial and marine protected areas (% of total territorial area)" (ER.PTD.TOTL.ZS) based on WDPA data, "GEF benefits index for biodiversity" (ER.BDV.TOTL.XQ) based on GEF data, "Population density (people per sq. km of land area)" (EN.POP.DNST) based on FAO and World Bank data.

The determinant f_i^* can be included as determinant for λ_i^K in the established per-member partition functions discussed in Section 4.3. Distributing the coalition benefit according to the determinant is in design close to the outcome-based benefit surplus sharing rule. The important difference, though, is that countries do not take the decision of joining the coalition based on the outcome but on the fair distribution of the expected assessable coalition benefit and thus also on the determinant itself–allocation- and process-based equity are important. Once countries gain more information, the outcome-based benefit surplus sharing rule with f_i^* as determinant for λ_i^K will become an acceptable game-theoretic model abstraction. Experts from Costa Rica and Brazil, for example, mentioned that information on benefits increased because they have gained some experience with commercial ABS (ref. Section 4.4.2). Extensive further additional information might eventually also enable the application of the outside option based benefit-sharing rule.

4.6 Conclusion

In this chapter I provide an analysis of benefit-sharing rules for biodiversity coalition formation games to open and enrich a discussion on the applicability of standard game-theoretic benefit-sharing rules for IEAs. To this end I transfer established benefit-sharing rules to a biodiversity conservation game with heterogeneous countries, discuss potential application impediments and assess these through empirical-qualitative research. The information requirements for game-theoretic per-member partition functions are too demanding in case of biodiversity cooperation–even the application of rules based on expected benefits is currently untenable–due ecological uncertainties and economic valuation problems. Based on the empirical results I propose an alternative benefit-sharing rule. It distributes the *expected assessable* coalition pay-off among the coalition members. I derive a tentative determinant for the benefit-sharing weight from technical and political economy considerations and the empirical findings. It distributes benefits according to the relative size of protected ecosystems weighed by a country's biodiversity richness and population density. It is flexible in that it can be incorporated into the established game-theoretic benefit-sharing rules and be applied to different states of the world of informational constraints on benefits.

An assessment of the relevance of game-theoretic assumptions is crucial for valid game-theoretic descriptive and predictive analyses of international environmental cooperation. Additional empirical research is needed both to further explore countries' preferences with regard to the modalities of multilateral sharing of benefits from biodiversity and to broaden the scope of the analysis by addressing other IEAs.

Bibliography

Barrett, C. and T. J. Lybbert (2000). Is bioprospecting a viable strategy for conserving tropical ecosystems? *Ecological Economics 34*(3), 293 – 300.

Barrett, S. (1994). The biodiversity supergame. *Environmental and Resource Economics 4*(1), 111–122.

Bortz, J. and N. Döring (2006). *Forschungsmethoden und Evaluation für Human- und Sozialwissenschaftler* (4 ed.). Heidelberg: Springer.

Carraro, C., J. Eyckmans, and M. Finus (2006). Optimal transfers and participation decisions in international environmental agreements. *The Review of International Organizations 1*(4), 379–396.

Chander, P. and H. Tulkens (1997). The core of an economy with multilateral environmental externalities. *International Journal of Game Theory 26*(3), 379–401.

Costello, C. and M. Ward (2006). Search, bioprospecting, and biodiversity conservation. *Journal of Environmental Economics and Management 52*(3), 615–626.

D'Aspremont, C., A. Jacquemin, J. J. Gabszewicz, and J. A. Weymark (1983). On the stability of collusive price leadership. *The Canadian Journal of Economics 16*(1), 17–25.

De Groot, R., L. Brander, S. van der Ploeg, R. Costanza, F. Bernard, L. Braat, M. Christie, N. Crossman, A. Ghermandi, L. Hein, S. Hussain, P. Kumar, A. McVittie, R. Portela, L. C. Rodriguez, P. ten Brink, and P. van Beukering (2012). Global estimates of the value of ecosystems and their services in monetary units. *Ecosystem Services 1*, 50–61.

Eyckmans, J., M. Finus, and L. Mallozzy (2012). A new class of welfare maximizing stable sharing rules for partition function games with externalities. *Working Paper, Department of Economics, University of Bath*.

Finus, M. and P. Pintassilgo (2013). The role of uncertainty and learning for the success of international climate agreements. *Journal of Public Economics 103*, 29–43.

Freeman, A. (2003). *The Measurement of Environmental and Resource Values: Theory and Methods* (2 ed.). Washington: Resources for the Future.

Groombridge, B. and M. D. Jenkins (2002). *World Atlas of Biodiversity.* Berkeley/Los Angeles/London: University of California Press.

Gudynas, E. (2011). Tensiones, contradicciones y oportunidades de la dimensión ambiental del Buen Vivir. In I. Farah and L. Vasapollo (Eds.), *Vivir bien: ¿Paradigma no capitalista?*, pp. 231–246. La Paz: CIDES - UMSA.

Jakob, M. and K. Lessmann (2012). Signaling in international environmental agreements: The case of early and delayed action. *International Environmental Agreements: Politics, Law and Economics 12*(4), 309–325.

Kamau, E., B. Fedder, and G. Winter (2010). The Nagoya Protocol on Access to Genetic Resources and Benefit Sharing: What is new and what are the implications for provider and user countries and the scientific community? *Law, Environment and Development Journal 6*(3), 246–262.

Kolstad, C. D. (2007). Systematic uncertainty in self-enforcing international environmental agreements. *Journal of Environmental Economics and Management 53*, 68–79.

Mayring, P. (2010). *Qualitative Inhaltsanalyse. Grundlagen und Techniken* (11 ed.). Weinheim: Beltz.

Pastor, S. and M. Sigüeñas (2008). *Bioprospección en el Peru.* Lima: Sociedad Peruana de Derecho Ambiental (SPDA).

Pearce, D. W. (2001). The economic value of forest ecosystems. *Ecosystem Health 7*(4), 284–296.

Purvis, A. and A. Hector (2000). Getting the measure of biodiversity. *Nature 405*, 212–219.

Rose, A., B. Stevens, J. Edmonds, and M. Wise (1998). International equity and differentiation in global warming policy. An application to tradeable emission permits. *Environmental and Resource Economics 12*(1), 25–51.

TEEB (2010). *The Eocnomics of Ecosystems and Biodiversity: Ecological and Economic Foundations.* London and Washington: Earthscan.

Ten Kate, K. and S. A. Laird (1999). *The Commercial Use of Biodiversity: Access to Genetic Resources and Benefit-Sharing*. London: Earthscan.

Ten Kate, K. and S. A. Laird (2000). Biodiversity and business: Coming to terms with the 'grand bargain'. *International Affairs 76*(2), 241–264.

Thrall, R. and W. Lucas (1963). n-person games in partition function form. *Naval Research Logistics Quarterly 10*(1), 281–298.

Van Asselt, M. B. A. and J. Rotmans (2002). Uncertainty in integrated assessment modelling. From positivism to pluralism. *Climatic Change 54*, 75–105.

Van der Ploeg, S., R. De Groot, and Y. Wang (2010). The teeb valuation database: overview of structure, data and results. Foundation for Sustainable Development, Wageningen, the Netherlands.

Weikard, H.-P. (2009). Cartel stability under an optimal sharing rule. *The Manchester School 77*(5), 575–593.

Weikard, H.-P., M. Finus, and J.-C. Altamirano-Cabrera (2006). The impact of surplus sharing on the stability of international climate agreements. *Oxford Economic Papers 58*(2), 209–232.

Winands, S., K. Holm-Müller, and H.-P. Weikard (2013). The biodiversity conservation game with heterogeneous countries. *Ecological Economics 89*, 14–23.

Part II

Multilateral Cooperation on the Genetic Resource Market

Chapter 5

Eco-regional Cooperation on the Genetic Resource Market and the Case of the Andean Community

Abstract: The United Nations *'Convention on Biological Diversity'* codified state sovereignty over genetic resources and subsequently bilateral contracts over genetic resource use evolved. However, countries currently obtain only few benefits from bilateral contracts, largely due to high transaction costs. In this chapter, we consider eco-regional cooperation by megadiverse countries in physical genetic resource trade. The main objective is to investigate whether such cooperation can increase benefits for provider countries and *in-situ* conservation of biodiversity. The Andean Community's access legislation serves as a case study. Our main finding is that eco-regional cooperation has the potential to significantly reduce transaction costs for both supplying countries and customers. It can thereby decrease prices for customers and increase demand, conservation levels and providers' benefits. Countries with a relatively higher biodiversity richness and a comparatively better institutional environment are able to appropriate a higher share of cooperation induced benefits. Collusion on the physical genetic resource market will not lead to high benefits as market power is limited by substitutes in form of *ex-situ* resources and freely available genetic information. The Andean Community realises few of the potential cooperation advantages.

Chapter 5 has been published as Discussion Paper as: *Winands, S. and K. Holm-Müller (2014). Eco-regional Cooperation on the Genetic Resource Market and the Case of the Andean Community. ILR Food and Resource Economics Discussion Paper 2014 (2), updated version, 1-32.*

5.1 Introduction

Genetic resources and their diversity are valuable for R&D in many industries. Numerous discoveries rely on *in-situ* conservation of genetic resources. Countries engage in costly active conservation by setting aside land as protected areas. Genetic resources are also passively conserved *in-situ* if countries lack the capital or human resources to exploit the land or if transaction costs are too high. Active and passive conservation create positive externalities for genetic resource users. A remuneration for passive and especially active conservation can be achieved through payments for the use of genetic resources. Thereby the positive externalities of conservation that accrue to genetic resource users can–at least partly–be internalised.

The *'Convention on Biological Diversity'*[1] (CBD) and its *'Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity'*[2] (NP) are the global institutional framework for payments for genetic resource use. With its entry into force, the CBD codified the sovereignty of states over their genetic resources. Subsequently, countries started to regulate access to their genetic resources in order to receive payments for the use of genetic resources and the associated traditional knowledge from bilateral *'Access and Benefit-Sharing'* (ABS) contracts. The Nagoya Protocol, which came into effect last year, specifies countries' ABS obligations.

As countries within an eco-region share many genetic resources, they may benefit from joint access regulation. The member countries of the Andean Community[3] (*'Comunidad Andina'*, CAN) were the first to opt for such special regulation. They decided to pass community law, *Decisión 391*[4], to govern access to their genetic resources already in 1996.

In this chapter we discuss advantages of eco-regional cooperation for the internalisation of positive conservation externalities accruing to genetic resource users. We study the scope of eco-regional cooperation to improve upon the currently common bilateral contracts with a view (a) to achieving payments for physical genetic

[1] United Nations (1992): Convention on Biological Diversity, 31 Int'l Leg. Mat. 818, Rio de Janeiro, 05.06.1992.

[2] United Nations (2010): Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity, Nagoya, 29.10.2010.

[3] The Andean states established the Andean Community with the Cartagena Accord in 1969. Chile was a member until 1976, Venezuela from 1973 until 2006.

[4] Decisión 391 on a 'Common Regime on Access to Genetic Resources' (Comision del Acuerdo Cartagena (1996): Decisión 391: Régimen Común sobre Acceso a los Recursos Genéticos, Gaceta Oficial del Acuerdo de Cartagena, Año XII, Numero 213, Lima, 17.06.1996).

resource use and thereby (b) to increasing conservation. In our analysis we consider a continuum of cooperation from loose cooperative behaviour to collusion. In light of transaction cost economics, we study on a generic level how general dimensions of cooperation impact on economies of scale and other institutional factors–and thereby on the volume of trade, the monetary and non-monetary benefits of cooperating countries, and conservation levels. Moreover, we analyse how a country's characteristics influence its share of cooperation induced benefits. We discuss the potential of collusion and its impact on conservation. The CAN serves as a case study and adds empirical insights to our theoretical analysis.

Economic and legal research have focused mainly on strong regional cooperation–cartelization on the genetic resource market–to increase the revenues of countries rich in biodiversity. From an economic perspective, Vogel et al. (i.a. 1995, 2000, 2007) have argued since long for an international cartel over genetic resources that also covers natural information[5]. Besides, they propose the conversion of traditional knowledge associated with genetic resources into trade secrets and the formation of local cartels over these, which may merge into regional and subsequently a global cartel. Others have touched upon genetic resource cartels and are more sceptical of their success (Reid et al. (1996, p. 169); Richerzhagen (2011, p. 2254)). Asebey and Kempenaar (1995) and Tilford (1998) provide legal studies of cartelization on the biodiversity market. We differ from the above mentioned cartelization literature in that we explicitly focus on regional cooperation over physical genetic resources, analyse a continuum of loose cooperation to collusion, and additionally consider implications for the level of biodiversity conservation. A related proposition by Winter (2009) are common pools of genetic resources, whereby countries of the same biogeographical region form corporations.

With regard to the CAN, Rosell (1997), Ten Kate (1997), Mariaca (1999), Tafur-Dominguez (2000), Ruiz (2003), and Bucher (2008) review the content of *Decisión 391* from a legal perspective; we add an economic analysis with our case study.

The chapter proceeds as follows: In Section 6.2 we provide a background on the genetic resource market under the CBD and its Nagoya Protocol. In Section 5.3 we introduce the dimensions of eco-regional cooperation in genetic resource trade. We analyse eco-regional cooperation advantages in Section 5.4. In Section 5.5 we study the CAN community access regulation. With Section 5.6 we conclude.

[5]Natural information is an even wider category than genetic information, including also, for example, biomimicry (Vogel et al. 2011, p. 55).

5.2 The genetic resource market under the CBD and its Nagoya Protocol

The CBD and its Nagoya Protocol established an *'Access and Benefit-Sharing'* (ABS) mechanism to govern genetic resource use and the fair sharing of the resulting benefits. The CBD defines genetic resources as "genetic material of actual or potential value", whereby "genetic material means any material of plant, animal, microbial or other origin containing functional units of heredity" (*Art. 2*). The predominant, though not uncontested (ref. Schei and Tvedt 2010, p. 18), interpretation is that the CBD applies only to genetic material, not to genetic or natural information. We focus on physical genetic resources in this chapter.

The Nagoya Protocol entered into force in October 2014 and specifies the ABS mechanism, which member countries have to implement.[6] It regulates countries access (*Art. 6, 7*), benefit sharing (*Art. 5*), and compliance obligations (*Art. 15 - 18, 30*) with regard to genetic resources and associated traditional knowledge. A user entity has to ask a provider country for access to its genetic resources and/or traditional knowledge associated with genetic resources, i.e. to obtain *'Prior Informed Consent'* (PIC). If granted, user and provider country negotiate the terms of access and benefit sharing, the *'Mutually Agreed Terms'* (MAT). The benefit sharing can take various forms and may include monetary (e.g. up-front payments, royalties) and non-monetary benefits (e.g. joint R&D, technology transfer) (ref. *Annex NP*). The benefits finally agreed upon in bilateral ABS mirror the relative negotiation power of provider and customer, but also costs of providers and benefits for users. Many countries, such as Brazil, are both provider and user countries.

The Nagoya Protocol foresees the creation of a *'National Focal Point'* with international information and cooperation duties and a *'Competent National Authority'* for granting access in member countries (*Art. 13*). A global *'Access and Benefit-sharing Clearing-House'* shall facilitate the information sharing (*Art. 14*). Moreover, the Nagoya Protocol provides for the development of model contractual clauses (*Art. 19*), codes of conduct, guidelines, and best practices and/or standards (*Art. 20*), as well as awareness-rising (*Art. 21*), capacity building (*Art. 22*), and technology transfer, collaboration, and cooperation (*Art. 23*).

The Nagoya Protocol explicitly encourages transboundary cooperation (*Art. 11*)

[6] The Nagoya Protocol is based on the 2002 *'Bonn Guidelines on Access to Genetic Resources and Fair and Equitable Sharing of the Benefits Arising out of their Utilization'* (UNEP/CBD/COP/6/24).

and prompts a discussion on a *'Global Multilateral Benefit-Sharing Mechanism'* for shared genetic resources or for resources for which PIC is not possible (*Art. 10*).

Genetic resources are important production factors for many industries, i.a. pharmaceutical and cosmetic firms, biotechnology, and food and beverage industries (Ten Kate and Laird 1999, p. 9). Physical genetic resources are, for example, accessed to be exported into another country for proliferation. They may also be accessed because of the genetic or natural information contained within them. Mostly, it is the information that is commercially used (Stone (1994, p. 597); Schei and Tvedt (2010)). Richerzhagen (2011, p. 2248) describes the current genetic resource market as oligopsonistic. Ten Kate and Laird (2000, p. 245) explain that "life science titans such as Monsanto, Novartis and Aventis evolve alongside a host of small research biotechnology companies". The supply-side concentration on the market for physical genetic resources depends on the type of screening. Only for random screening do all countries with reasonable biodiversity richness compete against each other. Most screening, though, is knowledge-based, be it 'biorational', 'chemotaxonomic' or 'ethnobotanical' (Ten Kate and Laird 2000, p. 249 f.). In this case, users search for specific genetic resources–which reduces the number of suppliers beforehand. Hence, we describe the market for physical genetic resources as a bilateral oligopoly.

So far, bilateral bioprospecting falls behind expectations in terms of contract numbers and magnitude of realised benefits (Boisvert and Vivien (2005, p. 466 f.); Pastor and Ruiz (2009, p. 8)). Currently difficult access regulations from provider countries raise transaction costs for users, which reduces the demand for access to genetic resources (Fernández Ugalde 2007, p. 7). Also for providers, bilateral contractual ABS involves–so far–considerable transaction costs for administration, monitoring, and enforcement (Vogel 2007, p. 59 ff.). For most resource-rich countries, especially monitoring of contract compliance is a challenge (Ten Kate and Laird 2000, p. 244). They face asymmetric information regarding the commercial research process in the purchasing country and the sources of a final product's components. Detection of genetic resources taken without prior consent of the host country or of resources acquired through illegal trade is similarly difficult. In addition, many countries implemented national legislation ineffectively and inefficiently (Kamau et al. 2010, p. 248). Besides, the bilateral approach covers access to physical genetic resources and may also be applied to genetic information not yet in the public domain; it cannot, however, capture the bulk of intangible genetic and natural information in the (semi-)public domain.

It has to be seen, whether and how far the Nagoya Protocol, which came into force recently, changes bilateral contractual ABS and whether and how *Art. 11*, NP, on transboundary cooperation and *Art. 10*, NP, on a *'Global Multilateral Benefit-Sharing Mechanism'* are implemented.

It is in this setting that we study the scope of eco-regional cooperation to improve upon the currently common bilateral contracts with a view to achieving payments for physical genetic resource use and thereby to increasing conservation.

5.3 Dimensions of eco-regional cooperation

In the following, we introduce different elements of eco-regional cooperation in physical genetic resource trade. Megadiverse countries can cooperate rather loosely by, for example, coordinating information they reveal to third parties. Or in the other extreme, they may collude in prices and reallocate benefits and thereby be close to maximising their joint benefit. In the following we present general degrees of cooperative behaviour from cooperation ((i)-(v)) to collusion (vi):

(i) Public notification of all bioprospecting processes.

(ii) A public register of genetic resources within the eco-region.

(iii) Coordination of access to genetic resources.

(iv) A regional competent authority.

(v) Reallocation of benefits according to a pre-defined rule.

(vi) Coordination in prices.

Public notification of bioprospecting processes (i) and a public register of biological or genetic resources within the eco-region (ii) are forms of loose cooperation between countries. They can vary in their set-up and comprehensiveness. The register might be similar to or make use of existing genetic barcode databases[7].

A stronger form of cooperation is the coordination of access to physical genetic resources within the eco-region or even a joint access regulation (iii). Besides the CAN's *Decisión 391*, there are other regional frameworks of more or less coordinated access: The *'African Union'* has developed a non-binding *'Model Legislation for*

[7]For example: GenBank of the National Library of Medicine of the United States of America (www.ncbi.nlm.nih.gov/ genbank/, last 19.09.2014), European Nucleotide Archive ENA (www.ebi.ac.uk/ena, last 19.09.2014), DNA Data Bank of Japan (www.ddbj.nig.ac.jp, last 19.09.2014).

the Protection of the Rights of Local Communities, Farmers and Breeders, and for the Regulation of Access to Biological Resources' in 2001 to assist its members in drafting national legislation (Munyi and Jonas 2013, p. 219 f.). The *'Association of South East Asian Nations'* has developed a *'Framework Agreement'* on ABS, which "leaves each Member State to determine the nature of the country's access instrument" (Cabrera Medaglia et al. 2012, p. 25) and is still a draft (ASEAN Centre for Biodiversity 2013). The *'Central American Commission on Environment and Development'* has drafted a *'Central American Protocol on Access to Genetic and Biochemical Resources and the associated Traditional Knowledge'*, which has been signed but not ratified by its member countries (Cabrera Medaglia et al. 2012, p. 80).[8]

A regional authority (iv) may coordinate joint action and represent the group of cooperating countries. The member countries decide upon the range and depth of its competencies; it might be responsible for or merely streamline information, communication, negotiation and/or trade.

An even more intense form of cooperation is the redistribution of monetary and possibly non-monetary benefits from genetic resource trade among members sharing the same genetic resources within their eco-region (v). Monetary benefits might, for example, be shared through a fund and non-monetary benefits through joint training workshops or cooperation in R&D.

Cooperation merges into a collusion if countries agree on and are able to enforce higher prices for physical genetic resources (vi). There are parallels to the industrial economics literature, which we transfer and adapt to eco-regional state-run collusion[9]. Most industrial cartels coordinate both in prices and market shares (Harrington 2006, p. 5).[10] Coordinating market shares typically implies agreeing on trade volumes (quota) or allocating bioprospecting agents (e.g. per industry sector) according to a pre-defined rule. Considering genetic resource collusions, such rule could prohibit undercutting prices of another member country that is already

[8]The Himalayan Region might develop a regional framework as well (Prasad Oli and Das Gupta 2008). The *'Group of Like-Minded Megadiverse Countries'* is not (yet) a cooperation in the sense of this chapter as it does not (yet) comprise entire eco-regions.

[9]State-run cartels are not identical to industrial cartels. Levenstein and Suslow (2006, p. 49) stress that "their goals are more complex than private cartels, including not only the maximization of joint profits, but national economic stability and international political influence as well".

[10]For example, the lysine cartel coordinated on one price, the citric acid cartel on two, and the electrical and mechanical carbon and graphite products cartel had many prices. The citric acid cartel additionally introduced a global sales quota for each firm, the lysine cartel a minimum sales target differentiated between the global and the European market, and the chlorine-chloride cartel followed the home-market-principle (Harrington 2006, p. 6, 24-26, 33).

negotiating with a customer. A quota, however, is not feasible because physical genetic resources accessed to obtain the contained information can only be sold once as the information is then likely to enter the public domain (Vogel et al. 2000, p. 105 f.). Hence, genetic resource collusions are likely to coordinate in prices. Fixing explicit prices is easier if the collusion can focus on comparable goods like several endemic species[11]. When a collusion's product is too heterogeneous, internal compliance control is difficult (Carlton and Perloff 2005, p. 135). Prices can be monetary or non-monetary benefits (ref. Section 6.2). Besides coordination in prices (vi), collusion may as well include all or some of the above described elements (i)-(v). It might facilitate public notification (i) and a resource register (ii). If a collusion enjoys cartel power and trust among its members exists, it might have an incentive to increase bioprospecting rates via pro-active genetic resource advertising. Benefit reallocation (v) among collusion members may include all or only collusion induced benefits. In contrast to the latter, the former implies that countries obtain benefit shares which would otherwise accrue exclusively to a neighbouring country. Such total benefit redistribution is the strongest collusion type.

5.4 Eco-regional cooperation advantages

In this section we discuss eco-regional cooperation advantages arising from different degrees of cooperation. We analyse on a generic level how the different design elements (i)-(vi) contribute to economies of scale (Section 5.4.1) and other institutional factors (Section 5.4.2) as well as market power and bargaining strength (Section 5.4.3). To address the entire amplitude of cooperation advantages in our analysis, we refer in the following to a far-reaching eco-regional cooperation covering the elements (i) to (vi). Table 5.1 summarises these impacts at the end of these three sections.

Once we have shown the impact of eco-regional collaboration elements on economies of scale, transparency, communal spirit, and market power and bargaining strength, we then discuss their impact on transaction costs as well as monetary and non-monetary benefits–and thereby on profits of cooperating countries (Section 5.4.4) and on the level of biodiversity conservation (Section 5.4.5).

[11]Endemic species are species that are unique to a confined geographic location.

5.4.1 Economies of scale

Economies of scale in administration, *monitoring*, and *enforcement* may arise from cooperation and mutual exchange of information, especially if facilitated by a regional competent authority (iv). The information complexity can be distributed over all cooperating countries. Besides, knowledge spillovers occur, which lessen each country's information burden share even further. This includes information on the CBD, the Nagoya Protocol, international negotiations, national ABS regulations, the reliability of customers, as well as information on genetic resources and related knowledge. Public notification of ABS processes (i) further contributes to economies of scale in monitoring a customer's usage of genetic material and information as well as products developed thereof. Especially with advancing technologies, economies of scale in monitoring are increasingly important. Public notification additionally generates economies of scale in enforcement by increasing transparency about customers (ref. Section 5.4.2). A regional authority also lowers the enforcement costs by discouraging non-compliance by customers via a higher threat of detection. Coordination of access regulation (iii) will facilitate the work of a regional competent authority and raise the described economies of scale.

