ISA TECHNICAL STUDY NO. 31

Equitable sharing of financial and other economic benefits from deep-seabed mining

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ACRONYMS AND ABBREVIATIONS

ABNJ	areas beyond national jurisdiction
SWF	Social Welfare Function
APG	Asia-Pacific Group
CHM	common heritage of mankind
CS	continental shelf
CTP	Contractor Training Programme
DSM	deep-sea mining
ECF	Environmental Compensation Fund
EDE	equally distributed equivalent
EEG	Eastern European Group
EEZ	exclusive economic zone
EFMSR	Endowment Fund for Marine Scientific Research
EO	Executive Office
GCF	Green Climate Fund
GDP	gross domestic product
GEF	Global Environment Facility
GNI	gross national income
GRULAC	Latin American and Caribbean Group
ICCAT	International Commission for the Conservation of Atlantic Tunas
IOC-UNESCO	Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization
ISA	International Seabed Authority
JTRC	ISA-China Joint Training and Research Centre
LLDC	landlocked developing country
MB	management board
MSR	marine scientific research
MSWWs	marginal social welfare weights
PPP	purchasing power parity
P-SIDS	Pacific Small Island Developing State
SDG	Sustainable Development Goal
SIDS	Small Island Developing State
SSF	Seabed Sustainability Fund
UN	United Nations
UNCLOS	Convention on the Law of the Sea
UNEP	United Nations Environment Programme
UNGA	United Nations General Assembly
WEOG	Western European and Other Group

PREFACE BY THE SECRETARY-GENERAL

This is without doubt one of the most important technical studies that the International Seabed Authority will have produced in the twenty-six years of its existence. Equitable sharing of the financial and other economic benefits from activities in the Area is fundamental to the legal regime created by part XI of the United Nations Convention on the Law of the Sea. The principles that exploitation of the mineral resources of the deep seabed should be carried out for the benefit of all humanity and that the proceeds from such exploitation should be shared on the basis of equity were recognized from the beginning of discussions in the Sea-Bed Committee in the United Nations. These principles were also recognized in the 1970 Declaration of Principles Governing the Seabed and Ocean Floor, and the Subsoil Thereof, Beyond the Limits of National Jurisdiction.

Although the principle of equitable benefit-sharing was broadly agreed upon, the detailed mechanics of the issue did not receive significant attention during the Third United Nations Conference on the Law of the Sea. The issue was not addressed further, either during the Preparatory Committee from 1984 to 1994 nor in the early years of the Authority. This meant that there was a lack of published source material on the topic, with the only official document being a report of the Secretary-General of the United Nations, issued in 1971 for the Committee on the Peaceful Uses of the Seabed and the Ocean Floor beyond the Limits of National Jurisdiction, on the possible methods and criteria for the sharing by the international community of proceeds and other benefits derived from the exploitation of the resources of the Area beyond the limits of national jurisdiction.

This technical study is the result of more than two years of work, performed under the supervision of the Finance Committee of the Authority. Whilst the 1971 report provides a starting point for the study, and indeed was far ahead of its time in providing a basis for a conceptual approach to the problem, we also took the opportunity to go back to fundamental principles and address the issue through a conceptual lens of equity and applied economic theory. The result is, I believe, a major contribution to the literature on how principles of equity and fair division can be used to define process and distributive justice. The study sets out alternative cardinal, fair and equitable sharing rules for royalties from deep-seabed mining using different ethical principles and formulae that balance individual and State interests, including equal division among States and Aristotle's Equity Principle. It demonstrates that evaluating estimated shares for distributive justice using alternative relative inequality metrics provides a superior formula that also maximizes social welfare. As well as being an important contribution to the literature relating to common heritage of mankind, the approach furnishes a design template for other non-market allocations made through global collective action requiring justice in process and distribution, including sharing vaccines, celestial

resources, climate change mitigation impacts, rain forest conservation or allocating high-seas fishing opportunities.

The present publication is a consolidation of three separate draft reports prepared for the Finance Committee in 2019, 2020 and 2021, respectively. The lead authors for parts I, II, III, IV and VI of the study were Professor Dale Squires of the University of California, San Diego, and Michael Lodge. Part V was co-authored by Stefaan Depypere and Heleen Raat, of SDP Consult, Belgium. The initial reports were very much improved by the comments and suggestions of members of the Finance Committee, and I wish to take this opportunity to thank the members of the Finance Committee for their support for this work. Their inputs, ideas and suggestions, individually and collectively, helped to enrich the study and led to many new avenues to explore. I particularly wish to acknowledge the contribution of Mr. Reinaldo Storani, member of the Finance Committee from Brazil, who sadly passed away before this report could be finalized. I remember Reinaldo's contribution to this discussion, his perceptive comments and his innovative ideas and suggestions.

In studying this issue, the seminal works of H. Peyton Young and Hervé Moulin (cited in the bibliography) were particularly influential and are highly recommended for further reading. Over the course of two years, many other individuals contributed to the work by making comments, suggestions and criticisms, and particular thanks are due to Ben Groom (University of Exeter, UK), Kathleen Segerson (University of Connecticut, USA), Quentin Grafton (Australian National University), Cameron Hepburn and Rick van der Ploeg (Oxford University, UK), Richard Carson (University of California, San Diego, USA), Gabe Englander (now at the World Bank) and Jeff Schraeder (Columbia University, USA). Their expert criticisms of the methodology used in the study were invaluable, but they share no responsibility for the ultimate outcome. Special thanks also to Zack Turk, who compiled the web-based model of the equitable distribution formulae and to Esam Alnour, who provided the underlying web programming.