Economies of scale in advertising may arise if a regional competent authority (iv) increases the visibility and effectiveness of marketing campaigns; a public resource register (ii) will support these activities. Coordination in access (iii) generates economies of scale in advertising as other countries will communicate identical or similar access conditions to customers–even in absence of a regional authority.

Economies of scale in biotechnological development may result from exchange of information through a regional authority (iv) as well. Cooperation increases the chance that the worldwide unevenly distributed information on genetic resources and biotechnological knowledge reaches a country. It also reduces the degree of uncertainty inherent in this information as it can be verified with cooperating countries. A public resource register (ii), public notification of ABS processes and the genetic resources involved (i), and benefit reallocation of non-monetary benefits in form of joint R&D (v) contribute to economies of scale in biotechnological development. They may occur even for the most developed country; it will gain from a wider research network with an increased rate of innovations.

Additional side-benefits from a regional authority (iv) are possible regarding the management of 'cross-border affairs' such as invasive alien species and effectiveness of regional policies such as nature conservation zones.[12]

5.4.2 Other institutional advantages

Eco-regional cooperation influences institutional aspects within the member countries. Neighbouring countries that build comparable institutions enable institutional learning and adaptation and thereby enhance institutional functioning. A regional authority (iv) is likely to reinforce institutional capacity. Joint action–in whichever form–may create communal spirit and trust. Trust among cooperating countries might enable pro-active resource advertising to increase bioprospecting rates. Moreover, a country's property rights over genetic resources will enjoy a stronger enforcement as other cooperating countries have an incentive to respect them in expectation of reciprocal enforcement of their property rights over genetic resources.

Cooperation reduces the information asymmetry problem on both resource demand and supply side. A genetic resource supply country has higher chances to dispose over knowledge about the bioprospecting firm from other countries, especially in case of public announcement of ABS processes (i). This diminishes the principal-agent-problem of moral hazard, i.e. the threat that a prospecting firm undermines a contract by, for example, using the genetic material for R&D other than agreed upon. In turn, a prospecting firm enjoys access to detailed public information on a countries' genetic resources and access requests by competitors. Moreover, a genetic resource register (ii) eases the identification of one or several countries of origin. Coordination of access (iii) lowers information costs on access requirements of different potential supply countries. A regional competent authority (iv) further increases transparency for customers and suppliers. Transparency in genetic resource trade lowers transaction costs in form of monitoring and enforcement costs for the host countries and in form of search costs for the prospecting firms.

Countries belonging to an eco-regional cooperation may build up reputation. As it is a transaction-specific expenditure and much dependent on the customer's perception, the return–becoming a preferable trading partner–is incalculable. Reputation generates "idiosyncratic exchange relations" that withstand trade disruptions better (Williamson 1979, p. 240 f.).

Eco-regional cooperation in physical genetic resource trade can influence some, although probably not the most important components of the institutional environ-

[12] We thank a reviewer from the 2nd International Conference on Environment and Natural Resources Management in Developing and Transition Economies (enrmdte), Clermont-Ferrand, 17. – 19.10.2012, for mentioning these additional side-benefits.

ment. The institutional environment refers to a country's political and economic setting, which is simultaneously dependent on many factors such as corruption, delinquency, unemployment, and trust (Davis and North 1970, p. 133). More specifically, eco-regional cooperation cannot, for example, provide remedy for poor statal enforcement such as control of illegal trade in genetic resources or even stealing of resources. Similarly, eco-regional cooperation does not have a direct impact on the deficiencies of national biodiversity governance institutions (e.g. those referred to by Kamau et al. (2010, p. 248)). It might give an additional (needed) stimulus, though, and reduce transaction costs of implementing these institutions.

5.4.3 Market power and bargaining strength

Collusion in prices of physical genetic resources (vi) may generate cartel profits, an economic rent besides the remuneration of provision costs of a resource. Economic rents are only possible in case of endemic resources, imperfect competition, or search costs. Achieving economic rents through collusion requires cartel power. Cartel power consists of the two related components 'market power' which is defined by "the ability to price profitably above the competitive level" (Carlton and Perloff 2005, p. 8) and 'bargaining strength'[13] which describes the cartels ability to speak with one voice, act as one, and commit credibly (Komorita 1977, p. 68).

Market power depends on the market share and the demand elasticity. The market share for physical genetic resources rises in the share of global biodiversity, the estimated share of unknown species, and the number of endemic species represented by the eco-regional genetic resource cartel. The effectiveness of the cartel's power in rising prices hinges on the demand elasticity, i.e. it being inelastic. Empirically estimated demand elasticities can currently not be obtained; the amount of available prices for and quantities of genetic resources is insufficient due to few and often confidential bioprospecting contracts. Reid et al. (1996, p. 168 f.) assume an elastic demand for biochemical resources for the pharmaceutical industry and a less elastic one for genetic resources for agricultural use. The demand elasticity rests upon the ease of substituting physical genetic resources as well as random or specific screening. The most important substitute is the increasing importance of genetic and natural information (ref. Section 6.2). It is a very imminent external factor threatening eco-reginal collusion in physical genetic resource trade. Besides, genetic resources that have been obtained prior to the entry into force of the Nagoya Protocol are

[13] Also termed 'tactical advantage' by Komorita (1977, p. 68).

substitutes as the obligations under the Protocol do not apply to them. In combination, these substitutes challenge the benefits and thus the impact of eco-regional collusion. Hence, there might, if at all, only be a short window of opportunity for colluding in prices of physical genetic resources before the continuously increasing stock of substitutes in form of freely available genetic and natural information as well as *ex-situ* resources nullifies market power. However, if any, market power, is likely to be weak due to already existing substitutes.

The lower the market share the more important is bargaining strength. Cartel members acting credibly as one may be able to appropriate a higher percentage of a potential price differential between the buyers willingness-to-pay and the own willingness-to-sell. Credibly implemented joint access regulation (iii) and a regional authority (iv), which is equipped with competences to negotiate binding trade agreements, are important elements for establishing bargaining strength. The cooperating countries will have to find a way of assuring the regional authority's credibility, for example, by agreeing on guidelines that balance freedom of authority and own sovereignty. This balancing act is tricky. The competent authority will negotiate every deal anew as there are no standardised products and prices, and will thereby accumulate considerable knowledge. This knowledge lead may erode the power of the countries and make them dependent on the regional authority.

For successful collusion, potential rents have to outweigh transaction costs of collusion. The latter include notification, coordination, and negotiation costs among collusion members, costs for enforcing the collusive agreement internally, as well as costs for commitment devices. Moreover, there are costs of compromises as the agreement might deviate from the individual optimum.

5.4.4 Impacts on the profits of cooperating countries

The profits of cooperating countries depend on the level of transaction costs and the amount of monetary and non-monetary benefits. Economies of scale (ref. Section 5.4.1) and other institutional advantages such as transparency and mutual trust (ref. Section 5.4.2) reduce transaction costs for biodiversity rich provider countries. New transaction costs associated with cooperation, e.g. coordination costs, attenuate the transaction cost reduction, but are arguably by far smaller than the transaction cost reductions from cooperation advantages. Thus, there is most likely a net transaction cost reduction for supply countries under eco-regional cooperation–raising profits.

Profits may also rise due to benefits induced by cooperation through an in-

Table 5.1: Eco-regional cooperation advantages from cooperation elements (i) - (vi)

Benefit type	**Public notification**	**Public resource register**	**Access coordination**	**Regional authority***	**Benefit reallocation**	**Price coordination**
Economies of scale						
Administration			x†	x		
Monitoring	x		x†	x		
Enforcement	x		x†	x		
Advertising		x	x	x		
Biotechnological development	x	x		x	x•	
Cross boarder affairs				x		
Other institutional advantages						
Communal spirit/trust◇	x	x	x	x	x	
Transparency for suppliers	x			x		
Transparency for customers	x	x	x	x		
Reputation▷	x	x				
Market power and bargaining strength vis-à-vis customers						
Better trade conditions			x	x		x

* The benefits realised through creating a regional authority are conditional on its institutional competencies. We consider a regional authority with far-reaching competencies.
† Indirect through facilitating economies of scale from a regional competent authority.
• In case of non-monetary benefits.
◇ Communal spirit manifests itself inter alia in the mutual recognition of property rights.
▷ Much dependent on the behaviour of the suppliers and expectations of the customers.

crease in the volume of trade. The reduction in transaction costs that arises for customers (ref. Section 5.4.2) is likely to increase the eco-region's attractiveness for bioprospecting agents and, thus, to raise demand for physical genetic resources and thereby benefits for supply countries. In addition, collusion induced benefits are theoretically possible (ref. Section 5.4.3). In both cases, benefits may be monetary and non-monetary.

Cooperating countries profit to different degrees from the increase in benefits. In the following, we analyse factors that largely determine the distribution of potential cooperation induced benefits. The benefit distribution is influenced by the countries' characteristics and cooperation design. We first consider eco-regional cooperation without benefit redistribution. Once the eco-region has attracted a trading partner, countries within the eco-region compete against each other in the process of finalising the contract between the customer and one of themselves. A country is the more attractive the higher its relative biodiversity share and the lower the transaction costs for the customer, i.e. the better the institutional environment.[14] If coun-

[14] We consider customers from CBD Parties who have an interest in complying with the CBD. 194

tries decide to redistribute benefits (v) as part of their eco-regional cooperation, the relative distribution of the total benefit among these countries depends on the respective allocation rule. A more in-depth analysis of a rule for the redistribution of benefits and internal benefit spillovers or of market share allocation regulations is beyond the scope of this chapter. In the end, though, these rules mirror the relative negotiation power of countries as they are the result of a negotiation process. The relative negotiation power assumably depends on the countries' relative biodiversity richness and relative political power, which tends to be correlated with the relative institutional environment.

A cooperating country's benefit share thus, arguably, generally depends on the country's (a) respective institutional environment and (b) relative level of biodiversity and number of species endemic in its territory as compared to the other countries of the eco-region. We give an overview of relative benefit shares in Table 5.2. Ceteris paribus, a relatively favourable institutional environment in comparison to other countries leads to higher benefits. The same applies to a ceteris paribus relatively higher biodiversity richness. The country with an institutional trade advantage or an Hecksher-Ohlin comparative advantage relating to biodiversity endowments will thus obtain the contract. Richerzhagen and Holm-Müller (2005) emphasize the importance of the institutional environment for attracting genetic resource trade. A cooperating country with the comparatively best institutional environment and the highest biodiversity richness will reap the highest benefits (++++). It can appropriate the largest share of cooperation induced benefits. Considering eco-regional cooperation among several biodiversity rich countries, we assume that a relatively favourable institutional environment is more decisive for the magnitude of the benefit share. Hence, a country characterised by a relatively good institutional environment and a relatively low biodiversity richness (+++) will, arguably, gain (slightly) more from eco-regional cooperation than a country with a relatively high biodiversity richness and a relatively unfavourable institutional environment (++). If biodiversity

Table 5.2: Cooperating countries' relative benefit shares

		Relative biodiversity richness	
		low	high
Relative institutional environment	unfavourable	+	++
	favourable	+++	++++

countries are Parties to the CBD. (Online: www.cbd.int/convention/parties/list, last 11.07.2014).

richness differs much among countries of the same eco-region, the ordering of these two country types is likely to reverse. The country with the poorest institutional environment and the relatively lowest biodiversity richness will hardly obtain any benefits from eco-regional cooperation (+).

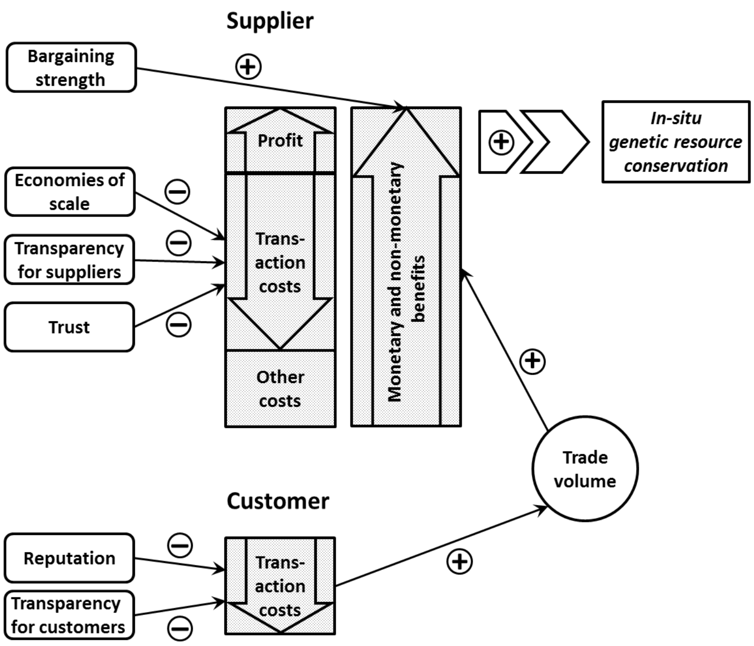
5.4.5 Indirect effects on the level of biodiversity conservation

The level of active and passive *in-situ* conservation of genetic resources depends on many factors. Passive conservation results from the inability to exploit the land cost-efficiently. Pressure on undeveloped land rises with increasing economic development and human capital. Active conservation efforts may be grounded in intrinsic motives. Besides, they may be induced by the prospect of income and job creation trough eco-tourism and other direct benefits from conservation. Payments for access to physical genetic resources are another factor that provides *in-situ* conservation incentives. The payments internalise positive conservation externalities accruing to users of physical genetic resources. Compared to the bilateral contractual approach, demand is higher in case of eco-regional cooperation of megadiverse countries as prices for customers are lower (ref. Section 5.4.2). A higher demand for physical genetic resources should lead to an increase in conservation of physical genetic resources and especially be an incentive for *in-situ* biodiversity conservation through its option value for future bioprospecting contracts.

The case of strong cooperation in form of collusion (vi), though, is special. Successful collusion would reduce demand for genetic resources compared to an ABS mechanism with equal levels of transaction costs. Higher prices, though, might create an incentive for *in-situ* conservation through the option value of profitable bioprospecting contracts. Moreover, compared to the status-quo ABS successful collusion does not necessarily reduce demand as the total access price might not increase if collusion simultaneously leads to a reduction in a customer's transaction costs. If access is much more streamlined, explicit and transparent after collusion, this reduction in transaction costs might overcompensate the rise in access price. Thus, the effect of collusion on the level of biodiversity conservation might also be positive, but is at least unclear.

A summary of this Section is provided by Figure 5.1, which illustrates the described interlinkages: the impact of eco-regional cooperation on economies of economies of scale (ref. Section 5.4.1), other institutional factors such as transparency and communal spirit (ref. Section 5.4.2), and market power and bargaining strength (ref. Section 5.4.3), and their impact on transaction costs as well as monetary and non-monetary benefits–and thereby on profits of cooperating countries (ref. Section 5.4.4) and on the level of biodiversity conservation (ref. Section 5.4.5).

Figure 5.1: Eco-regional cooperation advantages



5.5 Case Study: The Andean Community's cooperation in genetic resource trade

The Andean Community[15] (CAN) was the first eco-region that decided to regulate access to its genetic resources by community law. In 1996 it passed *Decisión 391*[16] on a *'Régimen Común sobre Acceso a los Recursos Genéticos'*. The Andean countries' motivation to collectively regulate access to genetic resources might be of monetary and non-monetary nature. Ruiz (2003, p. 11) reports that perceptions of excessive biopiracy and the related expectation of high potential commercial gains from genetic resource trade largely influenced the drafting of *Decisión 391*; those involved thought of bioprospecting as a "fountain of considerable richness". This might also explain

[15]For information on the Andean Community ref. footnote 3.
[16]Ref. footnote 4.

the–as we will expound–restrictiveness of the framework. But the CAN does not refer to itself as a collusion. It intends with *Decisión 391* to "establish the conditions for just and equitable participation in the benefits of the access" (*Art. 2a*) and to "strengthen the negotiating capacity of the Member Countries" (*Art. 2e*).

In this section we analyse the CAN's *Decisión 391* together with *Resoluciónes 414*[17] and *415*[18] detailing an application form and a model contract in light of the previously discussed advantages of eco-regional cooperation in physical genetic resource trade. In Section 5.5.1 we describe the characteristics of *Decisión 391* and in Section 5.5.2 we evaluate the cooperation advantages for the CAN members.

5.5.1 The Andean Community's access regulation

Decisión 391 is embedded in the political-institutional environment of the CBD and the Cartagena Agreement[19]. It directly applies in Colombia; Peru, Ecuador, and Bolivia drafted special national legislation (Díaz 2000, p. 10). Access regulation is thus streamlined, but not uniform. In the following, we analyse *Decisión 391* in light of the cooperation characteristics introduced in Section 5.3.

Public notification of all bioprospecting processes. Decisión 391 includes the notification of all other *'Competent National Authorities'* (*Art. 48, 49*) and the public of ABS processes (*Art. 18, 21, 27, 28*). It stipulates short time limits for the Competent National Authorities to notify the public after application entry (5 days, *Art. 28*), to evaluate the application after registration (30 days, *Art. 29*), and to inform the applicant after the evaluation has been completed (5 days, *Art. 30*).

Public genetic resource register. Art. 50n calls upon the Competent National Authorities to keep a national genetic resource register. Columbia created such inventory (Law 99, Art. 5). Yet *Art. 50n* neither requires additional screening and collecting activities nor public access to the inventory.

Coordination of access to genetic resources. Decisión 391 provides detailed genetic resource access regulation (*Art. 16 - Art. 47* as well as *Resolución 414* and *Resolución 415*). It includes access to *in-situ* and *ex-situ* resources as well as their

[17] Comision del Acuerdo Cartagena (1996): Resolución 414: Adopción del modelo referencial de solicitud de acceso a recursos genéticos, Gaceta Oficial del Acuerdo de Cartagena, Año XIII, Numero 217, Lima, 05.08.1996.

[18] Comision del Acuerdo Cartagena (1996): Resolución 415: Adopción del modelo referencial de contrato de acceso a resursos genéticos, Gaceta Oficial del Acuerdo de Cartagena, Año XIII, Numero 217, Lima, 05.08.1996.

[19] The CAN is based on the Cartagena Agreement signed in 1969.

by-products and intangible components[20] (*Art. 1, 3*). The CAN requires that: CAN nationals have to be part of the research, research in the country of origin has to be supported, knowledge transfer mechanisms have to be established, state of the art knowledge about the resource and method in question have to be transferred, and the institutional development in the country of origin as well as the competencies of local communities have to be supported (*Art. 17a-f*). Moreover, prospectors have to supply duplicates of collected resources, the research results, and the conditions of material transfer contracts signed with other parties to the Competent National Authority (*Art. 17g-i*). Only if the prospector provides the state of the art information about the resource, its uses, and the associated risks, access will be granted (*Art. 22*). *Art. 35* requires a benefit sharing agreement as annex to the access contract.

Regional competent authority. Decisión 391 inaugurates the *'Andean Committee on Genetic Resources'* with *Art. 51.* Alongside general coordination and recommendation tasks, it is responsible for proposing an outline of a joint database for access applications and contracts (*Art. 51c*) as well as a joint warning system for access problems (*Art. 51g*), for promoting joint research and technology transfer (*Art. 51d*), and for management and control of access to shared resources (*Art. 51f*). The Andean Committee functions as umbrella organisation of the Competent National Authorities. The latter keep their sovereignty over granting access and draft national access regulation subject to the CBD and CAN *Decisión 391* (*Art. 5*)[21].

Benefit reallocation. The CAN members do not redistribute benefits. The Competent National Authority viz. country that attracts a bioprospector enters into contract with the agent and obtains–if existent–the entire benefits.

Coordination in prices. Neither *Decisión 391* nor the model contract contained in *Resolución 415* specify a classification and assignment of genetic resources to benefit-sharing requirements.

5.5.2 Analysis of the Andean Community's cooperation advantages

We analyse the CAN's theoretical advantages from jointly regulating access by *Decisión 391* in form of transaction cost reductions and of an increase in benefits due to additional demand (Section 5.5.2.1) as well as the distribution of cooperation

[20] Intangible components refer to "all individual or collective knowledge, innovations and practices associated with a particular genetic resource or its derived products, whether or not protected by intellectual property regimes" (Glowka 1997, p. 250).

[21] *Decisión 391* has precedence over national law (Bucher 2008, p. 112).

induced benefits among CAN members (Section 5.5.2.2). Subsequently, we contrast them with realised cooperation advantages (Section 5.5.2.3).

5.5.2.1 Potential cooperation advantages for the Andean Community

In the following we discuss advantages, which the CAN members could theoretically realise through eco-regional cooperation as set out in *Decisión 391* as well as associated indirect impacts on conservation.

Economies of scale. CAN collusion members are to inform each other about all ABS related aspects including in cases of defraud (*Art. 48, 49*). Thereby they profit from a reduction in information costs regarding monitoring and enforcement activities. The CAN may achieve economies of scale in administration with *Resolución 414* specifying a model application form and *Resolución 415* outlining a model contract. Besides, the CAN is likely to realise economies of scale in biotechnological development. It aims to foster exchange and development of technologies and scientific and technological knowledge (*Art. 2d, 8, 9*). To this end CAN members are to organise subregional trainings (*Art. 10*), coordinated by the Andean Committee (*Art. 51d*). *Art. 17c* requires mechanisms to transfer state of the art knowledge about resources, which customers demand, and the methods they use. Moreover, economies of scale may arise from cooperation in conservation (*Art. 10*).

Other institutional advantages. The CAN stipulates "national, and not discriminatory, treatment" among members regarding access (*Art. 11*). *Decisión 391* acknowledges the property rights of "the native, Afro-American and local communities" (*Art. 7*) and requires the recognition of suppliers in access contracts (*Art. 34*). If implemented, these regulations have the potential to ease national as well as regional societal distress. However, there is also a risk that indigenous communities generally refuse the marketing of genetic resources they perceive as sacred. *Decisión 391* is likely to increase transparency in genetic resource trade on the demand and the supply side. A CAN member country should know about prospecting activities of, compliance by, and sanctions for an agent by other CAN members (*Art. 48, 49*). Information on all ABS processes and contracts has to be made public (*Art. 18, 21, 27*)–access applications and approvals are published in the newspaper (Art. 28, 38)–and hence the CAN members can possibly count on additional information about a customer from the public domain. The prospecting firm has to inform the CAN contract party about the requested genetic resource (*Art. 22*). The high discovering probability created by joint CAN action and strict disclosure provisions has the potential to reduce the threat of moral hazard. Similarly, the prospecting firm is supposed to enjoy transparency about the access procedure, the terms of the model contract (*Resolución 415*), and potential rival applicants[22] (*Art. 18, 21, 27, 28, 38*). *Art. 15* calls for "clear, effective, well-grounded and lawful" access processes and *Art. 28, 29, 30* ensure timewise procedural certainty. Furthermore, *Decisión 391* includes a "national inventory of genetic resources and their by-products"(*Art. 50n*), however does not mention whether bioprospectors can obtain access to it.

Market power and bargaining strength. The Andean countries host two biodiversity hotspots, the '*Tropical Andes Hotspot*' and the '*Tumbes-Chocó-Magdalena Hotspot*' (Mittermeier et al. 2004), as well as important wilderness areas. The Tropical Andes Hotspot is acknowledged in the community's name and the leading of the 35 world biodiversity hotspots[23] (Mittermeier et al. (2004); Williams et al. (2011)). It has the highest estimated number of endemic plant and vertebrate species and the second largest remaining primary vegetation area (Mittermeier et al. 2004, p. 32 f.). The current CAN members and Venezuela[24] cover 25% of global biodiversity (CAN 2002, p. 13). The CAN's high share of global biodiversity together with joint access regulation in form of *Decisión 391* and the *'Andean Committee on Genetic Resources'* as a regional authority are promising cooperation characteristics for building up market power and bargaining strength. However, substitutes for genetic resources qualify the high market share and reduce market power (ref. Section 5.4.3). Moreover, the Andean Committee is equipped with only few competences. It lacks, for example, the authorization to negotiate binding trade agreements (*Art. 5*). CAN member countries continue to negotiate unilaterally, not as a block with the other countries of the eoc-region. *Decisión 391* is therefore also unlikely to improve much upon the bargaining strength of the CAN countries.

Impacts on the CAN's profits. The profits of the CAN member countries have the potential to be higher than without cooperation due to transaction cost reductions and cooperation induced benefits. Considerable economies of scale and other institutional advantages can theoretically be realised; these would lead to transaction cost reductions and thereby increase the CAN's profits. As described above, transaction cost reductions also arise for customers. These are likely to increase demand for genetic resources of the Andean eco-region. Thereby the CAN is able

[22] *Art. 19* allows for confidential treatment of information that "could be put to unfair commercial use by third parties" subject to restrictive conditions.

[23] Biodiversity hotspots are areas hosting at least 0.5% of global plant species as endemic ones and that have diminished to 30% of its original size (Myers et al. 2000).

[24] Venezuela was part of the CAN from 1973 until 2006 (ref. footnote 3).

Table 5.3: Andean countries' biodiversity richness and endemism*

Country△	Diversity Index ◇	Deviation from expected richness†	Mammals			Birds			Plants	
			total	endemic	threatened no. (%)	total	endemic	threatened no. (%)	total	endemic
Argentina	0.196	0.423	320	49	32 (10)	897	19	38 (4)	9,372	1,100
Bolivia	0.239	0.882	316	16	23 (7)	–	18	27 (–)	17,367	4,000
Chile	0.112	0.229	91	16	21 (23)	296	16	15 (5)	5,284	2,698
Colombia	0.538	1.685	359	34	36 (10)	1,695	67	77 (5)	51,220	15,000
Ecuador	0.353	1.519	302	25	31 (10)	1,388	37	60 (4)	19,362	4,000
Peru	0.369	1.344	460	49	47 (10)	1,538	112	71 (5)	17,144	5,356
Venezuela	0.379	1.398	323	19	25 (8)	1340	40	24 (2)	21,073	8,000

* Endemism refers here to species endemic to one particular Andean country.

△ Andean countries which are not part of the CAN are written in italics.

◇ The diversity index is the mean of biodiversity richness and endemism. It ranges from 0 - 1. Globally, Brazil has the highest index value (0.74). Colombia ranks fifth. The calculation is given in Groombridge and Jenkins (2002, p. 295).

† The relative biodiversity richness with regard to a country's territorial size. Groombridge and Jenkins (2002, p. 296) use the Arrhenius equation for this calculation. Globally, Indonesia has the highest relative biodiversity richness with a value of 1.844. Colombia ranks second, Ecuador third, and Brazil forth with a value of 1.436.

Source: Data from the *'World Atlas of Biodiversity'* (Groombridge and Jenkins 2002, p. 295 ff.).

to appropriate cooperation induced monetary and non-monetary benefits. Market power and bargaining strength, however, are unlikely to be pronounced enough to raise benefits much beyond the effect of the increase in demand.

Indirect effects on conservation. The theoretically potential increase in profits is likely to provide an incentive for continued and increased *in-situ* conservation of genetic resources. Moreover, economies of scale may arise from the cooperation mechanism on conservation matters of common interest (*Art. 10*).

5.5.2.2 The distribution of potential cooperation induced benefits

Potential cooperation induced benefits vary between CAN members. Colombia, Ecuador, Peru, and Bolivia are all megadiverse countries, but differ in their relative biodiversity richness and number of endemic species. They also vary in their institutional environment. The two factors in combination determine the share each country can obtain from total cooperation induced benefits (ref. Section 5.4.4).

Relative biodiversity richness. Colombia, Ecuador, and Peru share the *'Tumbes-Chocó-Magdalena Hotspot'* in addition to the *'Tropical Andes Hotspot'*, which also stretches across Bolivia. Table 5.3 presents Groombridge and Jenkins's (2002) *'World Atlas of Biodiversity'* figures for biodiversity richness and endemism of the Andean countries. Not surprisingly, Bolivia has the comparatively lowest diversity in terms of biodiversity richness and endemism (0.239). Colombia scores highest (0.538), followed by Peru (0.369) and Ecuador (0.353). Biodiversity richness per area is important for the screening costs bioprospectors face. Here again, Colombia ranks first (1.685) and Bolivia last (0.882). Ecuador (1.519), though, has a higher per area biodiversity richness than Peru (1.344).

Relative institutional environment. We use selected indicators of the *'Worldwide Governance Indicators'*[25] (WGI) of the World Bank (Kaufmann et al. 2010) to compare the institutional environment of the Andean countries. Table 5.4 presents the WGI 2013 values for the indicators 'regulatory quality' (RQ), 'government effectiveness' (GE) and 'rule of law' (RL) for these countries. Regulatory quality captures "perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development", government effectiveness "perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's

[25] Online: http://info.worldbank.org/governance/wgi/index.aspx, last accessed on 29.11.2014.

Table 5.4: Relative institutional environment of the Andean countries

Country*	Regulatory quality (RQ)	Government effectiveness (GE)	Rule of law (RL)	Mean
Argentina	-0.99	-0.29	-0.73	-0.67
Bolivia	-0.79	-0.40	-1.07	-0.75
Chile	1.48	1.25	1.34	1.35
Colombia	0.39	0.04	-0.45	-0.01
Ecuador	-0.94	-0.49	-0.95	-0.79
Peru	0.45	-0.14	-0.61	-0.10
Venezuela	-1.64	-1.14	-1.79	-1.52

* Andean countries which are not part of the CAN are written in italics.

Source: Data from WGI 2013 (ref. footnote 25). The indicator range is -2.5 to 2.5, with higher values corresponding to better performance.

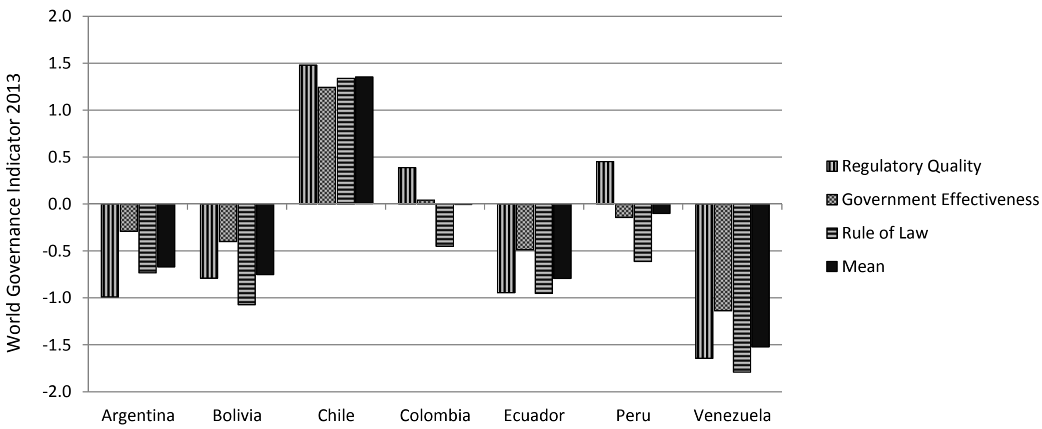
commitment to such policies", and rule of law "perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence"[26]. The three indicators are correlated in case of the Andean countries as can be seen in Figure 5.2. We therefore use the mean to compare the Andean Countries' institutional environment. Colombia achieves the relatively highest mean of the three indicator values (-0.01), closely followed by Peru (-0.10). Bolivia ranks third (-0.75), closely followed by Ecuador (-0.79). The ranking should, however, be interpreted cautiously, because the values lie close to one another, the aggregation level is high, and thresholds are likely regarding the importance of the relative institutional environment for benefit appropriability.

Relative benefit share. Combining the scores in relative institutional environment and biodiversity richness, we can deduce a very tentative ranking in benefit shares. Figure 5.3 shows the CAN members' performance in these two dimensions. A clear ranking in benefit shares is not possible. Colombia and Peru have a strict dominance in benefit share appropriability over Bolivia and Ecuador. A ranking between Colombia and Peru as well as between Bolivia and Ecuador is speculative.

Following our assessment, Chile, Argentina, and Venezuela, which belong to the same eco-region, but not to the CAN, have lower chances to appropriate benefits induced by eco-regional cooperation than the current CAN members. In the considered WGI 2013 indicators (ref. Table 5.4), Venezuela performs worst among the Andean

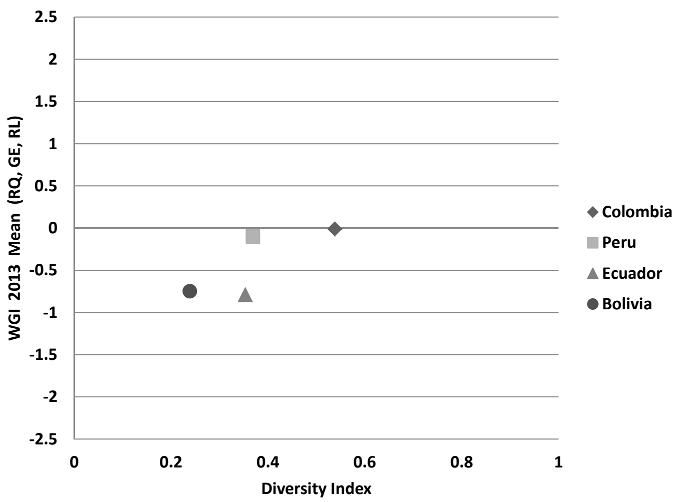
[26] Online: http://info.worldbank.org/governance/wgi/rq.pdf, http://info.worldbank.org/governance/wgi/ge.pdf, http://info.worldbank.org/governance/wgi/rl.pdf, last 29.11.2014.

Figure 5.2: Correlation of WGI 2013 indicator values for the Andean Countries



Source: Own diagram based on WGI 2013 data of the World Bank, ref. footnote 25.

Figure 5.3: Relative institutional environment and biodiversity richness of the Andean Community member countries



Source: Own diagram based on WGI 2013 data (ref. footnote 25) and data from the 'World Atlas of Biodiversity' (Groombridge and Jenkins 2002, p. 295 ff.).

countries (mean: -1.52). The mean of the three WGI indicator values is higher for Argentina (-0.67) and Chile has the by far highest mean (1.35), but they have comparatively very low diversity index scores (Chile 0.122, Argentina 0.196; ref. Table 5.3). The vast majority of the Tropical Andes is in effect located in the current CAN member states, and the Andes make up only a relatively small part of Venezuela's, Chile's, and Argentina's total land size. With in comparison relatively low biodiversity richness and endemism (Chile, Argentina) or an comparably unfavourable institutional environment (Venezuela), the three Andean non-member countries of the CAN have little chance of attracting numerous bioprospectors. An Andean country with a low probability to act as contracting party will over-proportionally shoulder cooperation costs, possibly to the extend that it has no incentive for regional cooperation. This coincidences with the actual composition of the CAN.

5.5.2.3 Realised cooperation advantages

The CAN members admit in their *'Regional Biodiversity Strategy'* (CAN 2002, p. 34) that there only "exist isolated experiences of sharing of benefits arising from access to genetic resources" and that they are "confronted by problems hindering the application of Decisión 391; and this Decision, in spite of its importance, has not so far proven itself to be an effective instrument for achieving the hoped-for sharing of benefits." Ruiz (2008, p. 17) compiles eight genetic resource access contracts for Colombia and five for Bolivia until 2007, whereby we have no information whether these are commercial contracts. Until early 2013 Peru has been involved in two commercial contract negotiations, but could not conclude them successfully[27]; Ecuador records none[28]. Viewed over one decade, these are few–if not none–commercial contracts and benefits compared to initial expectations and other countries: Costa Rica, arguably a benchmark for a successful provider country under the status-quo ABS, has signed about 65 contracts with industries and universities until early 2013[29], from which it realised a number of monetary and non-monetary benefits (Gámez 2007, p. 85 f.); however, so far no royalties[30].

The discrepancy between the potential eco-regional cooperation advantages described in Section 5.5.2.1 and the limited ones actually realised by the CAN may be explained by several factors. There is no cooperation between the national focal points, no benefit transfer between member countries exists, and the importance of

[27] Personal communication with the ABS National Focal Point (NFP) under the CBD of Peru on the occasion of the first meeting of the Plenary of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES-1) in Bonn on 23.01.2013.

[28] Personal communication with the ABS NFP of Ecuador on the same occasion and date.

[29] Correspondence with a member of the Biodiversity Commission of the University of Costa Rica on 04.05.2013.

[30] Presentation at the "Informal Meeting for the Implementation of Articles 19 and 20 of the Nagoya Protocol", Tokyo, 25.–26.03.2013.

the Andean Committee is limited, because it lacks own finance.[31] The scarce implementation of the provisions of *Decisión 391* implies that economies of scale and improvements in institutional factors will be limited. It is not clear to what extent communal spirit and trust prevail among the CAN members. Missing trust could explain why amendments that improve upon the known deficiencies of *Decisión 391* or advancements in its implementation are absent. Ruiz (2003, p. 12) contests the incentives for communitarian action and attests an absence of political will among the member countries to prioritise the functioning of *Decisión 391* (ibid., p. 18). In addition, new transaction costs arise for the CAN members from *Decisión 391* in form of coordination, notification, and communication costs as well as costs of compromises. Ruiz (2003, p. 13) reckons that the CAN states have underestimated the latter ex-ante.

For customers, some reductions in transaction costs may occur due to the time-wise procedural certainty provided by *Decisión 391* as well as the model application form (*Resolución 414*) and the model contract (*Resolución 415*). However, new transaction costs have been created by *Decisión 391*. Especially the requirements related to the involvement of 'subregional nationals', knowledge transfer and institutional development listed in *Art. 17* are costly for customers to deliver. Additionally, shared competencies between the Andean Committee, national authorities, and local communities are perceived as a hindrance (Bucher 2008, p. 147 f.). Taken altogether, the CAN cannot be described as an example of successful eco-regional cooperation in genetic resource trade.

5.6 Conclusion

In this chapter we analysed the scope of eco-regional cooperation in physical genetic resource trade to improve upon the status-quo bilateral approach with a view (a) to achieving payments for physical genetic resource use and thereby (b) to increasing conservation. We considered a continuum of cooperation from loose cooperative behaviour to price determining collusion, but conclude that the benefits of collusion will be low due to limited market power through the availability of substitutes. Especially easily distributable and accessible genetic and natural information are threatening collusion.

We evince eco-regional cooperation advantages on the market for physical genetic

[31] Personal communication with the ABS NFPs of Peru and Ecuador (ref. footnote 27, 28).

resources. Our findings suggest that, compared to the status-quo and dependent on the degree of cooperation, eco-regional coalitions have the potential to significantly reduce transaction costs for both suppliers and customers. Economies of scale in information, administration, monitoring, and enforcement together with other institutional advantages such as transparency and reputation are important advantages of eco-regional cooperation that lower transaction costs for suppliers. In particular transparency also reduces transaction costs for customers. Transaction cost reductions for customers reduce the price for physical genetic resources and thus increase their demand. An increase in demand of physical genetic resources increases the volume of benefits for biodiversity rich countries. Cooperating countries with a relatively higher biodiversity richness and–in case of megadiverse countries even more relevant–a comparatively better institutional environment are able to appropriate a higher share of these cooperation induced benefits. A higher demand for genetic resources should also lead to an increase in conservation of genetic resources. It increases the perceived option value for future bioprospecting contracts and thereby provides an incentive for *in-situ* biodiversity conservation. Our case study of the Andean Community's joint access legislation, however, reveals that the CAN members realise few of these potential cooperation advantages.

A successful implementation of the Nagoya Protocol, which came into force recently, might lower transaction costs of bilateral contractual ABS and thereby the advantages of eco-regional collusion. It remains to be seen whether and how far the Nagoya Protocol changes bilateral contractual ABS. Especially an effectively functioning global *'Access and Benefit-sharing Clearing-House'* (NP, *Art. 14*) may facilitate information sharing. So far, albeit highly promising, the implementation of the ABS Clearing-House[32] finds itself at the beginning. Besides, the provisions on model contractual clauses (NP, *Art. 19*), codes of conduct, guidelines, and best practices and/or standards (NP, *Art. 20*), awareness-rising (NP, *Art. 21*), capacity building (NP, *Art. 22*), and technology transfer, collaboration, and cooperation (NP, *Art. 23*) have the potential to reduce transaction costs for both providers and users. Hence, eco-regional cooperation might become less attractive. The Nagoya Protocol might, however, just as well increase the relevance of eco-regional cooperation–depending on whether and how its member countries implement *Art. 11*, NP, on transboundary cooperation. Moreover, the situation might change considerably if countries agree on the need for and modalities of implementation of a *'Global Multilateral Benefit-Sharing Mechanism'* (NP, *Art. 10*). The latter might even open up

[32]Ref. online: https://absch.cbd.int/, last 14.03.2015.

the possibility to address genetic and/or natural information.

Genetic and natural information are of high and growing importance for commercial users of genetic resources. They limit the scope, relevance, and benefits of eco-regional cooperation in trade of physical genetic resources. Genetic or natural information can hardly be included in a regional cooperation agreement due to their non-excludable nature. The prospect for eco-regional cooperation will thus be most relevant in the short-run. With technological progress and further growth of new commercial research fields that predominantly rely on genetic and natural information, a global mechanism becomes indispensable if one aims at simultaneously achieving the three goals of the CBD, namely "the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of benefits arising out of the utilisation of genetic resources" (CBD, *Art. 1*). In any case, regional and global mechanisms need to be designed such that they lead to marked reductions in transaction costs and thereby create incentives for countries to continue and deepen cooperation. Moreover, increased transparency for customers is vital for lowering their transaction costs and rising demand. If demand rises, we can expect the importance of *in-situ* conservation among biodiversity rich countries to follow suit.

Bibliography

ASEAN Centre for Biodiversity (2013). *An Urgent Need: Institutionalizing Access to Genetic Resources and Benefit Sharing in Southeast Asia*, Policy Brief Series. ASEAN Centre for Biodiversity.

Asebey, E. J. and J. D. Kempenaar (1995). Biodiversity prospecting: Fulfilling the mandate of the Biodiversity Convention. *Vanderbilt Journal of Transnational Law 28*(4), 703–754.

Boisvert, V. and F.-D. Vivien (2005). The Convention on Biological Diversity: A conventionalist approach. *Ecological Economics 53*(4), 461–472.

Bucher, S. (2008). *Der Schutz von genetischen Ressourcen und indigenem Wissen in Lateinamerika. Eine Untersuchung am Beispiel der Andengemeinschaft, Brasiliens und Costa Ricas.* Baden-Baden: Nomos.

Cabrera Medaglia, J., F. Perron-Welch, and O. Rukundo (2012). *Overview of National and Regional Measures on Access to Genetic Resources and Benefit-Sharing.*

Challenges and Opportunities in Implementing the Nagoya Protocol (2nd ed.). Montreal: Centre for International Sustainable Development Law (CISDL).

CAN (2002). *Regional Biodiversity Strategy.* General Secretariat of the Andean Community.

Carlton, D. W. and J. M. Perloff (2005). *Modern Industrial Organization* (4th ed.). New York: Person.

Davis, L. and D. North (1970). Institutional change and American economic growth: A first step towards a theory of institutional innovation. *The Journal of Economic History 30*(1), 131–149.

Díaz, C. L. (2000). Regional approaches to implementing the Convention on Biological Diversity: The case of access to genetic resources. Paper prepared for the EU Concerted Action Conference on the Effectiveness of International Environmental Agreements, Barcelona.

Fernández Ugalde, J. C. (2007). Tracking and monitoring of international flows of genetic resources: Why, how and, is it worth the effort? In M. Ruiz and I. Lapeña (Eds.), *A Moving Target: Genetic Resources and Options for Tracking and Monitoring their International Flows*, IUCN Environmental Policy and Law Paper No. 67/3. Gland, Switzerland: IUCN.

Gámez, R. (2007). The link between biodiversity and sustainable development: Lessons from INBio's bioprospecting programme in Costa Rica. In R. McManis (Ed.), *Biodiversity and the Law: Intellectual Property, Biotechnology and Traditional Knowledge*, Chapter 7, pp. 77–90. London: Earthscan.

Glowka, L. (1997). Emerging legislative approaches to implement Article 15 of the Convention on Biological Diversity. *RECIEL 6*(3), 249–162.

Groombridge, B. and M. D. Jenkins (2002). *World Atlas of Biodiversity.* Berkeley/Los Angeles/London: University of California Press.

Harrington, J. E. (2006). *How do cartels operate?*, Volume 2 of *Foundations and Trends in Microeconomics.* Delft: now Publishers.

Kamau, E., B. Fedder, and G. Winter (2010). The Nagoya Protocol on Access to Genetic Resources and Benefit Sharing: What is new and what are the implications for provider and user countries and the scientific community? *Law, Environment and Development Journal 6*(3), 246–262.

Kaufmann, D., A. Kraay, and M. Mastruzzi (2010). The Worldwide Governance Indicators. Methodology and Analytical Issues. *The World Bank, Policy Research Working Paper 5430.*

Komorita, S. S. (1977). Negotiating from strength and the concept of bargaining strength. *Journal for the Theory of Social Behaviour 7*(1), 65–79.

Levenstein, M. C. and V. Y. Suslow (2006). What determines cartel success? *Journal of Economic Literature 44*(1), 43–95.

Mariaca, J. (1999). Access to genetic resources in member countries of the Andean Community. In International Society for Horticultural Science (Ed.), *First International Symposium on Cherimoya*, Number 497 in Acta Horticulturae, pp. 367 – 374.

Mittermeier, R. A., G. P. Robles, M. Hoffmann, J. D. Pilgrim, T. Brooks, C. G. Mittermeier, J. Lamoreux, and G. A. B. da Fonseca (2004). *Hotspots revisited: Earth's biologically richest and most endangered ecoregions.* Mexico City: CEMEX.

Munyi, P. and H. Jonas (2013). Implementing the Nagoya Protocol in Africa: Opportunities and challenges for African indigenous peoples and local communities. In E. Morgera, M. Buck, and E. Tsioumani (Eds.), *The 2010 Nagoya Protocol on Access and Benefit-Sharing in Perspective. Implications for International Law and Implementation Challenges.* Leiden, Netherlands: Martinus Nijhoff Publishers.

Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. B. da Fonseca, and J. Kent (2000). Biodiversity hotspots for conservation priorities. *Nature 403*, 853–858.

Pastor, S. and M. Ruiz (2009). The development of an international regime on access to genetic resources and equitable benefit sharing in a context of new technological developments. *Peruvian Society for Environmental Law (SPDA) 4*(10), 1–16.

Prasad Oli, K. and J. Das Gupta (2008). *Regional Framework on Access and Benefit Sharing (ABS) in the Himalayan Region.* International Centre for Integrated Mountain Development (ICIMOD).

Reid, W. V., S. A. Laird, C. A. Meyer, R. Gámez, A. Sittenfeld, D. Janzen, M. A. Gollin, and C. Juma (1996). Biodiversity prospecting. In M. J. Balick, E. Elisabetsky, and S. A. Laird (Eds.), *Medicinal resources of the tropical forest. Biodi-*

versity and its importance to human health, Chapter 12, pp. 142–173. New York: Columbia University Press.

Richerzhagen, C. (2011). Effective governance of access and benefit-sharing under the Convention on Biological Diversity. *Biodiversity and Conservation 20*, 2243–2261.

Richerzhagen, C. and K. Holm-Müller (2005). The effectiveness of access and benefit sharing in Costa Rica: Implications for national and international regimes. *Ecological Economics 53*(4), 445–460.

Rosell, M. (1997). Access to genetic resources: A critical approach to Decision 391 'Common Regime on Access to Genetic Resources' of the commission of the Cartagena Agreement. *Review of European Community and International Environmental Law 6*(3), 274–283.

Ruiz, M. (2003). El tratado internacional de recursos fitogenéticos y la decisión 391 de la comunidad andina de naciones: Perú, la región andina, y los centros internacionales de investigación agrícola. Lima.

Ruiz, M. (2008). Guía Explicativa de la Decisión 391 y una Propuesta Alternativa para Regular el Acceso a los Recursos Genéticos en la Sub-región Andina. SPDA, GTZ, Lima.

Schei, P. J. and M. W. Tvedt (2010). "Genetic Resources" in the CBD: The wording, the past, the present and the future. Submission to the Executive Secretary of the Convention on Biological Diversity, UNEP/CBD/WG-ABS/9/INF/1.

Stone, C. D. (1994). What to do about biodiversity: Property rights, public goods, and the earth's riches. *Southern California Law Review 68*, 577–620.

Tafur-Dominguez, V. (2000). International environmental harmonization - Emergence and development of the Andean Community. *Pace International Law Review 12*, 283 – 317.

Ten Kate, K. (1997). The common regime on access to genetic resources in the Andean Pact. *Biopolicy 2*(6).

Ten Kate, K. and S. A. Laird (1999). *The Commercial Use of Biodiversity: Access to Genetic Resources and Benefit-Sharing*. London: Earthscan.

Ten Kate, K. and S. A. Laird (2000). Biodiversity and business: Coming to terms with the 'grand bargain'. *International Affairs 76*(2), 241–264.

Tilford, D. S. (1998). Saving the blueprints: The internacional legal regime for plant resources. *Case Western Reserve Journal of International Law 30*(2&3), 373–446.

Vogel, J. H. (1995). A market alternative to the valuation of biodiversity: The example of Ecuador. *ASC Newsletter 23*(5), 66–70.

Vogel, J. H. (2007). Reflecting financial and other incentives of the TMOIFGR: The biodiversity cartel. In M. Ruiz Muller and I. Lapeña (Eds.), *A Moving Target: Genetic Resources and Options for Tracking and Monitoring their International Flows*, IUCN Environmental Policy and Law Paper No. 67/3, pp. 74–74. Gland, Switzerland: IUCN.

Vogel, J. H., R. Alarcon, M. S. Garcia, M. Morales, and R. Lindstrom (2000). *The Biodiversity Cartel. Transforming Traditional Knowledge into Trade Secrets.* Quito, Ecuador: CARE, Proyecto SUBIR.