Michael W. Lodge
Secretary-General
International Seabed Authority

FOREWORD BY THE CHAIR OF THE FINANCE COMMITTEE

On behalf of the membership of the Finance Committee, I welcome the publication of this ISA Technical Study on the Equitable Sharing of the Financial and other Economic Benefits from Activities in the Area. The Committee has spent more than two years studying this important issue, mindful of the fact that pursuant to the 1994 Agreement for the Implementation of Part XI of the United Nations Convention on the Law of the Sea, it will be the task of the Committee to formulate rules, regulations and procedures on the equitable sharing of financial and other economic benefits derived from activities in the Area.

Following its consideration of the matter, the Finance Committee delivered a report to the Council and Assembly summarizing its preliminary findings and suggestions (ISBA/26/A/24-ISBA/26/C/39). This Technical Study provides all stakeholders with access to the extensive reports and analyses that were provided to, and requested by, the Committee during its deliberations. I believe this will facilitate a deeper understanding of the complexity of the issues involved and provide greater transparency and insight into the thought processes of the Committee as it formulated its recommendations to the Council and Assembly.

I wish to take this opportunity to thank the Secretary-General and staff of the ISA Secretariat for their efforts in providing the Committee with timely, comprehensive and high-quality responses to our requests for information. I also thank the expert consultants who were commissioned to prepare reports and who were able to respond to the many questions and suggestions raised by the Committee.

Most of all, I wish to acknowledge the contributions of all colleagues who served on the Committee since we first took up this agenda item in 2018. It was a challenging task, but all members provided important input and contributed to the discussion. I believe the report of the Finance Committee on this matter will move the discussion of this issue forward.

Finally, I wish to join the Secretary-General in paying tribute to our dear colleague, Mr Reinaldo Storani of Brazil, who sadly passed away before our work on this issue was concluded. Reinaldo made a major contribution to the work of the Finance Committee and we were all greatly saddened by his passing.

Andrzej Przybycin
Chair, Finance Committee
Warsaw, Poland, August 2021

EXECUTIVE SUMMARY

The present report reviews potential methodologies for the implementation of the stipulation in the United Nations Convention on the Law of the Sea (the Convention) relating to the equitable sharing of the financial and other economic benefits derived from deep-seabed mining.

The report begins with a review of the relevant provisions of the Convention and the general principles and objectives to be achieved through equitable sharing. Reference is made to the differences between monetary and non-monetary benefit sharing and there is a discussion of the hierarchy of distribution required by the Convention, including allocations to the economic assistance fund under Article 151(10) of the Convention.

Following a discussion of the conceptual basis of equity, founded in a literature survey, the report presents and evaluates, according to widely accepted measures of relative inequality and global social welfare, three alternative formulae for the fair and equitable allocation of a given sum of royalties available for distribution. It concludes that any of the three formulae could be applied, but that one formula (the geometric mean) provides superior outcomes according to ex-post and ex-ante evaluations. Empirical results are provided to support the conclusion. In addition to providing a complete statistical analysis, appendices also explain the theoretical basis for the application of a social welfare function to determine equity.

Without prejudice to the discussion of a formula for equitable sharing, the report presents the concept of a Seabed Sustainability Fund as an alternative or supplemental approach. Such a global fund could be used to support global public goods, investment in human and physical capital or deep-sea research and conservation. By supporting and enhancing knowledge of the deep-sea, which is a global public good, such a fund could operationalize the concept of the common heritage of humankind. The theoretical basis for such a qualitative distribution is outlined and practical issues associated with its implementation are reviewed.

Finally, the report considers the problem of revenue-sharing pursuant to Article 82(4) of the Convention in relation to the continental shelf beyond 200 nautical miles from the baseline. It finds that the same formula designed for distribution of royalties from mining in the Area could be utilized for this purpose. The differing distribution priorities reflected in Article 82(4) (which gives preference to least developed and landlocked States, and thus implies a remedial rationale based on geography and socio-economics) can be accommodated through adjustments to the social welfare function reflected in the relevant formula.

Alongside the publication of this report, a web-based model has been published by the International Seabed Authority which enables the user to review and evaluate the impact of alternative formulae and scenarios for fair and equitable distribution of a notional sum of royalties.

PART I: INTRODUCTION

At its twenty-third session in 2018, the Finance Committee of the International Seabed Authority (ISA) discussed the impact that the preparation of draft regulations on the exploitation of mineral resources in the Area of the seabed beyond national jurisdiction (referred to hereafter as "the Area") might have on its work plan. The Committee identified several areas that required its input, including the formulation of rules, regulations and procedures on the equitable sharing of financial and other economic benefits derived from activities in the Area (referred to hereafter as "equitable sharing") as required by article 160(f)(i) of the UN Convention on the Law of the Sea (UNCLOS).[1]

The Committee noted that the limited existing literature concerning the issue of equitable sharing included a report of the Secretary-General of the United Nations, issued in 1971 for the Committee on the Peaceful Uses of the Seabed and the Ocean Floor beyond the Limits of National Jurisdiction, on the possible methods and criteria for the sharing by the international community of proceeds and other benefits derived from the exploitation of the resources of the Area beyond the limits of national jurisdiction.[2] Although the principle of equitable benefit-sharing was broadly agreed upon, the detailed mechanics of the issue did not receive significant attention during the Third United Nations Conference on the Law of the Sea.

The 1971 report addressed the development of equitable sharing criteria and was aimed at providing the basis for a conceptual approach. It included the following list of non-financial benefits: expansion of world mineral resources, orderly development of resources, protection of the marine environment, enlarging the number of nationals with seabed technical competence, increasing the knowledge of the marine environment and seabed area, stability of raw material markets and preferential access to raw material for less developed countries. Financial benefits, on the other hand, were found to consist of the balance remaining after deduction of the expenditure from the revenues of the international machinery to be established (personnel, supplies, training, research, etc.). The report also contained a list of alternative criteria for the distribution of benefits, which were classified into two categories: direct distribution to governments, and allocation to programmes of particular interest to developing countries. According to the report, before net proceeds reached a sufficiently large volume, direct distribution to all governments might lead to a fragmentation of financial resources, which would result in benefits of modest significance to the receiving countries.