Vogel, J. H., N. Álvarez-Berríos, N. Quiñones Vilches, J. L. Medina-Muñiz, D. Pérez-Montes, A. I. Arocho-Montes, N. Val-Merniz, R. Fuentes-Ramírez, G. Marrero-Girona, E. V. Mercado, and J. Santiago-Ríos (2011). The economics of information studiously ignored in the Nagoya Protocol on Access to Genetic Resources and Benefit Sharing. *Law Environment and Development Journal 7*(1), 52–65.

Williams, K. J., A. Ford, D. F. Rosauer, N. De Silva, R. Mittermeier, C. Bruce, F. W. Larsen, and C. Margules (2011). Forests of East Australia: The 35th biodiversity hotspot. In F. E. Zachos and J. C. Habel (Eds.), *Biodiversity Hotspots. Distribution and Protection of Conservation Priority Areas*, Berlin/Mannheim, pp. 295–310. Springer.

Williamson, O. (1979). Transaction-cost economics: The governance of contractual relations. *Journal of Law and Economics 22*(2), 233–261.

Winter, G. (2009). Towards common pools of genetic resources - improving the effectiveness and justice of ABS. In E. C. Kamau and G. Winter (Eds.), *Genetic Resources, Traditional Knowledge and the Law. Solutions for Access & Benefit Sharing*, pp. 19–35. London: Earthscan.

Chapter 6

Bilateral vs. Multilateral? On the Economics and Politics of a Global Mechanism for Genetic Resource Use

Abstract: Many industries profit from public biodiversity conservation through the use of genetic resources in R&D processes. The conservation of biodiversity, though, is an under-provided public good. The aim of this chapter is to analyse a global mechanism as a policy tool to internalise the positive conservation externalities accruing to commercial users of genetic resources. The United Nations *'Convention on Biological Diversity'* (CBD) and its *'Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilisation'* provide a framework for such mechanism. Our inter- and transdisciplinary research consists of an economic analysis of the genetic resource market, the study of CBD documents, an online discussion forum launched by the Convention's Secretariat on a global multilateral mechanism, as well as expert interviews with important political stakeholders on genetic resource trade. We find that the economically preferable instrument of a comprehensive global mechanism is politically not feasible any time soon due to path dependencies and an arguably narrow understanding of national sovereignty. Technological progress in genetic resource use, though, might finally induce countries to establish a confined one in the mid-term future. We provide substantiated findings on countries' preferences for its scope and modalities.

6.1 Introduction

Genetic resources are an important production factor in many industries. They are a vital input for numerous R&D processes of new products. Novel research techniques and fields like genomics together with emerging markets such as the functional food industry indicate a further increasing significance of genetic resources. Biodiversity conservation maintains the diversity of genetic resources, which is one dimension of biodiversity[1] and essential for R&D, largely through protected areas. Genetic resource users thus profit from positive conservation externalities[2].

In this chapter we explore a global mechanism as a policy tool to internalise positive conservation externalities accruing to commercial genetic resource users–agents accessing and using physical genetic resources or genetic information[3] for profit-oriented R&D. Our research is motivated by the obvious and much deplored under-provision of biodiversity conservation together with the commitment by the international community to halt biodiversity loss by 2020, a target set in the *'Strategic Plan for Biodiversity 2011-2020'*[4] of the *'Convention on Biological Diversity'*[5] (CBD). To fulfil their commitment, parties to the CBD strive to increase the mobilisation of financial resources. However, biodiversity conservation is lower on the political agenda as the eradication of hunger, malnutrition and poverty, for which adequate finance is already a challenge. Thus, it will not be easy to rally financial pledges sufficient to achieve the social optimal level of biodiversity conservation (currently politically defined in the *'Strategic Plan for Biodiversity 2011-2020'*). A broader approach is necessary; one that mainstreams biodiversity and includes a portfolio of policy instruments, such as the elimination of subsidies that are harmful to biodiversity, the employment of positive incentives for biodiversity conservation and sustainable use, and the internalization of positive biodiversity conservation ex-

[1] Biodiversity "includes diversity within species, between species and of ecosystems" (CBD, *Art.2*).

[2] Positive externalities are unremunerated benefits for third parties arising from someone's action. For an introduction to the concept of externalities refer to, e.g., Varian (2006, p. 626 ff.). In this paper we focus on a fraction of all positive externalities of biodiversity conservation–those from which genetic resource users such as pharmaceutical firms profit. The internalisation of other positive conservation externalities as well as the internalisation of negative externalities through land use, production, and consumption, are beyond the scope of this paper.

[3] We focus on genetic information rather than on the wider category of natural information as our analyses addresses commercial genetic resource users in the context of current debates under the Nagoya Protocol. The mechanism can nevertheless be broadened by applying it to natural information, including, for example, users of biomimicry.

[4] UNEP/CBD/COP/DEC/X/2, Annex III.

[5] United Nations (1992): Convention on Biological Diversity, 31 Int'l Leg. Mat. 818, Rio de Janeiro, 05.06.1992.

ternalities to reduce the under-provision of conservation. In this chapter we focus on the latter.

Correcting market failures caused by externalities through their internalisation features prominently in the environmental economic literature. This chapter addresses a less frequent setting, namely the internalisation of positive externalities that accrue to internationally operating private entities when using physical genetic resources and genetic information spillovers to the public domain from other firms' uses. Through the internalisation the demand for genetic resources, and thereby arguably biodiversity conservation, increases. The policy instrument is a global mechanism based on an international environmental agreement without a superior enforcement authority. Commercial users pay a fee for physical genetic resources and a subsidy is employed to internalise benefits from genetic information spillovers. The instrument thus follows the user-pays-principle[6]. It complements others that address those engaging in the protection of biodiversity more directly according to the provider-gets-principle such as payments for ecosystem services (e.g. Ferraro and Kiss (2002); Wunder (2007)) and auctioning conservation contracts (e.g. Latacz-Lohmann and Van der Hamsvoort 1997). With our research we build on and contribute to the existing economic literature. Previous economic studies analysed multilateral *'Access and Benefit-Sharing'* (ABS) in the context of economics of information, transaction cost economics, and cartelization (Vogel (i.a. 1995, 2007, 2011), Ruiz et al. (2010), Winands and Holm-Müller (2014) id. Chapter 5). Deke (2004) discusses the internalisation of positive global externalities from protected areas by multilateral compensation agreements.

The aim of this chapter is twofold: to provide an economic analysis of the genetic resource market and to explore the political feasibility of a global mechanism that internalises positive biodiversity conservation externalities accruing to commercial users of physical genetic resources and genetic information with the objective of increasing biodiversity protection. The analysis is conducted against the background of the CBD's history in which the Convention granted much desired state sovereignty over biological resources and in which the *'Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utiliza-*

[6]Firms using genetic material individually remunerate the use and the entire society pays an additional subsidy on resource use to internalise information spillovers. The user-pays-principle differs from the provider-gets-principle in that the instrument's point of contact is the beneficiary of the positive externalities. In the context of the internalisation of negative externalities the user-pays-principle refers to the "indirect responsibilities of second order" as an extension of the polluter-pays-principle (Cordier et al. 2014, p. 1).

tion'[7] (NP) under the CBD has been implemented as a bilateral, contractual ABS mechanism where genetic resources are largely understood as physical resources. Politically, our analysis is timely as we take up a current discussion under the NP on the need for and modalities of a *'Global Multilateral Benefit-Sharing Mechanism'* (GMBSM) for a set of specific genetic resources for which benefits are then dedicated to conservation and sustainable use (ref. NP, *Art. 10*). We therefore also study the politically discussed option of a global mechanism restricted to specific genetic resources. Our analysis is inter- and transdisciplinary; besides the economic analysis, we study the genetic resource market from the political perspective, draw on legal texts and studies, and involve stakeholders. The empirical research methodology is a triangulation that consists of the study of CBD documents and an online discussion forum organised by the CBD Secretariat on a global multilateral mechanism as well as expert interviews with important political stakeholders. We consider this combination of economic theory and actors' perceptions essential for exploring appropriate policy tools.

The chapter proceeds as follows: In Section 6.2 we describe the political and institutional background of the genetic resource market. In Section 6.3 we provide an economic analysis of this market and motivate a global mechanism that internalises positive biodiversity conservation externalities accruing to commercial users of genetic resources. Subsequently, we evaluate the political feasibility of such mechanism; in Section 6.4 we outline the empirical research methodology and in Section 6.5 we present the results. We conclude with Section 6.6.

6.2 Political and institutional background

Genetic resources are defined by the CBD as "genetic material of actual or potential value", whereby material refers to "any material of plant, animal, microbial or other origin containing functional units of heredity" (CBD, *Art. 2*). The functional units of heredity comprise genetic information. Hence, genetic resources have a physical dimension and an informational dimension. New technologies involve a growing production and use of digital genetic information, allow research on genetic resources of increased scope, reduced time and higher precision, and open up new fields of R&D (Laird and Wynberg 2012).

[7] United Nations (2010): Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity, Nagoya, 29.10.2010.

Trade in (physical) genetic resources is governed by the CBD (i.a. state sovereignty) and by the NP, which codifies the rules on ABS[8]: Users have to solicit access to (physical) genetic resources in a provider country by requesting *'Prior Informed Consent'* (PIC). Both parties then negotiate the terms by which access is granted and benefits are shared (*'Mutually Agreed Terms'* (MAT)). The recipients of the benefits may use them to whichever end they like; conservation and sustainable use are merely encouraged (NP, *Art. 9*). However, the NP explicitly interlinks the Convention's three aims of biodiversity conservation, its sustainable use, and the fair and equitable sharing of benefits from genetic resource use (CBD, *Art. 1*) in the context of a potential *'Global Multilateral Benefit-Sharing Mechanism'* (GMBSM) for resources "that occur in transboundary situations or for which it is not possible to grant or obtain prior informed consent" (NP, *Art. 10*). In these cases benefits are earmarked for conservation and sustainable use. It requests parties to consider the need for and modalities of a GMBSM (ibid.)[9]. The potential GMBSM is denominated 'mechanism' rather than 'fund' to highlight that it may comprise monetary and non-monetary benefits (Greiber et al. 2012, p. 130). Delegates to the CBD's tenth Conference of the Parties (COP), at which the NP was adopted, decided that the GMBSM of *Art. 10* should be considered at the second meeting of the *'Intergovernmental Committee for the Nagoya Protocol'* (ICNP-2)[10], the interim governing body for the Protocol. The discussions at ICNP-2 and subsequently at COP 11, ICNP-3, and the first COP serving as the meeting of the parties to the Nagoya Protocol (COP-MOP 1) did not resolve the debate over the need for and modalities of a GMBSM (ref. Section 6.5.1).

An important issue, which has so far not been thoroughly discussed by the parties to the CBD or to the NP, is whether and how genetic information resources are addressed. The topic seems to surface under CBD agenda items as an aside from time to time–apparently without stirring up discussions.[11]

---

[8] The NP builds on the Bonn Guidelines (United Nations (2002): Bonn Guidelines on Access to Genetic Resources and Fair and Equitable Sharing of the Benefits Arising out of their Utilization. UNEP/CBD/COP/6/24).

[9] This compromise was reached with the African Union in last-minute informal ministerial negotiations (Earth Negotiations Bulletin, Vol. 9, No. 544, p.3, ref. Supplementary Material S.6.2).

[10] UNEP/CBD/COP/DEC/X/1, Annex II, Section B, Item 10, ref. Supplementary Material S.6.1.

[11] Among others, as information documents for meetings of the Ad-Hoc Open-Ended Working Group on Access and Benefit-Sharing in 2005 (Oldham 2004), 2009 (Garrity et al. 2009), and 2010 (Schei and Tvedt (2010), Singer (2009), CGIAR (2010)), in the online discussion forum on *Art. 10*, NP (ref. Supplementary Material S.6.1), and as information document on synthetic biology in preparation of COP 12 (UNEP/CBD/COP/12/INF/12, par. 172 ff, online: www.cbd.int/doc/meetings/cop/cop-12/information/cop-12-inf-12-en.pdf, last 24.10.2014).

A global mechanism that covers more genetic resources than those comprised under *Art. 10*, NP, or all genetic resources–physical and informational ones–would legally be possible under *Art. 4*, NP, as a specialised international agreement as long as it harmonises with the objectives of the CBD and the NP (Kamau et al. 2010, p. 258). A multilateral system already exists for genetic material from several crops governed under the *'International Treaty on Plant Genetic Resources for Food and Agriculture'* (ITPGRFA)[12] and listed in its Annex I.

6.3 Economic analysis of the genetic resource market

A global mechanism that internalises positive biodiversity conservation externalities accruing to commercial users of genetic resources, both physical and informational ones, is a potential alternative to the status-quo bilateral transactional ABS mechanism. From an economic perspective such global mechanism could include in its simplest form: no bilateral negotiations, access to all genetic resources, pre-determined payments for genetic resource use into a global fund, subsidies to internalise the benefits of genetic information in the public domain. We present findings from economic theory, namely economics of information and transaction costs economics, on such global mechanism and derive a simple model to illustrate the argument.

The informational dimension of genetic resources has similar characteristics and implications as artificial information. Genetic and natural information[13] is easily distributed, especially as digital genetic code, and thus quickly in the public domain (e.g. Schei and Tvedt 2010). Obtaining a remuneration for the provision of genetic information resources, let alone an economic rent, is most unlikely under bilateral ABS. Once genetic information is in the public domain, users can profit from it free of charge, because a single country, or a few countries together, cannot regulate intangible information. Novel genetic information may, if at all, be traded once. Users acquiring genetic material often release the information contained therein as part of the utilisation process and render further trade in the respective material or information improbable. A firm A, for example, remunerates a country Z for screening, discovers an interesting active ingredient, and subsequently develops a product out of it for which it files a patent. Firm B uses the genetic information about the active ingredient, which is not covered by the patent, also develops a product, and sells

[12] FAO (2001): International Treaty on Plant Genetic Resources for Food and Agriculture, Resolution 3/2001, Rome, 3.11.2001)

[13] Ref. Footnote 3.

it. Country Z has only been remunerated by firm A. The remuneration would have been higher if it had negotiated simultaneously with firm A, B, and other potential users. In other words, a social planner would pay more and demand more as an individual firm. Besides genetic information, physical genetic resources are also in the public domain in form of *ex-situ* resources, e.g. in research institutes or botanic gardens. With a global mechanism, countries may regulate ABS in a way that approximates trade in genetic resources to the social optimum and thereby respect the informational nature of resources more adequately.

Transaction costs are also lower in case of a global mechanism (Vogel (2007, p. 59 f.); for regional collusion ref. Winands and Holm-Müller (2014) id. Chapter 5). Under a bilateral regime, every country has to develop institutions and profound capacities in the fields of legislation, implementation, administration, monitoring, and enforcement. Monitoring and enforcement costs tend to be considerable under a bilateral regime as most physical genetic resources are non-endemic and thus widely distributed. Diffusion of secondary metabolites is even greater as they often occur in different species. Currently, most ABS regulations are neither effective nor efficient (Kamau et al. 2010, p. 248). Transaction cost result also from the existence of asymmetric information. Provider countries tend to pass strict regulations out of concern to be deceived by users as they often have few information on research and commercialisation processes. Opportunistic behaviour by one contract party, namely "incomplete or distorted disclosure of information" (Williamson 1985, p. 47), is a problem in case of bilateral ABS (Sampath 2005, p. 67). It remains to be seen whether and how the implementation of the Nagoya Protocol, which came into force recently, impacts transaction costs of bilateral contractual ABS.

The above-mentioned arguments can be illustrated by a simple economic model, where the pay-off function π_d of a representative firm using genetic resources reads:

$$\pi_d = py(x, z, \bar{z}) - c_x x - (c_z + \nu_1 + \nu_2)z, \tag{6.1}$$

with p = price of a final good produced with genetic resources as an input factor, y = output of such final good, x = a vector of other input factors such as labour and capital, z = appropriable genetic resources, $\bar{z}$ = genetic information in the public domain (exogenously given), c_x = price vector of the other production factors, c_z = price of genetic resources, ν_1 = transaction costs, ν_2 = costs due to asymmetric information.[14] Appropriable genetic resources z encompass mainly the physical

[14]The contribution of traditional knowledge associated with genetic resources can be considered

resources as they become private property of the firm after purchasing them, but also the information that can successfully be protected from becoming public information (e.g. due to patent law or non-disclosure policies within the firm). The genetic information $\bar{z}$ that cannot be shielded away from others (due to public research, expiring patent laws, knowledge spillovers and diffusion processes, use of the final products for further innovation by other firms, etc.) benefits the general use of genetic resources in an economy, but is not appropriable by a single commercial user. Although a representative firm, by purchasing z units of genetic resources, provides also $\bar{z} = \alpha z$ units, with α being the spillover rate, to the aggregate stock of public genetic information resources, it perceives $\bar{z}$ as exogenously given (as the marginal impact of the particular firm to $\bar{z}$ is negligible). For a representative firm the first order conditions with respect to genetic resource purchase imply (ref. Appendix 6.A.1):

$$c_z + \nu_1 + \nu_2 = p\frac{\partial y}{\partial z} \tag{6.2}$$

The sum of per unit costs of genetic resources, per unit transaction costs and per unit costs of asymmetric information is equal to the marginal productivity of the firm. Thus, the higher the transaction costs and the asymmetric information, the higher marginal productivity must be in order for trade in the genetic resources to take place.

On the supply side, the pay-off function π_s of a representative country or community supplying genetic resources reads:

$$\pi_s = c_z z - c(z), \tag{6.3}$$

with c(z) = costs function comprising costs of *in-situ* conservation of genetic resources and sample provision costs, whereby $c(z)$ is a convex function, i.e. $c'(z) > 0$ and $c''(z) > 0$. Solving the first order conditions with respect to z results in (ref.

by changing the the pay-off function π_d such that it reads: $\pi_d = py(x, z, \bar{z}, K) - c_x x - (c_z + \nu_1 + \nu_2)z$, with K = total amount of traditional knowledge, whereby $K = k + \bar{k}$, with k = private traditional knowledge and $\bar{k}$ = traditional knowledge in the public domain. The implications of internalising positive externalities of traditional knowledge accruing to commercial users of genetic resources, however, might have ambivalent effects on the level of demand for genetic resources (and thus indirectly conservation), because with traditional knowledge screening can be more precise, which implies that less resources are needed than for random screening. The analysis of traditional knowledge on the genetic resource market, though, is beyond the scope of this analysis.

Appendix 6.A.2):

$$c_z = c'(z) \tag{6.4}$$

Substituting c_z into Eq. 6.2, we can characterise the market equilibrium:

$$c'(z) + \nu_1 + \nu_2 = p\frac{\partial y}{\partial z} \tag{6.5}$$

In the social optimum, we assume asymmetric information to be close to zero, $\nu_2 \approx 0$, and genetic resources in the public domain $\bar{z}$ to be determined endogenously. The latter is based on the assumption that a social planner would anticipate the impact of employing z genetic resources on the overall available stock of genetic resources $\bar{z}$. The social planner's optimisation, thus, reads:

$$\max_{z} \quad py\left(x, z, \bar{z}\right)_{|\bar{z}=\alpha z} - c_x x - c(z) - \nu_1 z \tag{6.6}$$

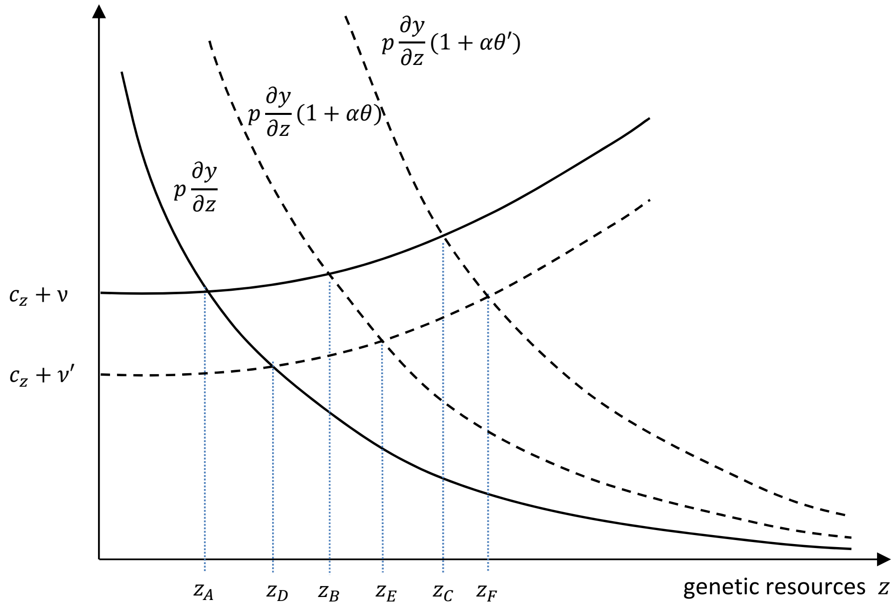
Solving the first order conditions for the social optimum results in (ref. Appendix 6.A.3):

$$\begin{aligned} c'(z) + \nu_1 &= p\left(\frac{\partial y}{\partial z} + \alpha\frac{\partial y}{\partial \bar{z}}\right)_{|\bar{z}=\alpha z} \\ \iff c'(z) + \nu_1 &= p\frac{\partial y}{\partial z}(1 + \alpha\theta), \end{aligned} \tag{6.7}$$

with $\theta := \left(\frac{\partial y}{\partial \bar{z}} / \frac{\partial y}{\partial z}\right)_{|\bar{z}=\alpha z}$ being the relative productivity of genetic information in the public domain. θ stands for the relevance of this information for production, i.e. if θ is small, the genetic information in the public domain is not very relevant. Technological progress is one factor likely to raise θ, because new technologies are increasingly based on the use of genetic information rather than physical genetic resources. Growing research fields like genomics or synthetic biology, for example, rely on genetic information and increase θ. Compared to the market equilibrium (Eq. 6.5), the marginal productivity considered is higher in the social optimum (Eq. 6.7) for the same amount of resources used as $\theta > 0$, even if ν_1 and ν_2 would remain unaffected. Fig. 6.1 depicts the market equilibrium characterised by Eq. 6.5 (solid line) and in the social optimum described by Eq. 6.7 (dashed line), where the left-hand side is associated to supply and the right-hand side to demand. Note that we assign the transaction costs to the left-hand side (as also indicated in Eq.

6.7 and Eq. 6.7) to facilitate the graphical illustration in Fig. 6.1. For any given

Figure 6.1: Genetic resource market



The intersections denote the levels of genetic resource demand dependent on different institutional settings, e.g. z_A: case with high transaction costs, high costs due to asymmetric information, no internalised genetic information spillovers, z_B: case with high transaction costs, high costs due to asymmetric information, internalised genetic information spillovers, and z_D: case with low transaction costs, low costs due to asymmetric information, no internalised genetic information spillovers.

aggregate per unit costs ($\nu + c_z$), more genetic resources are demanded in the social optimum, as $\theta > 0$, and demand rises in θ ($z_A < z_B < z_C$, with $\theta' > \theta$). Lower transaction costs and close to zero costs of asymmetric information in the social optimum ($\nu' + c_z$)[15] work in the same direction. In the social optimum these factors apply in combination and genetic resource demand is thus much higher (z_A vs. z_E, or even z_F if θ is large). A higher demand for genetic resources should lead to an increase in conservation of genetic resources.

A global mechanism can approximate the social optimum by reducing asymmetric information and transaction costs and by internalising the benefits from the provision of $\bar{z}$ through a subsidy on z. The subsidy matches the additional demand for z in the social optimum, i.e. the difference between private and social optimal

[15]Another issue might be that individual firms may shy away from the risks in investing in genetic resource acquisition as the outcome is highly uncertain. A social planner has better risk pooling and diversification possibilities. Hence, there might also be too little demand due to risk aversion.

demand. The subsidy s can be generated by governments e.g. from a lump-sum tax on the i'th agent τ_i, whereby $\sum_i \tau_i = sz$. It can be paid to either providers or users with the same economic effect, at least in theory. To achieve political acceptance the subsidy could be paid into a fund that distributes it to providers of genetic resources dependent on z. Under such regime, the pay-off function π_s of a representative country or community supplying genetic resources reads:

$$\pi_s = (c_z + s)z - c(z). \tag{6.8}$$

Solving the first order conditions with respect to z we obtain

$$c_z = c'(z) - s. \tag{6.9}$$

By substituting c_z into Eq. 6.2, we can characterise the market equilibrium under a global mechanism (reduction in trasaction costs, close to zero asymmetric information, a subsidy for suppliers of z):

$$c'(z) + s + \nu_1 = p\frac{\partial y}{\partial z} \tag{6.10}$$

Comparing Eq. 6.10 and Eq. 6.7, we can deduce the optimal subsidy s^*:

$$s^* = p\alpha\frac{\partial y}{\partial \bar{z}} = p\frac{\partial y}{\partial z}\alpha\theta. \tag{6.11}$$

A global mechanism that approximates the social optimum not only increases conservation (ref. Fig. 6.1), but, as we will show, also revenues for providers. When considering profit-maximisation by substituting c_z from Eq. 6.9 in Eq. 6.8, profits under a global mechanism are characterised by:

$$\pi_s = c'(z)z - c(z) \tag{6.12}$$

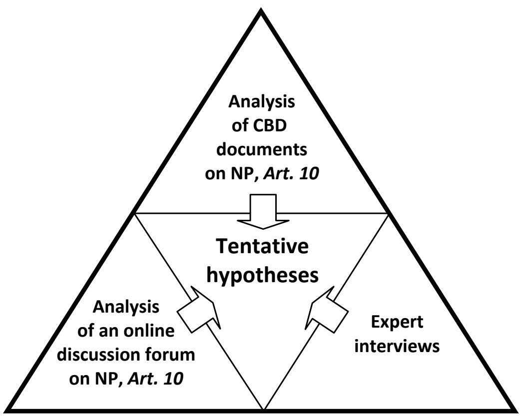
As the first derivative of Eq. 6.12 with respect to z is positive (given $c''(z) > 0$), pay-off rises with increasing z, and thus conservation. Hence, a global mechanism raises conservation levels as well as providers' net revenues. Importantly, the pay-off in the market equilibrium with a subsidy is higher for provider countries because of a higher z which is induced by the subsidy (see Fig. 6.1), not because of the subsidy *per se* (profits with and without a global mechanism are characterised by the same equation, Eq. 6.12, ref. Appendix 6.A.2).

The internalization of positive conservation externalities accruing to commercial users of genetic resources depends on the size of the coalition of states cooperating under the NP, an amended NP, or a separate global mechanism. A regional mechanism will not be able to internalise benefits from genetic information in the public domain and achieve less reductions in transaction costs and costs due to asymmetric information. Special attention will have to be given inter alia to the case of the United States of America, which is one of the few countries that have not ratified the CBD nor the NP.

6.4 Empirical research methodology

Our empirical research to explore the political feasibility of a global mechanism to internalise positive biodiversity conservation externalities accruing to commercial users of genetic resources complements the economic analysis (Section 6.3). We conduct inductive research, i.e. explorative research in a hardly scientifically researched field to lay the theoretic foundations for tentative hypotheses (Bortz and Döring 2006, p. 50), as we cannot build on and statistically test existing ones. Inductive reasoning does not deliver final conclusions. It aims at generating new knowledge by exploring a topic and preparing hypotheses which have to stand the test of future research and real world developments. Our methodology thus involves the study of relevant CBD documents and an online discussion forum on a global multilateral mechanism, as well as expert interviews. The three research phases link into each other to generate and substantiate hypotheses (ref. Fig. 6.2). Such methodologi-

Figure 6.2: Empirical research methodology



cal triangulation is a strategy for “further enriching and completing knowledge and (...) transgressing the (always limited) epistemological potentials of the individual method” (Flick 2009, p. 444). The CBD documents and statements in the online forum provide a broad overview of countries’ official perceptions with regard to the GMBSM specified under *Art. 10*, NP. The expert interviews allow to elicit more specific and in-depth views. Expert interviews are particularly suited in early explorative research as they allow “unrivalled dense data collection” with interview partners who are “cristallization points of practical insider knowledge” (Bogner and Menz 2009b, p. 8). The data collection for these two research phases is described in Section 6.4.1, the analysis in Section 6.4.2, and the results in Sections 6.5.1 and 6.5.2. In the context of the studied global mechanism we use the term genetic resources to simultaneously refer to physical genetic resources and genetic information.

6.4.1 Data collection

The CBD documents and the online discussion forum on the GMBSM of *Art. 10*, NP, are publicly available online. We studied the debate on *Art. 10* of the second and third meeting of the *‘Open-Ended Ad Hoc Intergovernmental Committee for the Nagoya Protocol’* (ICNP), COP 11, and COP-MOP 1 of the NP. Moreover, we analysed the online discussion forum[16] on *Art. 10* launched by the CBD Secretariat through the ABS Clearing-House in April–May 2013 and its synthesis provided by the CBD Secretariat. 142 participants took part in the online discussion and made over 350 interventions[17]. A number of participants were chosen for an expert meeting at which they reviewed the synthesis, further discussed the issues, and prepared a report for ICNP-3 that we also considered in our analysis. Besides, we reviewed the coverage of the CBD conferences related to *Art. 10* (COP 10, ICNP-2, COP 11, ICNP-3, COP-MOP 1) by the *‘Earth Negotiations Bulletin’*. We provide an overview of the analysed data in the Supplementary Material S.6.1.

As third empirical-qualitative exploration phase we conducted loosely structured face-to-face expert[18] interviews with sixteen experts from eight biodiversity rich

[16]The online discussion (ref. Supplementary Material S.6.1) served the purpose of the broad consultation on Art. 10 which was instructed by the COP 11 in decision XI/1 B (UNEP/CBD/COP/11/35, XI/1 B, p. 76, ref. Supplementary Material S.6.1.). It uses the list of questions included in decision XI/1 (UNEP/CBD/COP/11/35, XI/1, Annex I, p. 79 f.).

[17]UNEP/CBD/ABSEM-A10/1/2, par. 4, online: http://www.cbd.int/doc/meetings/abs/absem-a10-01/official/absem-a10-01-02-en.pdf, last 12.11.2013.

[18]Bogner and Menz (2009a, p. 73) define an expert as a person who “possesses technical, process, and interpretation knowledge, which relates to a specific field of action, in which he acts in a *relevant* way (for instance in a specific organisational or his professional area of activity)” [emphasis added

'Latin American and Caribbean' (LAC) countries in the context of a workshop on ABS in November 2013[19]. The LAC countries' perceptions are particularly interesting as these countries are rich in biodiversity and strongly value their sovereignty over their genetic resources. The experts were competent stakeholders with decision power[20] in the ABS process. The first author of this chapter, a quasi-expert (Pfadenhauer 2009, p. 106), conducted the interviews in the preferred language of the interviewee (12 in Spanish, 2 in English). We recorded all except two of the interviews; for one notes were taken, the other one was a written one. We used a pretested topic guideline[21] to carry out loosely structured interviews. The guideline questions concerned (i) a country's past experience and satisfaction with bilateral ABS, (ii) a country's ability to estimate its benefits from genetic resources, (iii) a country's attitude towards a global multilateral benefit-sharing mechanism, (iv) its preferences for certain benefit-sharing modalities, as well as (v) factors that are important in international negotiations about such a mechanism. The interviewer mainly listened. We left the experts freedom to decide which topics to discuss in more depth and to turn the interlocution to specific aspects of the main questions they considered decisive or urgent[22]. After each interview we wrote interview protocols to assure the quality of the later analysis.

6.4.2 Data analysis

We studied the CBD documents and the online discussion forum on *Art. 10*, NP, on "the need for and modalities of a global multilateral benefit-sharing mechanism"[23] with regard to the following aspects: (i) arguments in favour of a GMBSM, (ii) arguments against a GMBSM, (iii) situations for a GMBSM, and (iv) modalities for a GMBSM–all under the terms of *Art. 10*, NP. We excerpted the relevant statements

to reflect the authors' further elaboration].

[19] The Science-Policy Workshop on Access and Benefit-Sharing for non-commercial academic research in LAC was facilitated by DIVERSITAS, the International Council for Science, the Swiss Academy of Sciences, the International Union of Biological Sciences, University of Bonn, and the International Union for Conservation of Nature.

[20] Inter alia ABS national focal points in the government ministries.

[21] Ref. Supplementary Material S.6.4.

[22] We did not interrupt the interviewees as long as the information was not obviously unrelated, because the experts with their knowledge-edge might mention an aspect which at first does not seem relevant to the interviewer but which importance becomes clear eventually during the course of the interlocution. Atteslander (2010, p. 134) point to the importance of giving the interviewee considerable reaction space instead of provoking isolated reactions to specific stimuli in order to explore the experts' perceptions and preferences comprehensively.

[23] For a list of analysed documents and discussion forum threads ref. Supplementary Material S.6.1.

on (i) to (iv) made in the forum's 350 interventions and listed them in separate documents. In the CBD documents we likewise highlighted the data germane to (i) to (iv). Next, we condensed the list on situations for a GMBSM from the online discussion to remove duplications, grouped them by related situations, and added highlights from the analysed CBD documents that contained new situations not already covered by the list. For arguments against a GMBSM we proceeded in the same manner. Next, we examined the compilations from the online forum and the highlights from the CBD documents with regard to arguments in favour of a GMBSM as well as to the modalities of such mechanism and included significant statements in the results.

The expert interviews were inspected for adequate data quality prior to the analysis. The interview material is particularly authentic because the interviewees were familiar with a GMBSM due to previous discussions on *Art. 10*, NP[24]. We transcribed the interviewees' statements verbatim except for repetitions and obvious digressions, but did not record prosodic and para-linguistic data, because there is no additional benefit in case of expert interviews (Meuser and Nagel 2009, p. 56). We re-listened to the interviews and checked the accuracy of our transcripts. To analyse the verbal, qualitative data we used content analysis and interpretation. Our approach is inductive (similar to Mayring (2010)) as we aim to preserve the richness of the individual expert interviews. We examined the textual data line by line and marked relevant lines in different colours (codings). The codings were then aligned to the interview questions. Next, we copied the codings to meta-documents that include all codings belonging to one question from different interviews. We analysed the compilations of codings with direct relevance to this study in detail. The other codings served to generate situative background information. We checked internal validity by examining alternative interpretations of the interview material. External validity is ensured by a 'theoretical sample' (Bortz and Döring 2006, p. 335): we achieved a systematic choice of experts by using a pre-selected expert list created for an ABS workshop in the LAC region that we narrowed down by focusing on policy makers–whereas the workshop targeted researchers and policy makers–and by choosing experts from different countries. Comparability of the interviews was achieved by "the mutually shared institutional-organisational context of the experts" and the interview guideline (Meuser and Nagel 2009, p. 56).

[24]Prior to the interviews, *Art. 10*, NP, had already been debated during ICNP-2 as well as in the online discussion forum (www.cbd.int/doc/?meeting=icnp-02; http://absch.cbd.int /Art10_groups.shtml, last accessed 03.01.2014).

6.5 Empirical results on the political feasibility of a global mechanism

Countries currently implement ABS in form of a bilateral transactional mechanism. A global mechanism is a potential alternative, or possibly complement if implemented partially. Against this background we present findings from the analysis of the political debate (Section 6.5.1) and from expert interviews (Section 6.5.2).

6.5.1 The political debate on a global multilateral mechanism

The consultation process of countries by the CBD Secretariat previous to ICNP-2[25] and the discussions at ICNP-2[26] in July 2012 portrayed a mixed picture of countries' understanding of *Art. 10*, NP, and their preferences for some sort of multilateral benefit sharing. The online discussion among ABS experts initiated by the CBD Secretariat confirmed once more that the need and possible situations for a GMBSM are highly controversial; this question permeated all discussion threads. Besides positions in favour or against a GMBSM, some participants expressed their preference for regional case-to-case cooperation in line with Art. 11, NP[27]. Interestingly, the online discussion forum revealed that there is neither common understanding of transboundary resources, although they are the subject of *Art. 10* and *Art. 11*, NP, nor of the very focus of the NP: the definition of genetic resources as physical and/or information resources. The expert meeting that reviewed the synthesis of the online discussion identified six aspects of common understanding[28], of which the most significant ones are that parties can create a GMBSM "in the exercise of their sovereignty", and that a GMBSM "should not undermine state sovereignty", "contribute to conservation and sustainable use of biological diversity", and "supplement the bilateral nature of the Nagoya Protocol". Discussions at ICNP-3 did not advance the matter; a decision recommendation that includes further deliberations in form of a study and an expert workshop until NP COP-MOP 2 was agreed[29]. NP COP-MOP 1 subsequently adopted this decision without any changes[30]. The discussions

[25]UNEP/CBD/ICNP/2/7, ref. Supplementary Material S.6.1.

[26]Earth Negotiations Bulletin, Vol. 09, No. 579, ref. Supplementary Material S.6.1.

[27]*Art. 11*, NP, calls for cooperation between parties in case of *in situ* transboundary resources and traditional knowledge associated with genetic resources that is shared by communities living in more than one country.

[28]UNEP/CBD/ICNP/3/5, Item 4, ref. Supplementary Material S.6.1.

[29]UNEP/CBD/ICNP/3/L.8, ref. Supplementary Material S.6.1.

[30]UNEP/CBD/NP/COP-MOP/1/L.9, ref. Supplementary Material S.6.1. The brackets around "subject to the availability of funds" were removed from the ICNP-3 decision recommendation.

on the need for and design of a GMBSM are closely related to sovereignty aspects, ease to obtain access to genetic resources, benefit-sharing fairness, and benefit and cost expectations. Importantly, it is not a provider versus user discussion[31].

The data we analysed[32] provided us with a very large amount of statements in favour of (i) or against (ii) a GMBSM as well as on situations for such mechanism (iii) and its modalities (iv). The statements in favour of a GMBSM largely mirror those presented in Section 6.3–albeit not always expressed in economic terms. In addition to these, the African Group pointed out that a GMBSM may help countries "to discharge their cooperation obligations under *Art. 11* at a reasonable transaction cost and without needing to deal with every instance on a case-by-case basis"[33]. The statements[34] against a GMBSM can be grouped under the following arguments: a GMBSM undermines sovereignty and thus countries have less negotiation and decision power; countries might have conflicting interests with the GMBSM; the benefit sharing might not be fair and equitable; benefits do not go directly to the provider communities; benefits are earmarked for conservation; countries obtain fewer benefits as they share with other providers and bear transaction and administration costs; there is uncertainty about dispute resolution; a GMBSM may create disincentives for functioning national ABS mechanisms; it could create uncertainty for users around rights and applicable processes and create delays; there is no need for a GMBSM as all situations can be dealt with either under the bilateral ABS or *Art. 11*, NP, on transboundary cooperation.

The discussion of the need for a GMBSM includes deliberations on potential situations that could fall under the GMBSM (iii). A number of situations are mentioned and controversially debated in the context of *Art. 10*. These situations refer to the following clusters of resources[35]: that are transboundary including migratory species; that are outside national jurisdiction; that can be obtained without any physical access, i.e. genetic information resources (e.g. in databases, gene banks); for which it is not possible to obtain *'Prior Informed Consent'* (PIC) because the origin is unknown or the country of origin has no ABS system; for which it is not practical to obtain PIC (e.g. no reasonable time span); for which there are no legal obligations to share benefits but users choose to do so voluntarily; that were accessed

[31] Ref., e.g., to the interventions made in the online discussion forum.

[32] For a list of analysed documents and discussion forum threads ref. Supplementary Material S.6.1.

[33] African Group submission for ICNP-2, online: www.cbd.int/icnp2/submissions, last 12.02.2014.

[34] The statements against a GMBSM are listed in the Supplementary Material S.6.2.

[35] We provide a comprehensive list of situations in the Supplementary Material S.6.3.

before the entry into force of the NP (different scenarios); that are used for basic research; that are used in special research contexts (e.g. pathogens).

Situations for a GMBSM are trigger situations for benefit sharing and thereby one aspect of the mechanism's modalities (iv). In in the following we present information on the mechanism's modalities. In the discussions, the problem of identifying the 'object' that triggers benefit sharing was raised: it was noticed that species vary at the cell, gene, allelic, and mutation level between countries and regions, that a gene, which is present, is not necessarily expressed, and that external factors influence gene expression and the production of chemical compounds. The importance of binding trigger points was highlighted in the online discussion in light of the shortcomings of the ITPGRFA to generate benefits. Another aspect of the GMBSM's modalities discussed in the forum was its voluntary or mandatory nature. Some party representatives suggested that it might be both, mandatory for certain situations and voluntary for those for which the former is not possible. The use of the benefits and the benefit distribution were two other features subject to debate. As mentioned before, countries agree that the GMBSM should contribute to conservation and sustainable use of biodiversity. During the online discussion several party representatives proposed that the *'Global Environment Facility'* (GEF) could be involved to this end. It was suggested that the *'Intergovernmental Platform on Biodiversity and Ecosystem Services'* (IPBES) could identify the global priorities for conservation and sustainable use. Another suggestion was to use the mechanism to support developing countries to establish a genetic resource inventory and contribute to the *'International Barcode of Life'* (iBOL) project. Benefits from traditional knowledge, it was opined, should be devoted to projects that maintain traditional practices and knowledge and favour indigenous and local communities. In this context it was mentioned that benefits from traditional knowledge associated with genetic resources might have to be treated by different policy and legal approaches than benefits from genetic resources. Common understanding existed that the mechanism should include monetary and non-monetary benefits. A general remark made was that every party has to profit from the mechanism. Further aspects mentioned were that the mechanism needs to promote solidarity, contribute to poverty eradication, and should include capacity building on the implementation of the mechanism and lessons-learned. It was emphasised that discussions will have to address the rules of operation, the administration, and the financial and budgetary implications of a GMBSM. Moreover, some questioned whether the mechanism should be regional or global in scope.

6.5.2 Results from the expert interviews on a global mechanism

In this Section we describe the findings from the expert interviews on preferences for the benefit-sharing design–bilateral trade versus a global mechanism–and add contextual information given during the interviews where relevant.

Status-quo bilateral benefit sharing: country attractiveness, experiences, and satisfaction. The experts[36] stated that above all megadiversity, both terrestrial and marine biodiversity, and high endemism render countries attractive for genetic resource users. Further favourable factors that were mentioned are traditional knowledge associated with the identification and use of genetic resources–being 'megacultural'–, juridical certainty, experience in applying the respective legislation, the broader economic context, and an own biotechnological industry and research centres. Asked about their countries' attractiveness in comparison to other countries, many experts stated that all LAC countries are megadiverse. One expert opined that "rather than saying this country is more or less, it is about seeing us as Andeans, Amazonians; this is how we have to position our strength in the global context".

According to the experts much more progress has been made with non-commercial bilateral genetic resource contracts than with commercial trade: Mexico issues 500 to 600 permits per year for scientific research while the first commercial contract was being processed at the time of the interview. Costa Rica has granted around 322 permits out of which the majority were for basic or non-commercial research and around 30 to 40 permits for commercial bioprospecting projects. Colombia had 197 non-commercial and two commercial permit applications since 2003, out of which 88 non-commercial and one commercial contracts were signed. Peru has concluded more than 20 non-commercial contracts and no commercial one. Ecuador has received 19 applications since 2011 out of which it is about to negotiate one commercial and one research contract. Bolivia has formalized two to three commercial contracts out of ten solicitations and Cuba has signed a few commercial contracts. Brazil concluded 98 commercial contracts between 2004 and 2013. Consequentially and contrary to the governments' expectations, most countries have received few or no monetary benefits so far. An expert from Costa Rica, though, told us that her country has negotiated monetary benefits for non-commercial research processes

[36] If not explicitly requested otherwise, we refer to all experts without their names and in the female gender to disguise their identity.

which are predominantly used for the forest conservation areas, the main provider of the country's genetic resources. She explained that up to 10% of the investigation budget can be negotiated and estimated that altogether around some hundred thousand dollars have been obtained from non-commercial projects.

Besides few monetary benefits having been realised, several experts addressed deficiencies in their national legislation or institutional arrangement: too protective and bureaucratic legislation, various decrees in different laws instead of specific legislation, involvement of various administrations, lack of human resources, no differentiation between national and foreign laboratories, and problems with the intra-country benefit distribution. Experts from all member countries of the Andean Community (Bolivia, Colombia, Ecuador, Peru) considered that their joint access legislation, *Decisión 391*[37], has not evolved as intended and needs revision. The experts criticised an overly precautionary approach to access regulation, the need for a national counterpart for all utilisations of genetic resources, a lacking differentiation between commercial and scientific contracts, non-existing communication about solicitations and contracts, as well as frequent disagreements among the member countries.

Attitude towards the GMBSM of *Art. 10*, NP. The experts affirmed that their countries were not yet in a position to declare their stance towards the GMBSM of *Art. 10*. An expert from Costa Rica explained that her country has hardly worked on the topic so far. She considered a GMBSM difficult and problematic with regard to retaining the countries' sovereignty over their genetic resources as well as regarding bilateral negotiations, but imagined that it could solve problems related to transboundary resources and transboundary traditional knowledge. One Peruvian expert believed that the GMBSM would be necessary to avoid price dumping. But also the Peruvian experts explained that the country has not yet established a position concerning the proposition of *Art. 10*. They questioned how to realise a GMBSM in practice, how to identify, if existent, truly transboundary genetic resources and associated traditional knowledge, and how to distribute the resulting benefits. One Peruvian expert opined that the implementation has to be very different from the Andean Community's cooperation. Another stated that the scientists and those who suggested the mechanism should take the lead in substantiating the

[37] Decisión 391 on a 'Common Regime on Access to Genetic Resources' (Comision del Acuerdo Cartagena (1996): Decisión 391: Régimen Común sobre Acceso a los Recursos Genéticos, Gaceta Oficial del Acuerdo de Cartagena, Año XII, Numero 213, Lima, 17.06.1996.)

proposal. The Brazilian experts did not have a formed opinion regarding *Art. 10*; they said that it was still under discussion. An expert from Mexico opined that the idea of a GMBSM for transboundary genetic resources has good aspects, namely a fund supporting conservation in countries. However, she was not sure whether it should be a distribution of benefits or another approach to deal with shared resources. She considered that one should focus first on other aspects of the NP and think about the implementation of the GMBSM after having gained bilateral experiences. A Colombian expert said as well that her country has not yet developed a position with regard to *Art. 10*. She explained that some believe a multilateral system to be wonderful, especially for countries like hers that share a lot of biodiversity with neighbouring countries, but that others deem it to be impossible and a non-equitable benefit distribution to be the potential result. An expert from Cuba stated that her country has always been in favour of a fund and that benefit sharing of transboundary genetic resources is a justification for the fund. However, she added that before her country can support the fund the modalities will have to be established. An Ecuadorian expert was in favour of a multilateral mechanism and opined that "we have to see how to take decisions that go beyond the borders, it is complex, we need to mature a lot [...] on the political level".

Attitude towards a comprehensive global mechanism for benefit sharing from genetic resource use. Most experts were sceptical about a multilateral mechanism and, if generally in favour of it, they had doubts about its (current) practical feasibility. A Peruvian expert questioned global cooperation as countries are at different stages. She argued that cooperation should be regional–an opinion expressed by several experts–and without handing over some sovereignty to a multilateral mechanism. The expert affirmed the need for a multilateral mechanism "because we have many shared resources, all topics related to trade with species and genetic resources have to be coordinated in the block of the Andean and Amazonian countries, and we can be a more powerful block in negotiations". She emphasised, though, that these remarks represented her own opinion as her country did not have an agreed-upon position. The other Peruvian experts only spoke for themselves as well. One explained that bilateral negotiations are more adequate in light of countries' different characteristics such as varying property rights. Nevertheless, she could imagine that an improved multilateral system of the Andean Community could be beneficial if it provides a clear framework, increases transparency, and reduces asymmetric information within the country. She made clear that Peru's sovereignty has to be respected at all times and that Peru has to be able to negotiate for itself. Another Peruvian expert explained that the member countries of a multilateral mechanism would have to be able to decide about the use of the funds. Advantages of a mechanism, in her view, were that it would create a higher obligation with users and facilitate the monitoring of benefit sharing. She viewed a mechanism, if at all, as a regional one. Another was very sceptical but stated that an advantage could be security with regard to foreign patents. She reminded, however, that there are different realities within the countries as well as important legislative differences and that existing multilateral agreements in Latin America are in disarray. She observed that nationalism surges in response to imposed multilateral ideas. Moreover, she opined that a global mechanism "sounds like a communist inspiration–the lesser of the evils is the liberal market [...]. A state which supervises the market could help, but the market has to do the benefit and resource allocation". Another Peruvian expert expressed her opposition to a multilateral mechanism. An expert from Costa Rica regarded a global mechanism as potentially favourable for countries which have not yet established national ABS legislation, but not so for countries with existing legislation. She was unsure about the whole idea of a global mechanism for genetic resource trade and feared that monetary benefits would not arrive at the resource providers. She believed that one would have to be very innovative in designing such mechanism. A Bolivian expert considered that a regional mechanism similar to the one of the Andean Community, but with more solidarity, equity, and possibly sovereignty, could be imagined. She judged that "for the moment it is perhaps premature or too much ahead for that institution to function, but it is this attitude that Bolivia negotiates in block with the Latin American countries". An expert from Ecuador believed that regional cooperation is vital as ecosystems, water sources, and the indigenous population do not follow political borders. She stated that "this is an integrating vision that has not to be seen from the point of view of the political discourse, but rather from an ecosystem point of view, as people that are administrating biodiversity". The Ecuadorian expert confirmed that sovereignty is important for her country but that it is also about defending it globally. She said that "a lot of our genetic material is in the DNA banks, the germplasm banks, we already lost sovereignty about this [...]–for example among Andean countries as a block we have to demand the information that is in the international research centres [...]–we don't want the dry plant or animal back, but rather the information". The Ecuadorian expert advised to use regional and sub-regional fora that already exist and extend their scope to environmental topics rather than to create a new institution. She believed that a regional mechanism for sharing the benefits from genetic resource use could be established within these regional fora once the topic has matured at national level. A Mexican expert was sceptical about a global mechanism as there is no established value for genetic resources and because the communities would lose their autonomy to take decisions on their resources. She preferred case by case negotiations although she was aware that they are also complicated. The Mexican expert assumed a multilateral mechanism might be applicable to *ex-situ* genetic resources, albeit one needs to be cautious and respect the property rights held by different countries. An expert from Cuba assessed compliance enforcement including a lacking arbitrage court to be an obstacle to a global mechanism. She believed that from the point of view of Cuba a global mechanism for genetic resource use could be realised, but added that the many experiences with funds indicate that a global mechanism will not work. The Brazilian experts did not have a formed opinion on such a global mechanism.