[1] United Nations Convention on the Law of the Sea, 10 December 1982, 1833 UNTS 397.
[2] United Nations, "Possible Methods and Criteria for the Sharing by the International Community of Proceeds and Other Benefits Derived from the Exploitation of the Resources of the Area Beyond the Limits of National Jurisdiction", United Nations General Assembly, Committee on the Peaceful Uses of the Sea-bed and the Ocean Floor Beyond the Limits of National Jurisdiction, A/AC.138/38 and A/AC.138/38/Corr.1., mimeo, 1971.

During that initial period, there might be some advantages to concentrating available proceeds in programmes of high priority, such as the promotion of development in least developed countries.[3]

The Finance Committee requested the Secretary-General to prepare a report for the twenty-fourth session to assist the Committee in its consideration of the question of equitable sharing. In his report,[4] the Secretary-General identified key elements requiring interpretation and elaboration and made suggestions as to how the Committee might conduct the development of rules, regulations and procedures in parallel with the development by the Legal and Technical Commission of the regulations on the exploitation of mineral resources in the Area. The Committee took note of the report and requested the Secretary-General to prepare a technical study including suggested sharing criteria for consideration at the twenty-fifth session (2019). The Committee also noted the importance of advancing the implementation of Article 82(4) of UNCLOS, which refers to equitable sharing of payments and contributions derived from the exploitation of resources on the continental shelf beyond 200 nautical miles, in parallel, while avoiding duplication of work.

In response to the request made by the Committee, a report on criteria for the equitable sharing of financial and other economic benefits derived from deep-seabed mining was prepared, with the assistance of a consultant.[5] The Committee considered the report, including in a joint meeting with the Legal and Technical Commission held on 9 July 2019, and reported on its discussions to the ISA Council and Assembly at the twenty-fifth session. Based on the questions raised by the Committee and the additional issues identified, a supplementary report was prepared, with the assistance of a consultant, for the consideration of the Committee at the twenty-sixth session (2020). The supplementary report presented and evaluated, according to widely accepted measures of relative inequality and global social welfare, three alternative formulae for the fair and equitable allocation of a given sum of royalties available for distribution. The Committee also requested, and was provided with, a web-based model to enable it to visualize and compare the impact of each formula on any member of the Authority under the different scenarios.[6] These reports were considered further by the Committee during its 2020 meetings.

Without prejudice to its discussion of a formula for equitable distribution, the Committee also considered whether an alternative or supplemental approach might be the establishment of a global fund that could be used to support global public goods, investment in human and physical capital or deep-sea research and conservation. Such a fund could support and enhance knowledge about the deep sea, which is a global public good, and accordingly constitute a means to operationalize the concept of the common heritage of mankind. Such knowledge includes, for example, scientific knowledge about the marine environment of the Area, capacity-building for integrated participation of developing states in the work of the Authority and for the sustainable development of deep-seabed mining (such as enlarging the number of nationals with seabed technical competence), and research and

[3] A/AC.138/38, para. 47.
[4] ISBA/24/FC/4.
[5] Professor Dale Squires, University of California, San Diego.
[6] These are discussed in detail in parts III and IV below.

development of new technology that minimizes the environmental impact of deep-seabed mining.

A suggestion was also made that the fund could also support the establishment of regional marine scientific and technological centres. The Committee took note of the discussions in the Council during the first part of the twenty-sixth session (2020), during which delegations had emphasized the need to consider a fund dedicated to environmental research and training, which should be separate from the proposed environmental compensation fund, and noted that a number of proposals had been made to broaden the reach of such a fund to cover, for example, research to generate information for the review of regional environmental management plans.

Without reaching any decision, and without prejudice to its overall discussion on the issue of equitable sharing, the Committee requested the secretariat to provide it with a report further developing the concept of a global fund. In response to this request, the secretariat, with the assistance of a consultant,[7] prepared in 2021 a report on the structure and purpose of a "Seabed Sustainability Fund", which was considered by the Committee at its resumed meetings during the twenty-sixth session.

The present Technical Study is a consolidated version of the reports prepared for the Finance Committee in 2019, 2020 and 2021. It is organized as follows: Following this introduction, Part II reviews the applicable legal provisions relating to equitable distribution and the treatment of revenue received by ISA in light of stipulations contained in UNCLOS and the Agreement relating to the Implementation of part XI of the United Nations Convention on the Law of the Sea of 10 December 1982 ("the 1994 Agreement").[8] Part III discusses the theoretical importance of equity as a conceptual basis for benefit-sharing. Part IV introduces alternative approaches to the development of equitable sharing criteria, combining for this purpose the findings of the 2019 report and the 2020 report. Part V introduces the concept of the Seabed Sustainability Fund. Part VI discusses how the conceptual basis for equitable sharing of benefits from deep-sea mining (DSM) in the Area could be applied to distributions under Article 82(4) of UNCLOS in relation to payments made in respect of exploitation of non-living resources on the continental shelf beyond 200 nautical miles.

[7] SDP-Consult (De Pinte, Belgium).
[8] Agreement Relating to the Implementation of Part XI of the United Nations Convention on the Law of the Sea of 10 December 1982, July 28, 1994, 1836 UNTS 3.

PART II: APPLICABLE LEGAL PROVISIONS AND GENERAL PRINCIPLES

Provisions concerning the equitable sharing of benefits from activities in the Area are found in articles 140(2), 155(1)(f), 160(2)(f)(i) and (g), and 162(2)(o)(i) of UNCLOS and in section 9(7)(f) of the annex to the 1994 Agreement. Relevant provisions also appear in articles 171 and 173(2). Article 140, which belongs to section 2 (Principles governing the Area) of part XI, reads as follows:

Benefit of mankind

1. Activities in the Area shall, as specifically provided for in [part XI], be carried out for the benefit of mankind as a whole, irrespective of the geographical location of States, whether coastal or landlocked, and taking into particular consideration the interests and needs of developing States and of peoples who have not attained full independence or other self-governing status recognized by the United Nations in accordance with General Assembly resolution 1514 (XV) and other relevant General Assembly resolutions.

2. The Authority shall provide for the equitable sharing of financial and other economic benefits derived from activities in the Area through any appropriate mechanism, on a non-discriminatory basis, in accordance with article 160, paragraph 2(f)(i).

Article 160(2)(f)(i) provides that it is the Assembly that ultimately must consider and approve, upon the recommendation of the Council, the rules, regulations and procedures on the equitable sharing of financial and other economic benefits derived from activities in the Area and the payments and contributions made pursuant to Article 82(4), taking into particular consideration the interests and needs of developing States and peoples that have not attained full independence or other self-governing status. If the Assembly does not approve the recommendations of the Council, it is to return them to the Council for reconsideration in light of the views expressed by the Assembly.

The 1994 Agreement, however, also provides that decisions of the Assembly and the Council on the issue of the rules, regulations and procedures on the equitable sharing of financial and other economic benefits derived from activities in the Area and the decisions to be made thereon are to take into account recommendations of the Finance Committee.[9] The primary responsibility for drafting these rules and procedures therefore rests with the Finance Committee.

Whilst the 1994 Agreement does not explicitly refer to equitable sharing under Article 82(4), the similarities between articles 140 and 82(4) suggest that it would be efficient for the Finance Committee

[9] 1994 Agreement, Annex, sect. 9, para. 7(f).

to consider equitable sharing under Article 82(4) in parallel. It must be borne in mind, however, that the funds received under articles 140 and 82(4) must be kept separate and that the classes of beneficiaries under each article may be different. These similarities and differences are explored further in parts III and VII below.

Non-monetary benefit-sharing

Although the present study focuses on the distribution of financial benefits from DSM (referred to as "other economic benefits"), it is important to bear in mind that UNCLOS, and Article 140 in particular, give equal weight to non-monetary benefit-sharing as a means of giving effect to the overall objective of "benefit of mankind".

There is no limit to the category of non-monetary benefits, and it is not possible to quantify all these benefits as they may change over time. For example, the mere fact that UNCLOS establishes a legal regime for the Area that limits access to resources and prevents unrestrained exploitation is itself a benefit to mankind. This is implicit in the 1970 Declaration of Principles Governing the Seabed and the Ocean Floor, and the Subsoil Thereof, beyond the Limits of National Jurisdiction,[10] which called for the establishment of an international regime to "provide for the orderly and safe development and rational management of the Area and its resources". The purpose of the international regime is to create and enforce a set of rules and standards governing deep-sea mining and related activities, including marine scientific research in the Area, that balances the need for resource extraction with the preservation of the marine environment.

Several of the non-monetary benefits that flow from the international regime for the Area are identified in article 150 of UNCLOS, which sets out the policies relating to activities in the Area as follows:

> *(a) the development of the resources of the Area;*
>
> *(b) orderly, safe and rational management of the resources of the Area, including the efficient conduct of activities in the Area and, in accordance with sound principles of conservation, the avoidance of unnecessary waste;*
>
> *(c) the expansion of opportunities for participation in such activities consistent in particular with articles 144 and 148;*
>
> *(e) increased availability of the minerals derived from the Area as needed in conjunction with minerals derived from other sources, to ensure supplies to consumers of such minerals;*
>
> *(f) the promotion of just and stable prices remunerative to producers and fair to consumers for minerals derived both from the Area and from other sources, and the promotion of long-term equilibrium between supply and demand;*
>
> *(g) the enhancement of opportunities for all States parties, irrespective of their social and economic systems or geographical location, to participate in the development of the resources of the Area and the prevention of monopolization of activities in the Area;*
>
> *(i) the development of the common heritage for the benefit of mankind.*

[10] General Assembly resolution 2749 (XXV).

To this list may be added the following non-monetary benefits:

(a) Protection of the marine environment through the rules, regulations and procedures of the Authority.

(b) Capacity-building, mandatory in the case of the training programmes required of contractors and developed through international cooperation in the case of programmes developed through the Authority.

(c) Increased knowledge of the marine environment and deep seabed. This includes increased scientific knowledge made available through the Authority as a result of exploration activities, as well as international cooperation in marine science and the results of marine scientific research in the Area carried out pursuant to articles 143 and 144 of UNCLOS.

(d) Increased availability of marine technology.

Priority allocation of funds received by ISA

All amounts received by ISA in connection with activities in the Area are treated as "funds of the Authority" pursuant to article 171 of UNCLOS. Notwithstanding the reference to equitable sharing in Article 140, the allocation of these funds is specified in article 173(2) as follows:

2. The administrative expenses of the Authority shall be a first call upon the funds of the Authority. Except for the assessed contributions referred to in article 171, subparagraph (a), the funds which remain after payment of administrative expenses may, inter alia:

(a) be shared in accordance with Article 140 and article 160, paragraph 2(g);

(b) be used to provide the Enterprise with funds in accordance with article 170, paragraph 4;

(c) be used to compensate developing States in accordance with article 151, paragraph 10, and article 160, paragraph 2(l).

Despite the fact that the reference to "sharing" appears in subparagraph (a), the language of article 173(2) implies that what will be available to be shared are the net funds remaining after payment of the administrative expenses of ISA, and the items specified in subparagraphs (b) and (c). These "deductions" from gross revenue received are discussed below.