Asked about the general prospect of a global mechanism for the sharing of benefits from genetic resource use, Manuel Ruiz, director of the program *'International Affairs and Biodiversity'* from the *'Peruvian Society for Environmental Law'*, judged that politically it faces major obstacles. He explained that "there is not much intention [...] to consider a really multilateral alternative based basically on economic arguments; there are various reasons, but one of the reasons is that the current bilateral, contractual regime has already advanced too much".

Modalities of a global mechanism The experts named several modalities which they considered important for a hypothetical global mechanism for the sharing of benefits from genetic resource use: contractual nature, contracts that allow *a posteriori* adjustments, timely transactions, trade facilitating nature, precise legal framework, and the maintenance of countries' sovereignty. Comparing the types of benefits, experts regarded monetary and non-monetary benefits equally important in case of four countries, whereas for two countries monetary ones and for one country non-monetary ones were assessed to be more desirable. In this context one expert explained that there has been a shift in her country, that "at the beginning the expectations were monetary ones, today it is capacity building and technology, non-monetary". The distribution of funds and the administration board of the fund were highlighted as decisive design elements of a global mechanism. The experts gave the following input for designing benefit-sharing rules: just and equitable distribution, those who engage in conservation have to receive benefits, respect of countries' conservation efforts, accounting for endemic species, transfer of technology, as well as support for research projects. The Cuban, Ecuadorian, and Mexican experts preferred to dedicate the benefits to the financing of conservation projects, with clear rules for selecting and evaluating these projects. Besides conservation, the Ecuadorian expert added technology transfer and protection of traditional knowledge as possible project purposes. Overall, the experts expressed the need for further deliberations about the topic of benefit distribution. Experts from four countries stated that negotiations should be case by case rather than according to a standard procedure, because genetic resources differ in their value. One of these experts opined that in case the value is not known, benefits could be negotiated in a generic manner. Several experts highlighted that the modalities should be developed in a participatory way that includes the countries and the indigenous and local communities. According to the experts economic aspects as well as political, social, and environmental ones–such as biodiversity conservation and protection of traditional knowledge–will be relevant in international negotiations about the mechanism design.

In summary the expert interview results show that non-commercial research, which generates few monetary benefits and was not the original focus of ABS, is currently predominant. Benefits from commercial contracts are low, much lower than transaction costs of the status-quo bilateral ABS regime. Even Cost Rica, which is one of the most successful countries in generating benefits, obtained little benefits in relation to expenditures for establishing and operating national ABS institutions and for bilateral negotiations. The experts stated that their countries were not yet in a position to declare their stance towards the GMBSM of *Art. 10*, NP, nor towards a comprehensive global mechanism covering all genetic resources. Many experts were sceptical about a global mechanism, some opposed and some in favour of it. For many experts sovereignty was a critical issue, some found it hard to imagine the practical implementation of a global mechanism, some opined that a global mechanism would be positive for dealing with transboundary resources, some voiced concerns about equity and the role of communities, and some favoured regional over global cooperation. Increased transparency, reduced asymmetric information, legal security regarding patents, and easier monitoring and enforcement were voiced as advantages of a multilateral mechanism. Most experts made concrete proposals for individual aspects of the modalities of a global mechanism.

6.6 Conclusion

Internalising positive biodiversity conservation externalities accruing to commercial users of physical genetic resources and genetic information constitutes one policy instrument to contribute to the provision of the public good biodiversity conservation. If benefit sharing of genetic resources is regarded and further developed out of this understanding, countries might be able to refocus the debate on how to best implement ABS such that the Convention's three goals are promoted in a balanced way. Through our methodological triangulation we were able to provide ample insights into the political feasibility of such global mechanism. In the following we discuss the implications of these findings for a global mechanism and further research.

The economic arguments clearly favour a comprehensive global mechanism for internalization that covers all physical genetic resources and information resources. However, political realities render the implementation of economic theory difficult. The results from the analysis of the CBD documents, contributions to the online discussion forum, and interview statements revealed that the bilateral contractual approach to ABS enjoys broad political consent as the predominant mechanism design due to path dependencies and an arguably narrow understanding of national sovereignty. It seems that various stakeholders have not yet realised the implications of the informational nature of genetic resources for sovereignty (namely no possibility to unilaterally act effectively with regard to genetic information), nor the high importance of genetic information for commercial users.

Our evaluation of the political discourse suggests that a global mechanism for specific genetic resources might emerge under *Art. 10*, NP, in the mid-term future once experiences with the bilateral mechanism have been made. Then the need for a global mechanism will have become clearer. This might for example be the case once countries take the implications of the informational nature of genetic resources on board. The GMBSM could even be imagined to evolve into the common scenario for ABS given the transboundary nature of most physical resources–and virtually all genetic information resources. Countries seem to have common understanding that, theoretically, "in the exercise of their sovereignty over their natural resources, including genetic resources, parties could create a GMBSM and could require that benefits derived from the utilization of genetic resources be shared through a GMBSM"[38]. Our research provides substantiated information on the situations for which countries perceive a need for a multilateral mechanism and their preferences

[38] UNEP/CBD/ICNP/3/5, Item 4, ref. Supplementary Material S.6.1.

for its modalities (ref. Sections 6.5.1, 6.5.2). A number of experts preferred a regional ABS mechanism to a global one and the Ecuadorian expert suggested that such cooperation could be established within existing regional fora (ref. Section 6.5.2). Nevertheless, an Art. 10 mechanism will only lead a few short steps towards the social optimum if it does not address genetic and natural information and internalise related positive externalities. As long as the mechanism remains regional it cannot deal with intangible and easily distributable information resources–and will neither achieve the same reduction in transaction costs and costs due to asymmetric information as a global mechanism.

Hence, the key for economic research and communication into the political arena is to continue to highlight the economic and political advantages of a comprehensive global mechanism that covers physical genetic resources *and* genetic information resources–or ideally, even broader, natural information. Transaction costs and costs due to asymmetric information are much lower under a global mechanism. The bilateral status-quo ABS is characterised by frequently prohibitively high transaction costs resulting in few ABS contracts (ref. Section 6.5.2), whereby it remains to be seen whether and how the implementation of the recent Nagoya Protocol impacts transaction costs of bilateral contractual ABS. A global mechanism could facilitate payments for appropriable genetic resources and internalise benefits from genetic information spillovers to the public domain via a subsidy on genetic resource use. Such regime would increase revenues for providers of genetic resources and biodiversity conservation.

Appendix

6.A Appendix to Section 6.3

6.A.1 Demand side

Pay-off function of the representative firm *without* a global mechanism (subsidy):

$$\pi_d = py(x, z, \bar{z}) - c_x x - (c_z + \nu_1 + \nu_2)z \qquad (6.A.1)$$

FOC 1 :

$$\frac{\partial \pi_d}{\partial x} = 0 = p\frac{\partial y}{\partial x} - c_x \tag{6.A.2}$$

$$\iff \quad c_x = p\frac{\partial y}{\partial x} \tag{6.A.3}$$

FOC 2 :

$$\frac{\partial \pi_d}{\partial z} = 0 = p\frac{\partial y}{\partial z} - c_z - \nu_1 - \nu_2 \tag{6.A.4}$$

$$\iff \quad c_z + \nu_1 + \nu_2 = p\frac{\partial y}{\partial z} \tag{6.A.5}$$

6.A.2 Supply side

Supply function of a representative country *without* a global mechanism (subsidy):

$$\pi_s = c_z z - c(z) \tag{6.A.6}$$

FOC:

$$\frac{\partial \pi_s}{\partial z} = 0 = c_z - c'(z) \tag{6.A.7}$$

$$\iff \quad c_z = c'(z) \tag{6.A.8}$$

When considering profit-maximisation, profits are:
Substituting c_z (Eq. 6.A.8) back into π_s (Eq. 6.A.6):

$$\pi_s = c'(z)z - c(z) \tag{6.A.9}$$

$$\tag{6.A.10}$$

Supply function of a representative country *with* a global mechanism (subsidy):

$$\pi_s = (c_z + s^*)z - c(z) \tag{6.A.11}$$

FOC:

$$\frac{\partial \pi_s}{\partial z} = 0 = c_z + s^* - c'(z) \tag{6.A.12}$$

$$\iff \quad c_z = c'(z) - s^* \tag{6.A.13}$$

When considering profit-maximisation, profits are:

Substituting c_z *(Eq. 6.A.13) back into* π_s *(Eq. 6.A.11) and rearranging:*

$$\pi_s = (c'(z) - s^* + s^*)z - c(z) \quad (6.A.14)$$

$$\iff \quad = c'(z)z - c(z) \quad (6.A.15)$$

The profits under a global mechanism if form of a subsidy is higher for provider countries because of a higher z (see Fig. 6.1), not because of the subsidy (Eq. 6.A.10 = Eq. 6.A.15).

6.A.3 Social optimum

Pay-off function in the social optimum:

$$\max_{z} \quad py\left(x, z, \bar{z}\right)_{|\bar{z}=\alpha z} - c_x x - c(z) - \nu_1 z \quad (6.A.16)$$

FOC:

$$\frac{\partial \pi}{\partial z} = 0 = p\left(\frac{\partial y}{\partial z} + \alpha \frac{\partial y}{\partial \bar{z}}\right)_{|\bar{z}=\alpha z} - c'(z) - \nu_1 \quad (6.A.17)$$

$$\iff \quad c'(z) + \nu_1 = p\left(\frac{\partial y}{\partial z} + \alpha \frac{\partial y}{\partial \bar{z}}\right)_{|\bar{z}=\alpha z} \quad (6.A.18)$$

$$\iff \quad c'(z) + \nu_1 = p\frac{\partial y}{\partial z}(1 + \alpha\theta), \quad \textit{with } \theta := \left(\frac{\partial y}{\partial \bar{z}} / \frac{\partial y}{\partial z}\right)_{|\bar{z}=\alpha z} \quad (6.A.19)$$

Bibliography

Atteslander, P. (2010). *Methoden der empirischen Sozialforschung* (13 ed.). Berlin: Erich Schmidt Verlag.

Bogner, A. and W. Menz (2009a). Das theoriengenerierende Experteninterview. Erkenntnisinteresse, Wissensformen, Interaktion. In A. Bogner, B. Littig, and W. Menz (Eds.), *Experteninterviews. Theorien, Methoden, Anwendungsfelder* (3 ed.)., Chapter 3, pp. 61–98. Wiesbaden: VS Verlag für Sozialwissenschaften.

Bogner, A. and W. Menz (2009b). Experteninterviews in der qualitativen Sozialforschung. Zur Einführung in eine sich intensivierende Methodendebatte. In A. Bogner, B. Littig, and W. Menz (Eds.), *Experteninterviews. Theorien, Methoden, Anwendungsfelder* (3 ed.)., Chapter 1, pp. 7–31. Wiesbaden: VS Verlag für Sozialwissenschaften.

Bortz, J. and N. Döring (2006). *Forschungsmethoden und Evaluation für Human- und Sozialwissenschaftler* (4 ed.). Heidelberg: Springer.

CGIAR (2010). Leaving room in the CBD's ABS Protocol for the future development of specialized access and benefit-sharing arrangements. The example of agricultural microbial genetic resources. Submission to the Executive Secretary of the Convention on Biological Diversity, UNEP/CBD/WG-ABS/9/INF/19.

Cordier, M., W. Hecq, R. Hawi, and J. A. Pérez Agúndez (2014). How to make environmental targets affordable in estuarine waters: Extending the polluter pays principle? *CEB Working Paper 14/001*, 1–18.

Deke, O. (2004). Internalizing global externalities from biodiversity: Protected areas and multilateral mechanisms of transfer. *Kieler Arbeitspapiere 1226*, 1–57.

Ferraro, P. and A. Kiss (2002). Direct payments to conserve biodiversity. *Science 298*, 1718–1719.

Flick, U. (2009). *An Introduction to Qualitative Research* (4 ed.). Thousand Oaks, USA: Sage.

Garrity, G., L. Thompson, D. Ussery, N. Paskin, D. Baker, P. Desmeth, D. Schindel, and P. Ong (2009). Studies on monitoring and tracking genetic resources. Submission to the Executive Secretary of the Convention on Biological Diversity, UNEP/CBD/WG-ABS/7/INF/2.

Greiber, T., S. P. Moreno, M. Åhrén, J. N. Carrasco, E. C. Kamau, J. C. Medaglia, M. J. Oliva, and F. Perron-Welch (2012). *An Explanatory Guide to the Nagoya Protocol on Access and Benefit-sharing.* IUCN Environmental Policy and Law Paper No. 83. Gland, Switzerland: IUCN.

Kamau, E., B. Fedder, and G. Winter (2010). The Nagoya Protocol on Access to Genetic Resources and Benefit Sharing: What is new and what are the implications for provider and user countries and the scientific community? *Law, Environment and Development Journal 6*(3), 246–262.

Laird, S. and R. Wynberg (2012). *Bioscience at a Crossroads: Implementing the Nagoya Protocol on Access and Benefit Sharing in a Time of Scientific, Technological and Industry Change.* Montreal: Secretariat of the Convention on Biological Diversity.

Latacz-Lohmann, U. and C. Van der Hamsvoort (1997). Auctioning conservation contracts: A theoretical analysis and an application. *American Journal of Agricultural Economics 79*, 407–418.

Mayring, P. (2010). *Qualitative Inhaltsanalyse. Grundlagen und Techniken* (11 ed.). Weinheim: Beltz.

Meuser, M. and U. Nagel (2009). Experteninterview und der Wandel der Wissensproduktion. In A. Bogner, B. Littig, and W. Menz (Eds.), *Experteninterviews. Theorien, Methoden, Anwendungsfelder* (3 ed.)., Chapter 2, pp. 35–60. Wiesbaden: VS Verlag für Sozialwissenschaften.

Oldham, P. (2004). Global status and trends in intellectual property claims: Genomics, proteomics and biotechnology. Submission to the Executive Secretary of the Convention on Biological Diversity, UNEP/CBD/WG-ABS/3/INF/4.

Pfadenhauer, M. (2009). Auf gleicher Augenhöhe. Das Experteninterview – ein Gespräch zwischen Experte und Quasi-Experte. In A. Bogner, B. Littig, and W. Menz (Eds.), *Experteninterviews. Theorien, Methoden, Anwendungsfelder* (3 ed.)., Chapter 4, pp. 99–116. Wiesbaden: VS Verlag für Sozialwissenschaften.

Ruiz, M., J. H. Vogel, and T. Zamudio (2010). Logic should prevail: A new theoretical and operational framework for the international regime on access to genetic resources and the fair and equitable sharing of benefits. *Peruvian Society for Environmental Law (SPDA) 5*(13), 1–11.

Sampath, P. G. (2005). *Regulating Bioprospecting: Institutions for Drug Research, Access and Benefit-Sharing.* Tokyo: United Nations University Press.

Schei, P. J. and M. W. Tvedt (2010). "Genetic Resources" in the CBD: The wording, the past, the present and the future. Submission to the Executive Secretary of the Convention on Biological Diversity, UNEP/CBD/WG-ABS/9/INF/1.

Singer, G. A. C. (2009). Proceedings of the Seminar "Barcoding of Life: Society and Technology Dynamics - Global and National Perspectives" held at the Third International Barcode of Life Conference in Mexico City, Mexico, November 9th, 2009. Submission by the International Development Research Centre of Canada to the Executive Secretary of the Convention on Biological Diversity, UNEP/CBD/WG-ABS/9/INF/15.

Varian, H. R. (2006). *Intermediate Microeconomics* (7th ed.). New York / London: Norton & Company.

Vogel, J. H. (1995). A market alternative to the valuation of biodiversity: The example of Ecuador. *ASC Newsletter 23*(5), 66–70.

Vogel, J. H. (2007). Reflecting financial and other incentives of the TMOIFGR: The biodiversity cartel. In M. Ruiz Muller and I. Lapeña (Eds.), *A Moving Target: Genetic Resources and Options for Tracking and Monitoring their International Flows*, IUCN Environmental Policy and Law Paper No. 67/3, pp. 74–74. Gland, Switzerland: IUCN.

Vogel, J. H., N. Álvarez-Berríos, N. Quiñones Vilches, J. L. Medina-Muñiz, D. Pérez-Montes, A. I. Arocho-Montes, N. Val-Merniz, R. Fuentes-Ramírez, G. Marrero-Girona, E. V. Mercado, and J. Santiago-Ríos (2011). The economics of information studiously ignored in the Nagoya Protocol on Access to Genetic Resources and Benefit Sharing. *Law Environment and Development Journal 7*(1), 52–65.

Williamson, O. E. (1985). *The Economic Institutions of Capitalism: Firms, Markets, Relational Contracting.* New York: Free press.

Winands, S. and K. Holm-Müller (2014). Eco-regional cartels on the genetic resource market and the case of the Andean Community's legislation. *ILR Food and Resource Economics Discussion Paper 2014*(2), 1–32.

Wunder, S. (2007). The efficiency of payments for environmental services in tropical conservation. *Conservation Biology 21*(1), 48–58.

Chapter 7

Conclusion

To conclude, I summarise the main findings of the thesis and its contribution to the scientific and political debate in Section 7.1. The results have important implications for further research and policy making, which I address in Section 7.2.

7.1 Synthesis and contribution of the thesis

With this thesis, I provide an inter- and transdisciplinary perspective on fundamental and current aspects of international cooperation for biodiversity conservation and its sustainable and fair use. The inter- and transdisciplinary perspective is a central contribution in itself. More specifically, I contribute to the game theoretic modelling of multilateral cooperation for biodiversity conservation and to the scientific knowledge on the formation, stability, and effectiveness of international biodiversity conservation coalitions (*Objective 1*, ref. Chapter 1.2), as well as to the scientific and policy debate on multilateral cooperation on the genetic resource market (*Objective 2*, ref. Chapter 1.2)–all the while combining economic analyses with political and legal perspectives as well as various experts' inputs. In this section, I summarise the results and contributions from the previous chapters.

7.1.1 Methodological contribution to game theoretic modelling of multilateral biodiversity conservation cooperation

In Chapter 3, I show how international cooperation for biodiversity conservation of sovereign heterogeneous states can be modelled game theoretically (research question *Q I.1 part 1*, ref. Chapter 1.2). The general game theoretic biodiversity conservation model is purposely very general. It provides a conceptual framework for a game theoretic analysis, which considers important aspects of international biodiversity conservation. It is the first model conceptualisation that simultaneously covers (i) countries that differ in both ecosystems and wealth, (ii) a continuous action space, (iii) an ecosystem resilience threshold, (iv) imperfect substitutability between ecosystem services, (v) an explicit consideration of local benefits, and (vi) a fund that redistributes coalition benefits. A further specification of the functional forms would impair the generality. In order to provide some results nevertheless, I provide the model frame together with a numerical application, which delivers illustrative results (see below). The general model provides the framework for the numerical appraisal, without which it would lack theoretical grounding. As far as I am aware, the model is the most comprehensive game theoretic conceptualisation of multilateral biodiversity conservation cooperation. Moreover, the consideration of imperfect ecosystem substitutability or even imperfect complementarity is, to my knowledge, unique in stability analyses of biodiversity conservation agreements.

Furthermore, in Chapter 4, I derive a benefit sharing rule for coalition formation games, which is applicable to biodiversity conservation cooperation (*Q I.2 part 2*, ref. Chapter 1.2). Whereas sharing rules are in general based on purely theoretical considerations, I differ in grounding them on empirical-qualitative research as well as on technical and political economy deliberations. The proposed sharing rule allocates the expected assessable coalition pay-off among the coalition members. I suggest to specify the determinant of the sharing weight as the relative size of protected ecosystems weighed by a country's biodiversity richness and population density. The determinant is compatible with established game-theoretic benefit-sharing rules and can thus be used for different levels of information on benefits. It will nevertheless have to stand up to practical scrutiny. As far as I know, the benefit-sharing rule is the only one developed specifically for biodiversity conservation coalition formation that accommodates real-world constraints. Thereby, I contribute to game theoretic methodological research over and above the development of a general biodiversity cooperation model.

7.1.2 Findings on international biodiversity conservation coalitions

With the numerical application of the biodiversity model in Chapter 3, I enhance the understanding of how heterogeneity in wealth and imperfectly substitutable ecosystems impact the stability of international biodiversity conservation agreements among countries differing in ecosystems and wealth, as well as of how local benefits, ecosystem resilience thresholds, and transfers impact stability and effectiveness (*Q I.1 part 2*, ref. Chapter 1.2). The biodiversity game is a highly aggregated and stylized model of reality and the insights gained in the numerical application rely on specific assumptions, importantly on the number of players and ecosystems (I discuss the implications of relaxing the assumptions in Chapter 3.4.3). At this point the results are mainly illustrating what can be done with the model; I perceive the application as a numerical appraisal (as indicated in the heading of Chapter 3.4). Nevertheless, it reveals some general, important insights into coalition formation, stability and conservation that could not be obtained with previous models: Cooperation improves upon the Nash conservation share. The social optimum, which can be achieved by full cooperation, is characterised by the highest conservation share. The total grand coalition conservation share is highest under imperfect substitutability, lower under perfect substitutability and lowest under imperfect complementarity. The total conservation share increases in local benefits for all coalitions under all substitution elasticities. A higher ecosystem resilience threshold increases the total conservation share and leads to a larger total grand coalition conservation share even in case the threshold is not binding. The continuous action space allows countries to observe the ecosystem resilience threshold and conserve some (however little) of their biodiversity. The main further findings of the numerical model application are: (i) heterogeneity in the form of different, imperfectly substitutable ecosystems and wealth asymmetry as well as transfers are decisive for the stability of biodiversity conservation agreements; (ii) heterogeneity reduces the size of a stable coalition; (ii) the destabilizing effect is stronger the higher the ecosystem substitutability; (iii) high local benefits have a decreasing effect on the size of the stable coalition without transfers; (iv) optimal transfers in contrast facilitate a large stable coalition; (v) an increase in the resilience threshold decreases total pay-offs (and, *v.s.*, increases the total conservation share), especially in the Nash-equilibrium. Hence, the model application provides an illustration how important factors in the biodiversity game interact–so far countries' cross-heterogeneity, the imperfect substitutability of ecosystems and their resilience threshold have not been modelled.

In Chapter 4, I investigate whether established sharing rules for coalition formation games such as the benefit surplus sharing rule and the outside option sharing rule are applicable to biodiversity conservation cooperation (*Q I.2 part 1*, ref. Chapter 1.2). To this end I discuss potential application impediments and assess these through empirical-qualitative research in form of expert interviews with political stakeholders. I argue that the information requirements for game-theoretic per-member partition functions are too demanding in case of biodiversity cooperation. Decision makers face uncertainty about the dimensions of biodiversity, ecosystem behaviour, reproduction, thresholds, feedback loops and system interdependencies. Besides, the economic valuation of biodiversity is challenging. The results from the expert interviews confirm that benefit-sharing rules that consider rational utility maximisers who are aware of expected biodiversity benefits are currently not a feasible model abstraction. Even the application of rules based on expected benefits from various coalition structures is currently untenable. These arguments motivate the hypothesis that currently only a sharing-rule based on expected assessable total coalition benefits may be suitable–a joint estimate by coalition members of their expected assessable total coalition pay-off. Moreover, the expert interviews reveal that non-monetary benefits are important besides monetary benefits. Likewise, the expert interviews indicate that in international negotiations about a benefit-sharing rule economic benefits and costs are likely to be only one aspect countries consider besides political, social and environmental ones.

7.1.3 Findings on multilateral cooperation for genetic resource use

In Chapter 5, I explore the scope of payments for *in-situ* conservation of genetic resources to internalise positive conservation externalities which accrue to commercial users of physical genetic resources (*Q II.1*, ref. Chapter 1.2). I show that eco-regional cooperation has the potential to improve upon the status-quo on the market for physical genetic resources as regards the level of payments and conservation. Dependent on the degree of cooperation, such coalitions may significantly reduce transaction costs for both suppliers and customers. Suppliers face lower transaction costs due to economies of scale in information, administration, monitoring, and enforcement together with other institutional advantages such as transparency and reputation. Transaction cost reductions arise for customers in particular through an increase in transparency. This diminishes the overall price customers have to pay for physical genetic resources. As a result their demand increases–which in turn increases the volume of benefits for biodiversity rich countries. Besides, I contribute to the debate on eco-regional cooperation by discussing differences between countries with a view to their ability to appropriate cooperation induced benefits. I evince that countries with a relatively higher biodiversity richness and a comparatively better institutional environment tend to obtain a higher benefit share. Moreover, I argue that an increase in genetic resource demand should also lead to higher conservation levels. The perceived option value for future bioprospecting contracts provides an incentive for *in-situ* biodiversity conservation. Nevertheless, in a case study of the Andean Community's joint access legislation, I find that the member countries realise few of these cooperation advantages. This observation is significant, because the Andean Community member countries host two biodiversity hotspots as well as important wilderness areas and thereby cover large parts of global biodiversity. It has to be evaluated in light of the role of genetic information resources and *ex-situ* resources. Eco-regional cooperation and in particular the potential for collusion are limited through substitutes which impede market power. Especially easily distributable and accessible genetic and natural information are threatening collusion and eco-regional cooperation–as well as bilateral ABS contracts.