Administrative expenses

The administrative expenses of ISA shall be a first call upon the funds of ISA. At present these expenses are funded by assessed contributions from Member States, determined according to the scale used for the regular budget of the United Nations, adjusted for differences in membership. Over time, as revenue from DSM increases, assessed contributions will theoretically reduce, although this reduction may be temporarily offset by increased demand for budgetary resources.[11] The current budget of ISA is approximately US$10 million per annum, but it can be anticipated that this will increase as DSM activity increases and there is a need to fund additional

[11] The situation may be envisaged where the need for ISA to increase its regulatory capacity will temporarily outstrip the income immediately available from DSM. This may result in temporarily increased Member State contributions, or a period where ISA requires a combination of Member State contributions and DSM revenue.

programmes including, for example, an inspection and monitoring programme. These programmes are likely to be needed before commercial mining begins and revenue starts to flow to ISA. It will therefore be important to understand what a "future ISA" would look like, exercising its full regulatory powers.[12]

It is also important to note that there will be an administrative cost to managing the funds received under articles 140 and 82(4), especially in terms of establishing a separate financial unit within the secretariat for this purpose. In terms of evaluating ISA's administrative costs for providing this service, one option could be to continue the current budgetary process, whereby an administrative budget is determined for a two-year financial period based on estimations provided by the Secretary-General.

Another option could be to take a fixed percentage of revenue from Article 140 funds, to allow for future programme growth and inflation (measured by GDP implicit price deflator, since the ISA budget is in US dollars). Whilst this would promote growth in programmes, the drawback of this methodology is that as revenues grow, the amount deducted as a percentage would grow to an unacceptable amount. With respect to funds received pursuant to Article 82(4), the principle is clear that funds "pass through" ISA and may not be used to support the regular budget. Nevertheless, the Authority will incur administrative costs in collecting payments and contributions and then distributing them in a timely and efficient manner to States parties. The establishment of such a mechanism may entail additional costs which should be recovered from the amounts collected. Whether this would be on a strict cost recovery basis, or through an agreed percentage overhead charge, will need to be considered.

As revenues from Article 140 grow, one question that might arise is whether the costs of participation of some of the developing States in the activities of ISA, and specifically the regular sessions of the Council and the Assembly, should be supported from the regular budget. The same consideration applies to the costs of supporting the participation of members of the Legal and Technical Commission, Economic Planning Commission and Finance Committee from developing countries in the meetings of those bodies. These costs are currently met in part by voluntary trust funds. The question would need to be considered whether such costs would be considered part of the administrative costs of ISA, and therefore factored into the budget, or whether they would be considered as part of the equitable distribution to developing countries.

One option that may be considered in this respect is the mechanism adopted in the case of the U.S. Tuna Treaty with the Pacific Island States, whereby a fixed percentage of the revenue accruing under the treaty is deposited into a Project Development Fund and held in equal shares for each developing State. The Fund is held by the administering authority, but each beneficiary can choose how to use the credit in the Fund, whether to support attendance at meetings or for other developmental purposes.[13]

[12] A report prepared for the Finance Committee in 2021 addresses the problem of the "funding gap" in the time between the submission of the first plan of work for exploitation and the start of commercial mining. ISBA/26/FC/8.

[13] Multilateral Treaty on Fisheries between the Governments of Certain Pacific Island States and the Government of the United States of America, done at Port Moresby, 2 April 1987. Under the treaty, 15 per cent of the revenue is to be deposited into a Project Development Fund, shared equally between the parties. The remaining 85 per cent of revenue is distributed according to catch.

Funds allocated to the Enterprise

Although article 173 stipulates that the funds of ISA may be used to provide the Enterprise with funds in accordance with article 170(4), the application of this provision was significantly adjusted by the 1994 Agreement. That Agreement provides (annex, section 2(3)) that States parties shall be under no obligation to finance any of the operations in any mine site of the Enterprise or under its joint venture arrangements and that the provisions of article 170 shall be interpreted accordingly. In particular, the obligation of States parties to fund one mine of the Enterprise (previously contained in annex IV, article 11 of UNCLOS) has been removed. Considering these provisions, it is assumed that no funds would be allocated to the Enterprise pursuant to article 173. The possibility of using the Seabed Sustainability Fund as a vehicle for co-financing or investing in the Enterprise is discussed in Part V below (page 63).

Economic assistance fund under article 151(10)

Article 151(10) of UNCLOS establishes the principle that the Assembly shall establish a system of compensation or take other measures of economic adjustment assistance, including cooperation with specialized agencies and other international organizations to assist developing countries which suffer serious adverse effects on their export earnings or economies resulting from a reduction in the price of an affected mineral or in the volume of exports of that mineral, to the extent that such reduction is caused by activities in the Area. Such a system is to be established by the Assembly upon the recommendation of the Council, based on advice from the Economic Planning Commission.

The 1994 Agreement made several important modifications to the implementation of this provision. First, it provided that the functions of the Economic Planning Commission are to be carried out by the Legal and Technical Commission until such time as the Council decides otherwise, or until the approval of the first plan of work for exploitation. Second, the implementation of article 151(10) is further qualified by section 7 of the 1994 Agreement, which provides that the policy of ISA in relation to assisting developing countries which suffer serious adverse effects on their export earnings or economies shall be based on several stated principles. These include that the form of assistance to be provided under article 151(10) shall be through an economic assistance fund created from a portion of ISA's funds exceeding those necessary to cover the administrative expenses of ISA. The amount of the fund is to be determined by the Council, based on a recommendation of the Finance Committee. Only funds from payments received from contractors, including the Enterprise, and voluntary contributions shall be used for this purpose. All related provisions of UNCLOS are to be interpreted accordingly.

The amount that will need to be allocated to the Economic Assistance Fund is likely to vary from year to year, depending upon the amount of production from the Area. For the purposes of the present Study, it is sufficient to note that a certain proportion of the gross revenue from DSM will need to be allocated to the Economic Assistance Fund prior to any further distribution to States parties. In 2019 the secretariat, at the request of the Legal and Technical Commission, in its capacity of performing the functions of the Economic Planning Commission, produced a study of the potential impact of mineral production from the Area on the economies of developing land-based producers of those minerals which are likely to be most

seriously affected.[14] The Commission has also recommended the establishment of the Economic Planning Commission, which would be responsible to consider how disbursements from the Economic Assistance Fund would be managed.[15]

Repayment of Member State contributions

Although not specifically referenced in article 173, there is an argument that the logical consequence of transferring the burden of financing ISA from Member States to revenue from DSM is that equity requires that prior contributions by Member States be repaid before any distribution of net revenue. The clear intention of UNCLOS is that ISA should be self-financing, out of revenue derived from DSM, but the fact is that Member States have borne the burden of financing the initial operations of ISA since 1998.[16] The prolonged delay in DSM has also meant that the burden of financing the operations of ISA has fallen disproportionately on those who ratified UNCLOS and became members of ISA earliest. Between 1998 and 2020, total assessed contributions by Member States amounted to US$144 million.[17] Whether this amount should be refunded in full prior to any distribution of excess funds, or whether it may be refunded progressively, is a matter which will need to be considered further.

Without such a mechanism for refunding prior investments by States, it may be argued that those States that join UNCLOS only after revenue from DSM replaces assessed contributions as the source of funds for ISA could be considered as free riders, who would have benefited unfairly from such advantage.

The objectives of Article 140 distributions

Article 140 derives from the Declaration of Principles Governing the Seabed and the Ocean Floor, and the Subsoil Thereof, beyond the Limits of National Jurisdiction of 1970.[18] It provides that DSM must be carried out for the benefit of mankind as a whole, irrespective of the geographical location of States, whether coastal or landlocked. This implies a joint ownership rationale for equitable sharing. Article 140 also requires ISA to take into particular consideration the interests and needs of developing States and of peoples who have not attained full independence or other self-governing status, implying an income redistribution rationale as well.

UNCLOS provides different guidance in different places regarding prioritization in the implementation of these two rationales. Thus, article 162(2)(o)(i) refers to the need to give particular consideration to the interests and needs of developing States and of peoples who have not attained full independence or other self-governing status but does not make any separate reference to landlocked States. In this regard, it can be distinguished from Article 82(4), which indicates different priorities in relation to the payments and contributions

[14] ISA, Study of the Potential Impact of Polymetallic Nodules Production from the Area on the Economies of Developing Land-based Producers of those Metals which are Likely to be Most Seriously Affected (2020) https://www.isa.org.jm/files/documents/impactstudy.pdf.
[15] See Report of the Chair of the Legal and Technical Commission on the Work of the Commission at the second part of its twenty-sixth session, ISBA/26/C/12/Add.1, para. 19.
[16] ISA was established in 1994, but its initial budget was financed from the regular budget of the United Nations, and it was not until 1998 that Member States were required to contribute to the first autonomous budget.
[17] This represents the total of assessed contributions up to and including 2020. Unpaid contributions up to December 2019 total US$1 million, including six members that have made no payments since they became States parties. The corollary of the argument presented here is that unpaid prior contributions should be recovered in full from members before they can be eligible to receive any distribution.
[18] General Assembly resolution 2749 (XXV).

made by coastal States in respect of the exploitation of non-living resources on the continental shelf beyond 200 nautical miles.[19] These priorities are discussed further in Part VI below.

The text of UNCLOS suffers from considerable ambiguity. For example, what are "interests and needs", and how are they to be assessed and measured? Does the language of "taking into account" imply a preferential consideration for such States? How should the reference to "States parties" in Article 82(4) be reconciled with the generic reference to "States" in articles 140 and 162(2)(o)(i)? Overall, it seems reasonable to assume that although the objectives of both Article 82(4) and Article 140 include distributive justice or "correction of inequalities", the remedial rationale is not the same. In the case of Article 140 and associated provisions in part XI, the remedial effect is broadly socio-economic, geographical and political. In the case of Article 82(4), the remedial effect is geographic and socio-economic, hence the highlighting of the needs and interests of landlocked States, which have no entitlement to a continental shelf.

A particular difficulty with the development of equitable sharing criteria under Article 140 will be how to recognize the interests and needs of peoples who have not attained full independence or other self-governing status. Article 140 contains a specific reference to the Declaration on the Granting of Independence to Colonial Countries and People of 1960,[20] but the political situation now is completely different from the situation when UNCLOS was adopted in 1982. Membership of ISA is confined to States parties to UNCLOS, and there is no provision for participation by non-independent territories or indigenous peoples who might be considered beneficiaries under this provision. One way to understand this provision might be to infer from it some preference within the overall distributional hierarchy for States parties that have relevant non-self-governing territories, or indigenous peoples. Even then, however, it is difficult to see how ISA could, practically, ensure that benefits are directed to the ultimate beneficiaries.

Developing a hierarchy of needs

Beyond establishing basic principles for implementing the somewhat ambiguous guidance regarding the target beneficiaries discussed above, ISA will also need to develop more specific principles and associated metrics for conceptualizing a hierarchy of needs and equitable shares. Metrics based on population and per capita income, such as those used to determine United Nations budget contributions, could be used.[21] Alternatively, priorities could be based on a composite index combining various well-known and generally accepted development indicators and statistics. These might include, for example, the Human Development Index maintained by the United Nations Development Programme and the World Development Indicators developed by the World Bank. These issues are developed further in parts III and IV below.