Against this background, I analyse in Chapter 6 whether a global mechanism that internalises positive biodiversity conservation externalities accruing to commercial users of physical genetic resources and genetic information with the objective of increasing biodiversity protection is politically feasible (*Q II.2*, ref. Chapter 1.2). With a small economic model I show that the economic arguments clearly favour a comprehensive global mechanism for internalization that covers all physical genetic resources as well as information resources. A global mechanism could facilitate payments for appropriable genetic resources and internalise benefits from genetic information spillovers to the public domain via a subsidy on genetic resource use. Such regime would increase revenues for providers of genetic resources and biodiversity conservation. Yet, my observation is that political realities obstruct implementing such mechanism. The results from the analysis of the *'Convention on Biological Diversity'* (CBD) documents, contributions to the online discussion forum, and interview statements show that the status-quo ABS is largely met with approval. Path dependencies and restricted perceptions of national sovereignty seem to influence this support of a contractual approach to ABS. In addition, the implications of the informational nature of genetic resources for ABS seem not to be clear to a number of politicians and other stakeholders. Nevertheless, my research suggests that in the mid-term future a global mechanism for specific genetic resources might emerge under *Art. 10* of the *'Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits'* (NP). Through the triangulation of empirical research, I provide substantiated findings on the situations for which this might be the case and countries' preferences with regard to such mechanism.

7.2 Outlook and suggestions for further research

The outlook brings me back to my reference to the United Nations *'World Commission on Environment and Development'* (WCED)'s report (1987) *"Our common future"* in the introductory chapter and thereby closes the circle: Biodiversity is the backbone of our existence, a global public good. Yet, biodiversity conservation is not free of conflicts. A Peruvian expert I interviewed outlined impressively potential conflicts between the objectives of biodiversity conservation and development:

> *"I make the example that communities currently are like a family that has castles full of treasures and is spending all its income by protecting these treasures and starves from hunger. We are putting too much effort in protecting, protecting, protecting, but our people and our children are undernourished. The undernourishment reaches up to fifty per cent of the indigenous population, in the Andean communities thirty and something. It's paradox that we are protecting so much, but our people starve from hunger. The perspectives of economic development in the Amazon are zero short term. They live from illegal trade of wood and drugs, wild emigration to urban settlements, especially of the youth. In this situation you ask yourself, why protect? Tomorrow no one will be left, the Shamans die with all their knowledge and the people emigrate. What are we protecting? This is a question we ask ourselves from time to time–and the protectionists tell us 'You are extractionist'."*

The international community is currently taking a major further step towards reconciling the ecological, economic, and social dimensions of development under the *'United Nation's post-2015 development agenda'* and the *'Sustainable Development Goals'*. The biodiversity game can be used and further refined to understand the dynamics behind the biodiversity-development nexus. The results of the numerical application in Chapter 3 show that poverty reduction can contribute to effective global biodiversity conservation: Conservation facilitating coalition formation is eased in a world with low heterogeneity in wealth and biodiversity quality between countries. Besides, wealthier countries assign higher values to biodiversity. Hence, the redistribution of wealth can be one measure to increase the size of a stable coalition–whereas the redistribution of ecosystem quality is impossible. This underpins once more the importance of transfers. In Chapter 4, I deduced a tentative benefit-sharing rule that is assumably feasible under current information constraints regarding biodiversity benefits. Given the relevance of transfers, further research on benefit-sharing rules is advisable both with regard to testing and fine-tuning the proposed sharing rule as well as in the context of biodiversity benefit valuation. Besides, additional empirical research can contribute to further explore countries' preferences with regard to the modalities of sharing rules for benefits from biodiversity and to broaden the scope of the analysis by addressing other international environmental agreements.

In the past, global cooperation efforts to preserve and sustainably use the planet's biodiversity have often focused on the international level. The national and subnational perspective has to be strengthened within global governance regimes such as the CBD. Biodiversity has a complex, multidimensional nature on the entire continuum of private to public goods. Hence, biodiversity governance should follow a comprehensive and inclusive approach that mainstreams biodiversity into all policy areas, economic sectors, and across the society. This is particularly important, as the efficiency of biomass use has to increase throughout all sectors given the continuously rising demand for biological resources (Von Braun and Gerber 2012, p. 494 f.). Mainstreaming biodiversity implies to better pay attention to individual cases and local benefits within a global setting. Future research could build on the biodiversity game outlined in Chapter 3 and provide a deeper analysis of the mechanisms linked to local benefits that underlie the model. A consequent mainstreaming of biodiversity would also imply the inclusion of natural assets into welfare accounting. So far, though, biodiversity and ecosystem services are insufficiently defined for this purpose–the inclusion of intermediate services, for example, would lead to double-counting (Boyd and Banzhaf 2007). Further research is needed on how to accurately identify and assess final ecosystem services. Yet, individual conservation decisions can be conducted without precise valuation.[1]

The Nagoya Protocol is one example of mainstreaming a particular aspect of biodiversity, viz. genetic resources, across economic sectors. Conservation and sustainable use, however, feature arguably not as prominently in its current implementation as the third goal of the CBD and primary focus of the Nagoya Protocol, the "access to genetic resources and the fair and equitable sharing of benefits arising from their utilization" (CBD, *Art. 1*; NP). Yet, it is not clear to which extend the holders of knowledge associated with genetic resources, which are often indigenous and local communities, participate on equal footing in ABS. Siriwardane and Winands (2013, p. ii) even argue that "whilst the public and institutional hype

[1] Heal (2000, p. 29) highlights that "Valuation is neither necessary nor sufficient for conservation. (...) It lies in incentives: to conserve systems we must give their owners incentives to conserve them. We must make conservation more attractive than any other uses." Economic valuation can inform specific decisions on marginal changes in biodiversity taken by economic minded persons. Often partial valuation suffices to show that the cost-benefit ratio is negative for destroying biodiversity *en lieu* of land use and development. In cases where the assessment is not straight forward, more detailed evaluation is necessary (Helm and Hepburn 2012, p. 7).

around traditional knowledge may have resulted in its prioritization within international conventions and frameworks, its institutionalization may have adversely impacted marginalized communities, and in particular contexts, unintentionally led to the creation of "new" marginals." The role of indigenous and local communities within national ABS contexts and the impact of ABS on individual communities and their knowledge governance regimes would be interesting aspects for further empirical research.

The window of opportunity exists during the further elaboration of the provisions of the Nagoya Protocol to stronger respect the link between benefit sharing and biodiversity conservation. A key level is to give priority to *Art. 9*, Nagoya Protocol, which stipulates that "the Parties shall encourage users and providers to direct benefits arising from the utilization of genetic resources towards the conservation of biological diversity and the sustainable use of its components". Importantly, though, the Nagoya Protocol will only gain long-term relevance if parties succeed in reducing transaction costs and broadening the application scope to genetic and natural information. Genetic and natural information are of high and growing importance for commercial users of genetic resources. In particular marine genetic resources still promise a huge potential and patents over these are growing at an annual rate of 12% (Arrieta et al. 2010). Whereas eco-regional cooperation can be most relevant to reduce transaction cost (ref. Chapter 5), a global mechanism may in addition also cover genetic information (ref. Chapter 6). Further empirical research on the political feasibility of the *Art. 10* mechanism of the Nagoaya Protocol and of a general global mechanism can build on the respective findings of the methodological triangulation in Chapter 6. If countries acknowledge and respect the informational nature of genetic resources, the *Art. 10* mechanism could even evolve into a general mechanism for ABS; the *Art. 10* mechanism refers to transboundary genetic resources and virtually all genetic information resources are transboundary. Such mechanism of reduced transaction costs and increased scope is likely to rise genetic resource demand–by which, in turn, *in-situ* conservation in biodiversity rich countries can be expected to increase as well, as shown by the small economic model in Chapter 6. Further research could model more complex game structures with sub-coalitions and different coalition designs in order to enhance the understanding of and incentives for regional coalition formation and their merge into a grand coalition.

Bibliography

Arrieta, J. M., S. Arnaud-Haond, and C. M. Duarte (2010). What lies underneath: Conserving the oceans' genetic resources. *Proceedings of the National Academy of Sciences of the United States of America 107*, 18318–18324.

Boyd, J. and S. Banzhaf (2007). What are ecosystem services? The need for standardized environmental accounting units. *Ecological Economics 63*(2-3), 616–626.

Heal, G. (2000). Valuing ecosystem services. *Ecosystems 3*, 24–30.

Helm, D. and C. Hepburn (2012). The economic analysis of biodiversity: An assessment. *Oxford Review of Economic Policy 28*(1), 1–21.

Siriwardane, R. and S. Winands (2013). Between hope and hype: Traditional knowledge(s) held by marginal communities. *ZEF Working Paper 115*, 1–26.

Von Braun, J. and N. Gerber (2012). The economics of land and soil degradation. Toward an assessment of the costs of inaction. In R. Lal, K. Lorenz, R. F. Hüttl, B. U. Schneider, and J. von Braun (Eds.), *Recarbonization of the Biosphere. Ecosystems and the Global Carbon Cycle*, Chapter 23, pp. 493–516. Dordrecht/Heidelberg/New York/London: Springer.

WCED (1987). *Our Common Future.* World Commission on Environment and Development. Oxford: Oxford University Press.

Supplementary Material

Supplementary Material Chapter 3

S.3.1 Stability analysis

Note that the notation π_i^K employed in the paper is changed to $\pi(K, i)$ in the following tables for better readability.

S.3.1 Stability analysis without transfers

Coalition	Country A	Country B	Country C	Country D
1	$\pi(1, A) - \pi(5, A)$	$\pi(1, B) - \pi(4, B)$	$\pi(1, C) - \pi(3, C)$	$\pi(1, D) - \pi(2, D)$
2	$\pi(2, A) - \pi(9, A)$	$\pi(2, B) - \pi(7, B)$	$\pi(2, C) - \pi(6, C)$	$\pi(2, D) - \pi(1, D)$
3	$\pi(3, A) - \pi(10, A)$	$\pi(3, B) - \pi(8, B)$	$\pi(3, C) - \pi(1, C)$	$\pi(3, D) - \pi(6, D)$
4	$\pi(4, A) - \pi(11, A)$	$\pi(4, B) - \pi(1, B)$	$\pi(4, C) - \pi(8, C)$	$\pi(4, D) - \pi(7, D)$
5	$\pi(5, A) - \pi(1, A)$	$\pi(5, B) - \pi(11, B)$	$\pi(5, C) - \pi(10, C)$	$\pi(5, D) - \pi(9, D)$
6	$\pi(6, A) - \pi(13, A)$	$\pi(6, B) - \pi(12, B)$	$\pi(6, C) - \pi(2, C)$	$\pi(6, D) - \pi(3, D)$
7	$\pi(7, A) - \pi(14, A)$	$\pi(7, B) - \pi(2, B)$	$\pi(7, C) - \pi(12, C)$	$\pi(7, D) - \pi(4, D)$
8	$\pi(8, A) - \pi(15, A)$	$\pi(8, B) - \pi(3, B)$	$\pi(8, C) - \pi(4, C)$	$\pi(8, D) - \pi(12, D)$
9	$\pi(9, A) - \pi(2, A)$	$\pi(9, B) - \pi(14, B)$	$\pi(9, C) - \pi(13, C)$	$\pi(9, D) - \pi(5, D)$
10	$\pi(10, A) - \pi(3, A)$	$\pi(10, B) - \pi(15, B)$	$\pi(10, C) - \pi(5, C)$	$\pi(10, D) - \pi(13, D)$
11	$\pi(11, A) - \pi(4, A)$	$\pi(11, B) - \pi(5, B)$	$\pi(11, C) - \pi(15, C)$	$\pi(11, D) - \pi(14, D)$
12	$\pi(12, A) - \pi(16, A)$	$\pi(12, B) - \pi(6, B)$	$\pi(12, C) - \pi(7, C)$	$\pi(12, D) - \pi(8, D)$
13	$\pi(13, A) - \pi(6, A)$	$\pi(13, B) - \pi(16, B)$	$\pi(13, C) - \pi(9, C)$	$\pi(13, D) - \pi(10, D)$
14	$\pi(14, A) - \pi(7, A)$	$\pi(14, B) - \pi(9, B)$	$\pi(14, C) - \pi(16, C)$	$\pi(14, D) - \pi(11, D)$
15	$\pi(15, A) - \pi(8, A)$	$\pi(15, B) - \pi(10, B)$	$\pi(15, C) - \pi(11, C)$	$\pi(15, D) - \pi(16, D)$

For a coalition to be stable all pay-off differences in the respective coalition row of this table have to be positive.

S.3.2 Stability analysis with transfers

Internal Stability

Neg. π	Coalition 1	Coalition 2	Coalition 3	Coalition 4
A	$\sum_i \pi(1,i) \geq \sum_i \pi(5,i)$	$\sum_i \pi(2,i) \geq \sum_i \pi(9,i)$	$\sum_i \pi(3,i) \geq \sum_i \pi(10,i)$	$\sum_i \pi(4,i) \geq \sum_i \pi(11,i)$
B	$\sum_i \pi(1,i) \geq \sum_i \pi(4,i)$	$\sum_i \pi(2,i) \geq \sum_i \pi(7,i)$	$\sum_i \pi(3,i) \geq \sum_i \pi(8,i)$	—
C	$\sum_i \pi(1,i) \geq \sum_i \pi(3,i)$	$\sum_i \pi(2,i) \geq \sum_i \pi(6,i)$	—	$\sum_i \pi(4,i) \geq \sum_i \pi(8,i)$
D	$\sum_i \pi(1,i) \geq \sum_i \pi(2,i)$	—	$\sum_i \pi(3,i) \geq \sum_i \pi(6,i)$	$\sum_i \pi(4,i) \geq \sum_i \pi(7,i)$
AB	$\sum_i \pi(1,i) \geq \sum_i \pi(11,i)$	$\sum_i \pi(2,i) \geq \sum_i \pi(14,i)$	$\sum_i \pi(3,i) \geq \sum_i \pi(15,i)$	—
AC	$\sum_i \pi(1,i) \geq \sum_i \pi(10,i)$	$\sum_i \pi(2,i) \geq \sum_i \pi(13,i)$	—	$\sum_i \pi(4,i) \geq \sum_i \pi(15,i)$
AD	$\sum_i \pi(1,i) \geq \sum_i \pi(9,i)$	—	$\sum_i \pi(3,i) \geq \sum_i \pi(13,i)$	$\sum_i \pi(4,i) \geq \sum_i \pi(14,i)$
BC	$\sum_i \pi(1,i) \geq \sum_i \pi(8,i)$	$\sum_i \pi(2,i) \geq \sum_i \pi(12,i)$	—	—
BD	$\sum_i \pi(1,i) \geq \sum_i \pi(7,i)$	—	$\sum_i \pi(3,i) \geq \sum_i \pi(12,i)$	—
CD	$\sum_i \pi(1,i) \geq \sum_i \pi(6,i)$	—	—	$\sum_i \pi(4,i) \geq \sum_i \pi(12,i)$
ABC	$\sum_i \pi(1,i) \geq \sum_i \pi(15,i)$	—	—	—
ABD	$\sum_i \pi(1,i) \geq \sum_i \pi(14,i)$	—	—	—
ACD	$\sum_i \pi(1,i) \geq \sum_i \pi(13,i)$	—	—	—
BCD	$\sum_i \pi(1,i) \geq \sum_i \pi(12,i)$	—	—	—

Neg. π	Coalition 5	Coalition 6	Coalition 7	Coalition 8
A	—	$\sum_i \pi(6,i) \geq \sum_i \pi(13,i)$	$\sum_i \pi(7,i) \geq \sum_i \pi(14,i)$	$\sum_i \pi(8,i) \geq \sum_i \pi(15,i)$
B	$\sum_i \pi(5,i) \geq \sum_i \pi(11,i)$	$\sum_i \pi(6,i) \geq \sum_i \pi(12,i)$	—	—
C	$\sum_i \pi(5,i) \geq \sum_i \pi(10,i)$	—	$\sum_i \pi(7,i) \geq \sum_i \pi(12,i)$	—
D	$\sum_i \pi(5,i) \geq \sum_i \pi(9,i)$	—	—	$\sum_i \pi(8,i) \geq \sum_i \pi(12,i)$
AB	—	—	—	—
AC	—	—	—	—
AD	—	—	—	—
BC	$\sum_i \pi(5,i) \geq \sum_i \pi(15,i)$	—	—	—
BD	$\sum_i \pi(5,i) \geq \sum_i \pi(14,i)$	—	—	—
CD	$\sum_i \pi(5,i) \geq \sum_i \pi(13,i)$	—	—	—

Neg. π	Coalition 9	Coalition 10	Coalition 11
A	—	—	—
B	$\sum_i \pi(9,i) \geq \sum_i \pi(14,i)$	$\sum_i \pi(10,i) \geq \sum_i \pi(15,i)$	—
C	$\sum_i \pi(9,i) \geq \sum_i \pi(13,i)$	—	$\sum_i \pi(11,i) \geq \sum_i \pi(15,i)$
D	—	$\sum_i \pi(10,i) \geq \sum_i \pi(13,i)$	$\sum_i \pi(11,i) \geq \sum_i \pi(14,i)$

For a coalition to be internally stable all inequalities in the respective coalition column have to be satisfied.

External stability

A coalition is externally stable if the coalition is not internally stable with any additional member joining from the set of non-members, i.e. if there is no enlarged internally stable coalition (for a formal proof refer to Weikard (2009, p. 581)).

S.3.2 Model results

The following tables present the results of the various analysis runs, which examine the impact of variations in biodiversity quality, wealth, the magnitude of the local benefits, and the minimum conservation share on coalition stability, the total Nash and the total social optimum pay-off and conservation share. The table in Section S.3.1 shows the results for perfect ecosystem substitutability, the table in Section S.3.2 for imperfect ecosystem substitutability, and the table in Section S.3.3 for imperfect ecosystem complementarity. The first percentage in a row describes by how much the total pay-off under the largest stable coalition is short of the total pay-off under the social optimum. The second percentage in a row gives the conservation potential of the social optimum, the third percentage in a row the welfare enhancing potential of the social optimum. The coalitions are numbered from one to sixteen according to:

1	ABCD	**4**	ACD	**7**	AC	**10**	BD	**13**	B	**16**	Nash
2	ABC	**5**	BCD	**8**	AD	**11**	CD	**14**	C		
3	ABD	**6**	AB	**9**	BC	**12**	A	**15**	D		

S.3.1 Model results for perfect ecosystem substitutability

ρ = 1.0										
Scenario	**Stable coalitions without t.**			**Stable coalitions with transfer**			**total conservation share P**		**total payoff**	
	#	**total P largest c.**	**total payoff largest c.**	**#**	**total P largest c.**	**total payoff largest c.**	**Nash**	**Full coop.**	**Nash**	**Full coop.**
Base-Scenario	9	1.540	51.008 89.535%	1	2.803	56.970	0.245	2.803 1142.763%	34.116	56.970 166.990%
Barrett-Scenario	11	0.001	9.339 40.072%	1	2.001	23.306	0.000	2.001 503658.445%	9.335	23.306 249.664%
ωi = 5 qi = 0.55 yi = 0.45	1	4.000	55.912 100.000%	1	4.000	55.912	0.161	4.000 2480.363%	25.636	55.912 218.102%
ωi = 5 qA, qB = 0.625 qC, qD = 0.475 yA, yB = 0.475 yC, yD = 0.425	1	4.000	55.912 100.000%	1	4.000	55.912	0.161	4.000 2479.451%	25.712	55.912 217.453%
ωi = 5 qA, qB = 0.7 qC, qD = 0.4 yA, yB = 0.5 yC, yD = 0.4	1	4.000	55.912 100.000%	1	4.000	55.912	0.162	4.000 2476.417%	25.944	55.912 215.512%
ωi = 5 qA, qB = 0.775 qC, qD = 0.325 yA, yB = 0.525 yC, yD = 0.375	6	2.052	47.324 84.640%	1	4.000	55.912	0.162	4.000 2470.298%	26.338	55.912 212.291%

ωi = 5 qA, qB = 0.85 qC, qD = 0.25 yA, yB = 0.55 yC, yD = 0.35	6	2.042	49.721 88.927%	1	4.000	55.912	0.163	4.000 2459.259%	26.907	55.912 207.801%
ωi = 5 qA, qB = 0.925 qC, qD = 0.175 yA, yB = 0.575 yC, yD = 0.325	6	2.034	52.265 93.344%	1	3.519	55.991	0.164	3.519 2146.682%	27.674	55.991 202.327%
ωi = 5 q Base (1.0; 0.1) y Base (0.6; 0.3)	6	2.026	54.998 97.100%	1	2.708	56.641	0.166	2.708 1629.366%	28.680	56.641 197.491%
qi = 0.55 yi = 0.45 ωi = 5	1	4.000	55.912 100.000%	1	4.000	55.912	0.161	4.000 2480.363%	25.636	55.912 218.102%
qi = 0.55 yi = 0.45 ωA,ωD = 4 ωB,ωC = 6	9	2.056	43.571 77.927%	1	4.000	55.912	0.170	4.000 2356.953%	26.145	55.912 213.855%
qi = 0.55 yi = 0.45 ωA,ωD = 3.5 ωB,ωC = 6.5	9	2.047	45.162 80.773%	1	4.000	55.912	0.180	4.000 2218.942%	26.782	55.912 208.770%
qi = 0.55 yi = 0.45 ωA,ωD = 3 ωB,ωC = 7	9	2.039	46.883 83.851%	1	4.000	55.912	0.195	4.000 2050.810%	27.674	55.912 202.040%
qi = 0.55 yi = 0.45 ω Base (2;8)	9	2.028	50.719 90.646%	1	3.675	55.953	0.237	3.675 1548.946%	30.228	55.953 185.101%
qi = 0.55 yi = 0.45 ωA,ωD = 1 ωB,ωC = 9	9	2.022	55.100 96.659%	1	2.605	57.004	0.296	2.605 878.834%	33.825	57.004 168.527%
SMin=0.05	9	1.660	37.039 65.978%	1	2.883	56.138	0.405	2.883 711.331%	33.782	56.138 166.179%
SMin=Base(0.01)	9	1.540	51.008 89.535%	1	2.803	56.970	0.245	2.803 1142.763%	34.116	56.970 166.990%
SMin=0.005	9	1.525	51.106 89.545%	1	2.793	57.073	0.225	2.793 1239.785%	34.158	57.073 167.086%
v = 3.29 → bli large	13	1.129	53.409 90.268%	1	2.850	59.167	1.128	2.850 252.739%	53.398	59.167 110.804%
v = Base (10)	9	1.540	51.008 89.535%	1	2.803	56.970	0.245	2.803 1142.763%	34.116	56.970 166.990%
v = 120 → bli small	9	1.515	48.701 86.990%	1	2.782	55.984	0.045	2.782 6189.898%	15.732	55.984 355.854%

S.3.2 Model results for imperfect ecosystem substitutability

ρ = 0.2

Scenario	Stable coalitions without t.			Stable coalitions with transfer			total conservation share P		total payoff	
	#	total P largest c.	total payoff largest c.	#	total P largest c.	total payoff largest c.	Nash	Full coop.	Nash	Full coop.
Base-Scenario	9	1.461	20.999 67.171%	1	3.980	31.261	0.126	3.980 3160.092%	16.158	31.261 193.466%
Barrett-Scenario	11	0.021	8.532 86.716%	1	0.382	9.839	0.000	0.382 136568.226%	8.391	9.839 117.262%
ωi = 5 qi = 0.55 yi = 0.45	1	4.000	55.912 100.000%	1	4.000	55.912	0.161	4.000 2480.363%	25.636	55.912 218.102%
ωi = 5 qA, qB = 0.625 qC, qD = 0.475 yA, yB = 0.475 yC, yD = 0.425	1	4.000	55.503 100.000%	1	4.000	55.503	0.160	4.000 2492.683%	25.468	55.503 217.928%
ωi = 5 qA, qB = 0.7 qC, qD = 0.4 yA, yB = 0.5 yC, yD = 0.4	1	4.000	54.249 100.000%	1	4.000	54.249	0.158	4.000 2530.949%	24.959	54.249 217.353%
ωi = 5 qA, qB = 0.775 qC, qD = 0.325 yA, yB = 0.525 yC, yD = 0.375	1	4.000	52.068 100.000%	1	4.000	52.068	0.154	4.000 2599.545%	24.084	52.068 216.195%
ωi = 5 qA, qB = 0.85 qC, qD = 0.25 yA, yB = 0.55 yC, yD = 0.35	1	4.000	48.788 100.000%	1	4.000	48.788	0.148	4.000 2707.696%	22.795	48.788 214.028%
ωi = 5 qA, qB = 0.925 qC, qD = 0.175 yA, yB = 0.575 yC, yD = 0.325	1	4.000	44.059 100.000%	1	4.000	44.059	0.139	4.000 2874.499%	20.998	44.059 209.827%
ωi = 5 q Base (1.0; 0.1) y Base (0.6; 0.3)	1	4.000	37.039 100.000%	1	4.000	37.039	0.127	4.000 3146.423%	18.471	37.039 200.528%
qi = 0.55 yi = 0.45 ωi = 5	1	4.000	55.912 100.000%	1	4.000	55.912	0.161	4.000 2480.363%	25.636	55.912 218.102%
qi = 0.55 yi = 0.45 ωA,ωD = 4 ωB,ωC = 6	1	4.000	55.026 100.000%	1	4.000	55.026	0.161	4.000 2487.494%	25.207	55.026 218.299%
qi = 0.55 yi = 0.45 ωA,ωD = 3.5 ωB,ωC = 6.5	2	4.000	53.891 100.000%	1	4.000	53.891	0.160	4.000 2497.433%	24.665	53.891 218.494%