Regardless of the metrics used, some provision for changes, over time, will be needed. For example, as States develop and economies grow, redistributive priorities can be expected to change as well. As exploitation of deep-sea minerals is expected to occur over a period of decades, if not longer, any approach used to define

[19] Under Article 82(4), the equitable sharing criteria to be developed must take into account the interests and needs of developing States, but particularly "the least developed and land-locked among them".
[20] General Assembly resolution 1514 (XV).
[21] A/AC.138/38 (*supra* note 2) provides some illustrative examples of ways for defining shares based on population but adjusted for per capita income (to favour developing countries).

priorities for the distribution of resource rents must factor in the potential for future economic growth within individual States and across the world. However, changes in redistributive priorities or rules, over time, can create greater uncertainty about future revenue streams for individual States. To the extent that States make investments or spending plans based on announced rules for redistribution of resource rents, any changes in those rules, as a result of changes in redistributive priorities, can undermine the ability of States to plan and meet commitments that rely on anticipated receipts of resource rents.

Intergenerational equity

In designing equitable sharing rules, ISA will need to determine both the rate at which exploitation of the Area will be allowed and the way in which the proceeds from exploitation will be shared between current and future consumption. As with intra-temporal sharing, the equitable sharing of the benefits from extraction across generations can be based on either the principle of shared ownership or on an implicit or explicit income or wealth redistribution goal, or both. In general, societal decisions about how to allocate resources across generations reflect some implied principle of justice embodied in an inter-temporal social welfare function that assigns weights to the well-being of different generations, where those weights reflect an implicit "utility-based" social discount rate. However, even with equal utility-based weights across all generations, society may choose to weight consumption differently for different generations based on differences in income or wealth.

If future generations are likely to be wealthier (due to technological advances and economic growth), then a progressive approach to intergenerational allocation would assign greater weight to consumption by current generations because they are less well off than future generations. Conversely, if future generations are likely to be poorer than current generations (for example, due to resource degradation), then a progressive approach would put more weight on consumption by future generations by, for example, placing greater weight on investment in physical, human or natural capital that leads to higher future consumption when evaluating policy options. Neither UNCLOS nor the 1994 Agreement provide any guidance on the appropriate allocation of DSM benefits across generations.

A global resource fund

One way to address inter-temporal concerns is through creation of a resource fund (like a sovereign wealth fund) for managing and distributing royalties from resource rents over time. Whereas some portion of the royalty revenue could be spent as it is collected, an appropriate share could be put into a fund that is invested in human, physical, financial and natural capital; the returns on that investment could then be used to finance consumption benefits (through the provision of goods and/or services) in the future. Such a fund could help smooth out the flow of disbursements, delink disbursements from the dynamics of resource revenue (such as price and revenue pro-cyclicality), help address uncertainty over the overall wealth to be shared, and contribute to macroeconomic stability, thereby providing a useful tool for macro-fiscal management. The goal is to increase current spending in a sustainable way while scaling up investment appropriately given capacity constraints, and to sustain the resulting higher public capital stock. Thus, long-run considerations – influenced by inter-temporal consumption/savings and investment decisions and inter-temporal equity decisions related to an exhaustible resource – need to be linked.

A resource fund of this type could provide a mechanism for handling appropriate intergenerational distribution of the resource rents collected by ISA. In this case, with appropriate restrictions on drawing down the fund's principal and limiting disbursements to the returns earned on that principal, the fund could provide a flow of benefits for generations after the cessation of DSM.

Alternative forms of distribution

Even if royalties from resource extraction are managed through some form of wealth fund and a long-term fiscal sustainability framework, ISA must still grapple with the means by which the money available to be spent at a given point in time will be distributed. At least three alternative approaches are possible: (i) distribute the money through cash payments to the appropriate States or claimants; (ii) use the money to fund projects designed to provide goods and services (such as sanitation and health care, housing, and food) to benefit current populations of those States; or (iii) use the money for investment in public goods such as human capital (through education) or physical capital (such as infrastructure) that will primarily benefit future generations. Again, UNCLOS provides no guidance on any choice among these alternatives, and therefore leaves ISA to make this determination.

One could argue that cash disbursement should be preferred because it would be both simpler for ISA to administer and would allow recipient States, acting on behalf of their populations, to use the money in the ways that they deemed to be most beneficial to their populations. However, there are at least three cogent arguments for funding projects rather than making cash disbursements.

First, there is no guarantee, for various reasons, that funds distributed to governments would be used for the benefit of their populations, as implied by the "benefit to mankind" mandate. Second, because ISA is an organization charged with managing returns from DSM for the benefit of mankind as a whole rather than for the benefit of individual States or governments, it should encourage uses of the money that generate the greatest good for mankind as a whole, for example, to invest in global public goods that are otherwise underprovided. This would include promoting uses that have the potential to benefit multiple States, and discouraging uses that have negative spillovers on, for example, other States, specific groups within a State (e.g., indigenous peoples) or future generations. Individual States that are free to make their own determinations about how any cash they received would be spent would likely not consider these positive or negative spillover effects, in current and/or future time periods, in making their spending decisions.

Third, especially in the early years when revenue available for disbursement is relatively low, the total amount allocated to each of the many individual claimant States is likely to be rather small and not sufficient for major initiatives that could have a significant beneficial impact on the population of an individual State, or projects that exhibit significant economies of scale (and would therefore benefit from large-scale production) or have high levels of uncertainty, such as projects related to deep-sea exploration.

Seabed sustainability fund as an alternative form of distribution

Global public goods that benefit all of humanity, such as adaptation or mitigation of climate change, scientific knowledge about new technology and the deep-sea ecosystem, or biodiversity conservation, are well known to be underprovided and would

therefore benefit from funding sourced from all humanity. An alternative form of distribution, which is discussed in Part VI below, could be a Seabed Sustainability Fund, administered by ISA. Such a fund would support and enhance knowledge about the deep sea, a global public good.