Scenario	#	total P largest c.	total payoff largest c.	#	total P largest c.	total payoff largest c.	Nash	Full coop.	Nash	Full coop.
qi = 0.55 **yi = 0.45** **ωA,ωD = 3** **ωB,ωC = 7**	9	2.062	34.540 66.112%	1	4.000	52.245	0.159	4.000 2513.446%	23.894	52.245 218.649%
qi = 0.55 **yi = 0.45** **ω Base (2;8)**	9	2.042	30.530 64.819%	1	4.000	47.100	0.155	4.000 2575.835%	21.604	47.100 218.013%
qi = 0.55 **yi = 0.45** **ωA,ωD = 1** **ωB,ωC = 9**	9	2.027	24.525 64.252%	1	4.000	38.169	0.147	4.000 2730.118%	18.053	38.169 211.427%
SMin=0.05	9	1.621	20.664 67.017%	1	4.000	30.834	0.286	4.000 1398.895%	15.824	30.834 194.857%
SMin=Base(0.01)	9	1.461	20.999 67.171%	1	3.980	31.261	0.126	3.980 3160.092%	16.158	31.261 193.466%
SMin=0.005	9	1.441	21.040 67.192%	1	3.976	31.314	0.106	3.976 3753.106%	16.200	31.314 193.292%
v = 1.6 **→ bli large**	13	1.505	31.118 83.147%	1	4.000	37.425	1.505	4.000 265.844%	31.117	37.425 120.273%
v = Base (10)	9	1.461	20.999 67.171%	1	3.980	31.261	0.126	3.980 3160.092%	16.158	31.261 193.466%
v = 120 **→ bli small**	9	0.903	15.756 52.074%	1	3.976	30.256	0.042	3.976 9450.677%	10.507	30.256 287.962%

S.3.3 Model results for imperfect ecosystem complementarity

ρ = -1.0

Scenario	**Stable coalitions without t.**			**Stable coalitions with transfer**			**total conservation share P**		**total payoff**	
	#	**total P largest c.**	**total payoff largest c.**	**#**	**total P largest c.**	**total payoff largest c.**	**Nash**	**Full coop.**	**Nash**	**Full coop.**
Base-Scenario	9	0.141	10.497 65.940%	1	1.729	15.919	0.089	1.729 1946.083%	10.269	15.919 155.019%
Barrett-Scenario	1	0.012	8.206 100.000%	1	0.012	8.206	0.000	0.012 5354.251%	8.172	8.206 100.419%
ωi = 5 **qi = 0.55** **yi = 0.45**	1	4.000	55.912 100.000%	1	4.000	55.912	0.161	4.000 2480.363%	25.636	55.912 218.102%
ωi = 5 **qA, qB = 0.625** **qC, qD = 0.475** **yA, yB = 0.475** **yC, yD = 0.425**	1	4.000	54.893 100.000%	1	4.000	54.893	0.160	4.000 2505.529%	25.265	54.893 217.270%

ωi = 5 qA, qB = 0.7 qC, qD = 0.4 yA, yB = 0.5 yC, yD = 0.4	1	4.000	51.835 100.000%	1	4.000	51.835	0.155	4.000 2585.000%	24.152	51.835 214.625%
ωi = 5 qA, qB = 0.775 qC, qD = 0.325 yA, yB = 0.525 yC, yD = 0.375	1	4.000	46.739 100.000%	1	4.000	46.739	0.146	4.000 2732.202%	22.296	46.739 209.629%
ωi = 5 qA, qB = 0.85 qC, qD = 0.25 yA, yB = 0.55 yC, yD = 0.35	1	3.446	39.829 100.000%	1	3.446	39.829	0.134	3.446 2562.963%	19.704	39.829 202.136%
ωi = 5 qA, qB = 0.925 qC, qD = 0.175 yA, yB = 0.575 yC, yD = 0.325	1	2.891	31.469 100.000%	1	2.891	31.469	0.119	2.891 2435.126%	16.409	31.469 191.775%
ωi = 5 q Base (1.0; 0.1) y Base (0.6; 0.3)	1	2.435	21.586 100.000%	1	2.435	21.586	0.100	2.435 2439.069%	12.579	21.586 171.599%
qi = 0.55 yi = 0.45 ωi = 5	1	4.000	55.912 100.000%	1	4.000	55.912	0.161	4.000 2480.363%	25.636	55.912 218.102%
qi = 0.55 yi = 0.45 ωA,ωD = 4 ωB,ωC = 6	1	4.000	53.720 100.000%	1	4.000	53.720	0.153	4.000 2621.732%	24.431	53.720 219.882%
qi = 0.55 yi = 0.45 ωA,ωD = 3.5 ωB,ωC = 6.5	1	4.000	50.979 100.000%	1	4.000	50.979	0.143	4.000 2805.707%	22.980	50.979 221.836%
qi = 0.55 yi = 0.45 ωA,ωD = 3 ωB,ωC = 7	2	4.000	47.142 100.000%	1	4.000	47.142	0.130	4.000 3073.792%	21.053	47.142 223.922%
qi = 0.55 yi = 0.45 ω Base (2;8)	9	0.287	16.792 46.030%	1	3.333	36.481	0.104	3.333 3199.008%	16.220	36.481 224.907%
qi = 0.55 yi = 0.45 ωA,ωD = 1 ωB,ωC = 9	9	0.119	11.295 50.149%	1	2.552	22.524	0.089	2.552 2867.877%	11.277	22.524 199.726%
SMin=0.05	9	0.301	10.163 65.294%	1	1.839	15.564	0.249	1.839 738.872%	9.935	15.564 156.667%
SMin=Base(0.01)	9	0.141	10.497 65.940%	1	1.729	15.919	0.089	1.729 1946.083%	10.269	15.919 155.019%
SMin=0.005	9	0.121	10.539 66.020%	1	1.715	15.963	0.069	1.715 2491.517%	10.311	15.963 154.819%
v = 1.1 → bli large	13	1.381	19.170 85.256%	1	2.878	22.485	1.379	2.878 208.731%	19.170	22.485 117.295%
v = Base (10)	9	0.141	10.497 65.940%	1	1.729	15.919	0.089	1.729 1946.083%	10.269	15.919 155.019%
v = 120 → bli small	9	0.051	8.918 57.781%	1	1.661	15.433	0.041	1.661 4033.787%	8.801	15.433 175.365%

Supplementary Material Chapter 4

S.4.1 Topic guideline for the expert interviews

The guideline served as a loose topic guideline. The interviewer varied the formulation, accompanying explanations, and order of questions according to the interview situation and the flow of the conversation.

1. In general, which characteristics render a provider country attractive for genetic resource users? Please, could you describe briefly why your country is interesting for users of genetic resources? Compared to other provider countries, where do you see your country–above or below the average?

2. Has your country signed commercial *'Access and Benefit-Sharing'* (ABS) treaties since 1992? Has your country obtained monetary benefits from these contracts? Compared to your / your country's initial expectations, how satisfied are you / is your country with the benefits your country / it has received? Do you believe that your country has obtained more or less benefits than the average of other countries?

3. Has your country received non-monetary benefits from ABS contracts? Which ones? Do you think that the non-monetary benefits, which your country has obtained, are important?

4. How easy or difficult is it for your country to estimate its monetary benefits from genetic resource trade? Do you believe that it is now easier to estimate the monetary and non-monetary benefits than in the early years of the CBD? Can your country make benefit estimates with more confidence?

5. Are you familiar with *Article 10* of the *'Nagoya Protocol'* on a *'Global Multilateral Benefit-Sharing Mechanism'* [for transboundary genetic resources and associated traditional knowledge and for those resources, for which it is not possible to grant or obtain prior informed consent]? What is your country's position with regard to this proposal?

6. According to which rule should the benefits from transboundary genetic resources be distributed among the affected provider countries? Should such rule be based on a global agreement or should the benefit sharing be negotiated every time anew?

7. *Article 10* only covers a benefit-sharing mechanism for specific genetic resources, but not a general global ABS mechanism. What is your country's position with regard to an multilateral ABS mechanism which applies to *all* genetic resources? (*Possibly:* What are arguments for and against both options–a bilateral and a multilateral mechanism? Is a multilateral mechanism a realistic option?)

8. Could you imagine some regulations of such a multilateral mechanism which could be attractive for your country? Under which conditions would your country be willing to participate? (*Possibly:* How important is the distribution of benefits? The sovereignty over the resources? Or which other aspects are important?)

9. How should a fund of such a multilateral mechanism distribute the benefits from genetic resources among provider countries?

10. Would the costs and benefits of different possibilities to design such a multilateral mechanism be important for the position of your country in international negotiations about such a multilateral mechanism? How important are they in comparison to other political, social, and environmental aspects?

    If the benefits and costs are important:

11. How easy or difficult is it for your country in international negotiations to estimate the monetary benefits and costs of different options to regulate genetic resource trade?

    If easy:

12. How easy or difficult is it for your country in international negotiations to estimate the change in its own benefits and costs if another country leaves or joins a global agreement on genetic resource trade?

Supplementary Material Chapter 6

S.6.1 Documents on *Art. 10* of the Nagoya Protocol

S.6.1 UNEP/CBD documents

1. Article 10, Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity, United Nations, Nagoya, 29.10.2010;
   Online: www.cbd.int/abs/doc/protocol/nagoya-protocol-en.pdf, last 14.02.2014.

2. UNEP/CBD/COP/DEC/X/1, Annex II, Section B, Item 10;
   Online: www.cbd.int/doc/decisions/cop-10/cop-10-dec-01-en.pdf, last 14.02.2014.

3. UNEP/CBD/ICNP/2/INF/2
   Morten Walløe Tvedt (Ed.) (2011): A Report from the First Reflection Meeting on the Global Multilateral Benefit-Sharing Mechanism, FNI Report 10, Lysaker, Norway: Fridtjof Nansen Institute;
   Online: www.cbd.int/doc/meetings/abs/icnp-02/information/icnp-02-inf-02-en.pdf, last 07.02.2014.

4. Submissions received for the Second Meeting of the Open-ended Ad Hoc Intergovernmental Committee for the Nagoya Protocol on Access and Benefit-sharing;
   Online: www.cbd.int/icnp2/submissions, last 12.02.2014.

5. UNEP/CBD/ICNP/2/7
   Synthesis of views with respect to the need for and modalities of a global multilateral benefit-sharing mechanism (Article 10)–*and*
   UNEP/CBD/ICNP/2/7/Corr.1;
   Online: www.cbd.int/doc/meetings/abs/icnp-02/official/icnp-02-07-en.pdf, last 07.02.2014.

6. UNEP/CBD/ICNP/REC/2/3
   Recommendation adopted by the Intergovernmental Committee for the Nagoya Protocol at its second meeting, The need for and modalities of a global multilateral benefit-sharing mechanism (Article 10);
   Online: www.cbd.int/doc/recommendations/ICNP-02/icnp-02-rec-03-en.pdf, last 07.02.2014.

7. UNEP/CBD/COP/DEC/XI/1(B)
Decisions adopted by the Conference of the Parties to the Convention on Biological Diversity at its eleventh meeting, Status of the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization and related developments, The need for and modalities of a global multilateral benefit-sharing mechanism (Article 10);
Online: www.cbd.int/doc/decisions/cop-11/full/cop-11-dec-en.pdf, last 12.11.2013.

8. Online discussion groups on Article 10 of the Nagoya Protocol, ABS Clearing-House Portal on Art. 10, 8. April – 24 May 2013;
Online: http://absch.cbd.int/Art10_groups.shtml, last 10.01.2014.

Round 1

- What could be the ‘transboundary situations’ covered by Article 10 of the Nagoya Protocol that are within the scope of the Protocol?
- What could be the situations where it is not possible to grant or obtain prior informed consent?
- How could a global multilateral benefit-sharing mechanism be used to support the conservation and sustainable use of biological diversity globally?

Round 2

- How might the operation of a global multilateral benefit-sharing mechanism co-exist with the underlying principles, objective and scope upon which the Nagoya Protocol is based?
- What could be the advantages and disadvantages of a global multilateral benefit-sharing mechanism?
- What influence might other articles of the Nagoya Protocol have in the context of a global multilateral benefit-sharing mechanism?

Round 3

- Are there any existing international instruments or processes that could offer lessons learned for consideration in the context of a global multilateral benefit-sharing mechanism under the Nagoya Protocol?
- What other aspects of a global multilateral benefit-sharing mechanism should be considered?

Round 4

- Perspectives on other matters which should be considered

9. UNEP/CBD/ABSEM-A10/1/2
Synthesis of the Online Discussions on Article 10 of the Nagoya Protocol on

Access and Benefit-Sharing;
Online: www.cbd.int/doc/meetings/abs/absem-a10-01/official/absem-a10-01-02-en.pdf, last 07.02.2014.
= UNEP/CBD/ICNP/3/INF/4
Synthesis of the Online Discussions on Article 10 of the Nagoya Protocol on Access and Benefit-Sharing;
Online: www.cbd.int/doc/meetings/abs/icnp-03/information/icnp-03-inf-04-en.pdf, last 03.03.2014.

10. UNEP/CBD/ABSEM-A10/1/3
Report of the expert meeting on Article 10 of the Nagoya Protocol on Access and Benefit-Sharing;
Online: www.cbd.int/doc/meetings/abs/absem-a10-01/official/absem-a10-01-03-en.pdf, last 07.02.2014.
= UNEP/CBD/ICNP/3/5
Report of the Expert Meeting on Article 10 of the Nagoya Protocol on Access And Benefit-Sharing;
Online: www.cbd.int/doc/meetings/abs/icnp-03/official/icnp-03-05-en.pdf, last 14.02.2014.

11. UNEP/CBD/ICNP/3/L.8
The Need for and Modalities of a Global Multilateral Benefit-Sharing Mechanism (Article 10);
Online: www.cbd.int/doc/meetings/abs/icnp-03/in-session/icnp-03-L-08-en.doc, last 04.03.2014.

12. UNEP/CBD/NP/COP-MOP/1/L.9
The Need for and Modalities of a Global Multilateral Benefit-Sharing Mechanism (Article 10);
Online: www.cbd.int/doc/meetings/abs/np-mop-01/insession/np-mop-01-L-09-en.pdf, last 24.10.2014.

S.6.2 Other documents

- International Institute for Sustainable Development (2010): Tenth Meeting of the Conference of the Parties to the Convention on Biological Diversity, Earth Negotiations Bulletin, Vol. 9, No. 534 - 544;
Online: http://www.iisd.ca/biodiv/cop10/, summary: http://www.iisd.ca/download/pdf/enb09544e.pdf, last 15.04.2014.

- International Institute for Sustainable Development (2012): Second Meeting of the Open-ended Ad Hoc Intergovernmental Committee for the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization (ICNP-2), Earth Negotiations Bulletin,

Vol. 09, No. 574 - 579;
Online: http://www.iisd.ca/biodiv/icnp2/, summary: http://www.iisd.ca/download/pdf/enb09579e.pdf, last 15.04.2014.

- International Institute for Sustainable Development (2012): Eleventh Meeting of the Conference of the Parties to the Convention on Biological Diversity, Earth Negotiations Bulletin, Vol. 9, No. 534 - 544;
Online: http://www.iisd.ca/biodiv/cop11/, summary: http://www.iisd.ca/download/pdf/enb09595e.pdf, last 07.07.2014.

- International Institute for Sustainable Development (2014): Third Meeting of the Open-ended Ad Hoc Intergovernmental Committee for the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization (ICNP 3), Earth Negotiations Bulletin, Vol. 09, No. 612 - 617;
Online: http://www.iisd.ca/biodiv/icnp3/, summary: http://www.iisd.ca/download/pdf/enb09617e.pdf, last 15.04.2014.

- International Institute for Sustainable Development (2014): Twelfth Meeting of the Conference of the Parties to the Convention on Biological Diversity (CBD COP 12) and First Meeting of the Conference of the Parties serving as Meeting of the Parties to the Nagoya Protocol on Access and Benefit-sharing (NP COP/MOP 1), Earth Negotiations Bulletin, Vol. 09, No. 630 - 645;
Online: http://www.iisd.ca/biodiv/cop12/compilatione.pdf, last 24.10.2014.

S.6.2 Arguments against a Global Multilateral Benefit-Sharing Mechanism (*Art. 10*, Nagoya Protocol)

In the following, we provide a list of arguments against a *'Global Multilateral Benefit-Sharing Mechanism'* (GMBSM) stated in CBD documents and the online discussion forum. They are literal excerpts from the CBD documents and the online discussion forum given in Supplementary Material S.6.1, whereby some are partly paraphrased:

- A GMBSM undermines a country's sovereignty over its genetic resources (*Art. 15(1)*, CBD). It is those who hold the resource at the time that it is accessed who have the right to determine how the benefits from its future use should be shared.

- A GMBSM might create incentives for non-compliance with national requirements; it could be seen as an alternative process that applies when a user does not meet national legislative requirements.

- A GMBSM would remove users' ability to negotiate benefit-sharing directly with a provider, to customize benefit-sharing arrangements with providers and tailor benefit-sharing to the needs of the provider.
- A GMBSM could replace the role of states in decision-making by an outside organization that could be subject to lobbying pressure by users, which could create frustration and disputes.
- A GMBSM would relinquish a country's ability to negotiate benefit-sharing to a multilateral body whose interests may not be aligned with its own.
- A GMBSM might not be motivated to negotiate benefit-sharing as quickly and efficiently as a country.
- A GMBSM could require users to negotiate with a global body that likely would not have as much understanding of the value of the genetic resource in question as would the provider country.
- A GMBSM could extend benefit-sharing requirements to genetic resources that previously did not carry such obligations.
- A GMBSM increases the likelihood that benefit-sharing focuses on monetary benefits.
- It is unresolved how to address non-monetary benefits under a GMBSM.
- The benefit-sharing under a GMBSM might not be fair and equitable.
- There is uncertainty over how benefits would be received by the provider and whether they would be used to solve specific conservation problems in the country of origin.
- Providers with "more valuable" genetic resources might be giving up value to the benefit of other providers (to global conservation via a GMBSM).
- Benefits would go to conservation rather than to provider communities, obscuring the rationale of the Convention in that those conserving genetic resources would not be the ones reaping the benefits.
- Monetary and non-monetary benefits will not be directly received by the conservation areas, indigenous communities or local people who are making conservation efforts.
- Multiple processes may produce uncertainty for providers over which process or mechanism applies and could result in a situation where a GMBSM seeks to override a provider's claim.
- Benefits to providers might be reduced if there is a need to also provide benefits to a GMBSM and to use benefits towards the administration of a GMBSM.

- There is uncertainty whether a GMBSM will cost parties, collectively, more than it benefits them: Will a GMBSM only raise the level of uncertainty and the transaction costs in return for the possibility that a fraction of profit will be shared among all parties to the Protocol? What will it cost to administer such a system? How much R&D will be dissuaded?

- A GMBSM creates a disincentive for cooperation between countries.

- A GMBSM could provide a disincentive to create functional national *'Access and Benefit-Sharing'* (ABS) frameworks. Will countries with no / less capacity use the multilateral mechanism for endemic species and share benefits in a global way?

- There is uncertainty how to handle the prerogative of governments that elect not to require benefits-sharing.

- There is uncertainty what would be a dispute resolution mechanism for cases of disputes about benefit-sharing between several providers and for resolving jurisdictional disagreements between providers and a GMBSM.

- There is no need for a multilateral mechanism as transboundary cooperation is already covered by *Art. 11* of the Nagoya Protocol.

- There is no need for a multilateral mechanism because in both in-situ and ex-situ situations *'Prior Informed Consent'* (PIC) from a legitimate provider should always be possible for resources that fall under the scope of the Nagoya Protocol.

- There is no need for a multilateral mechanism, because the Nagoya Protocol does not provide for implementing ABS retroactively.

- A GMBSM that sets up rules on genetic resources which lie outside the countries' jurisdiction contradicts *Art. 4* of the CBD.

- There is no need for a multilateral mechanism as the cases in which PIC is not possible to grant or obtain should be solved via capacity building measures.

- A GMBSM might not resolve difficulties around unclear benefit-sharing situations. They might only be transferred from bilateral ABS to a multilateral mechanism.

- A GMBSM will not close gaps in the existing ABS system but will create new loopholes.

- In situations where only two countries are involved, a GMBSM will make things more difficult by involving a larger number of countries.

- A GMBSM might create uncertainty around rights and applicable processes for users, e.g. in case of conflicting jurisdictional claims between the GMBSM and providers.

- A GMBSM's lack of legal authority to enforce its jurisdictional claims on a national government leaves open the possibility that providers could require additional protections on top of a GMBSM. Users would face an additional level of bureaucracy, compliance costs and PIC / *'Mutually Agreed Terms'* (MAT) requirements.

- A GMBSM could create delays for users who, having followed the appropriate process established in national legislation, then find there is an additional process under a GMBSM.

S.6.3 Potential situations for a Global Multilateral Benefit-Sharing Mechanism (*Art. 10*, Naogya Protocol)

In the following we present results from the analysis of the CBD documents and the online discussion forum given in Supplementary Material S.6.1. We list all potential situations for a *'Global Multilateral Benefit-Sharing Mechanism'* (GMBSM) under *Art. 10* of the Nagoya Protocol mentioned in the analysed data to provide a comprehensive overview. They are excerpts from the CBD documents and the online discussion forum given in Supplementary Material S.6.1 that are partly paraphrased.

A GMBSM might apply to genetic resources, traditional knowledge associated with genetic resources, or both,

- that exist in more than one country.

- that are shared by countries which have no specific cooperation agreement.

- that belong to migratory species (air, land, and water; including genetic resources of species which are migratory from the national jurisdiction to outside).

- that are 'outside national jurisdiction'
  - the high seas and the deep seabed
  - the Antarctica
  - all areas outside national jurisdiction

- that can be obtained without any physical access (e.g. from databases, gene banks).

- for which it is not possible to obtain *'Prior Informed Consent'* (PIC) because the country of origin has decided not to establish access requirements.
- for which it is not possible to obtain PIC because the country of origin does not have an operational *'Access and Benefit-Sharing'* (ABS) system (lack of capacity, or no priority, no consensus with indigenous communities).
- for which it is not practical to grant or obtain PIC (e.g. PIC not available within a reasonable time span; political difficulties involved in granting a PIC; no consensus with indigenous communities).
- whose biological source is unknown (lack of documentation or lack of scientific knowledge).
- that exist in *ex-situ* collections where the country of origin is unknown.
- for which the origin is unknown (situations where resource has been taken without any PIC by another agent and the exact origin cannot be traced; or resources that were taken out illegally; traditional knowledge associated with genetic resources that is in public domain).
- for which there are no legal obligations to share benefits but users choose to do so voluntarily.
- from countries which have designated that the benefits from the utilization of genetic resources and/or traditional knowledge associated with genetic resources go to the multilateral mechanism.
- that were taken out from countries of origin prior to the *'Convention on Biological Diversity'* (CBD).
- that were taken out from countries of origin after the entry into force of the CBD, but prior to the Nagoya Protocol.
- that were first 'accessed' in the biological material after the entry into force of the Nagoya Protocol, but the biological material had been acquired before its entry into force.
- that were acquired and accessed in the biological material before the entry into force of the Nagoya Protocol, but generate new benefits from prior or ongoing uses of the resource.
- that were acquired and accessed in the biological material before the entry into force of the Nagoya Protocol, but generate new benefits from new uses of the resource.
- for which there is a change of intended use.
- that are transferred to third parties.

- that are used for basic research and generate benefits from basic research.
- that are used in a very large quantity at the same time for explorative research with R&D aim, but which are not used or only used peripherally in the final product.
- Plant genetic resources taken under the Annex 1 of the *'International Treaty on Plant Genetic Resources for Food and Agriculture'* (ITPGRFA) but used for non-food or non-feed purposes.
- Access to microorganisms (situations where they occur globally; where collected samples contain millions of cells of unknown species).
- Access to genetic resources of pathogens.

S.6.4 Topic guideline for the expert interviews

Refer to Supplementary Material S.4.1.

Bibliography

Weikard, H.-P. (2009). Cartel stability under an optimal sharing rule. *The Manchester School 77*(5), 575–593.