As marine scientific knowledge is a global public good, all peoples of the world benefit from the results (the non-excludability property of a public good) without reducing the benefits of others (the non-rivalry property of a public good). The global benefits satisfy Aristotle's equity or proportionality principle (Aristotle, 2009 1130b-1132b). Aristotle's principle states that a good should be distributed in proportion to the contribution (or claim) of each of the claimants. The claimants – in this case, the global population – have equal claims under UNCLOS and equally benefit from the increase in scientific knowledge, capacity building and research and development, and their contribution to the sustainable development and production of deep-seabed minerals enjoyed by the global population. Scientific knowledge about the technology of sustainable production yields clear benefits in terms of royalties. Better scientific knowledge about the deep-sea environment contributes to sustainable mining that minimizes the loss of any ecosystem services that result from deep-seabed mining and that may adversely impact the global population.

The risks of providing global public goods are minimized by spreading costs across humanity. Some provision of global public goods, notably climate change mitigation, may also be progressive in that lowest income populations gain but also are often most disproportionately impacted and least capable of adjusting to adverse climate impacts – a classic case in point may be Small Island Developing States (SIDS). By funding projects rather than making cash disbursements, ISA could overcome these limitations. In addition to funding projects designed primarily to benefit current populations, ISA could also fund projects that were designed primarily to generate benefits for future generations, thereby addressing inter-generational equity, such as investment in physical and human capital and research and development (e.g., of new technologies). Of course, the downside of funding projects rather than distributing cash is that ISA would need to develop mechanisms for choosing which projects to fund and for overseeing the projects to ensure that funds are spent appropriately and benefit the intended recipients. The selection of indivisible and heterogeneous projects can also be conducted using equity principles such as the priority principle (currently used for organ transplants). However, significant administrative costs and overheads could also be anticipated.

The following parts of this Technical Study explore further the considerations to be applied in implementing these provisions. In Part III, we discuss the theoretical importance of equity as the conceptual basis for benefit-sharing. Part IV introduces alternative approaches to the development of equitable sharing criteria. Part V introduces the concept of the Seabed Sustainability Fund, and Part VI discusses how the conceptual basis for equitable sharing of benefits from DSM could equally be applied to distributions under Article 82(4) of UNCLOS in relation to payments made in respect of exploitation of non-living resources on the continental shelf beyond 200 nautical miles.

Table 1. Overview of distribution mechanisms. Distribution of financial benefits received pursuant to Article 140.

	Description	Comments	Status
Total amount received from payment mechanism			
Less			
(1)	Administrative expenses of the Authority	Pursuant to UNCLOS, article 173 and Financial Regulation 5.7, administrative costs are always a first call upon the funds of the Authority.	Mandatory
(2)	Funds allocated to the Enterprise in accordance with article 170(4)	1994 Agreement (annex, section 2, para. 3) makes it clear that States parties are under no obligation to finance any operations of the Enterprise.	Requirement no longer applies
(3)	Economic Assistance Fund under article 151(10)	Council is required to determine the amount to be set aside for this Fund, based on the recommendation of the Finance Committee.	Mandatory, but amount discretionary
(4)	Repayment of member State contributions since 1994	Theoretical basis is that ISA member States are regarded as "original investors" and should receive repayment of assessed contributions. States becoming party after mining starts would otherwise be free riders.	New concept
(5)	Seabed Sustainability Fund	Supports deep-sea science as a global public good and addresses intergenerational equity	New concept
Net amount available for distribution under equitable sharing criteria			

PART III: EQUITY AS A CONCEPTUAL BASIS FOR DEVELOPING SHARING CRITERIA

UNCLOS requires ISA to develop rules, regulations and procedures for the equitable sharing, for the benefit of mankind as a whole, of any payments received from DSM contractors. However, exactly what this means and how it is to be accomplished have yet to be determined.

Equity is a complex idea that resists simple formulations. It is strongly shaped by cultural values, by precedent, and by the specific types of goods and burdens being distributed. To understand what equity means in a situation we must therefore look at the contextual details. Equity is a central concern in the most basic political decisions.

Normative theories of equity and justice

Three theories of justice have figured prominently in discussions of equity (Young, 1992; Moulin, 2003). Aristotle's equity principle or proportionality principle states that the goods or services of concern should be divided in proportion to each's claimant's contribution (or claim) (Aristotle, 2009 1130b-1132b). This approach requires measuring each claimant's contribution (claim) on a cardinal scale, which is sometimes clear and in other cases is not. Aristotle's equity principle also requires that goods or services be divisible (Young, 1992).

In the case of revenue from DSM, the good is homogeneous, divisible and measured on a cardinal scale in a common metric (US$), and each individual has an equal claim to share benefits from DSM in the Area due to the status of mineral resources as the common heritage of mankind. This equal claim may be adjusted for progressivity in response to requirements of UNCLOS to redistribute income on a more equitable basis, so that the distribution is not an exact or even one. Instead, the distribution is an uneven one with unequal entitlements with claimants weighted by social distribution weights.

A second theory is classical utilitarianism, which states that the goods or services of concern should be distributed to maximize the total welfare of the claimants – the greatest good for the greatest number. Utilitarianism requires that utility must be understood as a measure of psychic satisfaction or well-being that can be measured on a cardinal scale and added across individuals. Utilitarianism also can impose harm on a few to confer a small benefit on the many.

A third theory, due to Rawls (1971), has the central distributive principle that the least well-off in society or a group should be made as well-off as possible, known as the maximin principle. Well-off does not pertain to an individual's subjective level

of satisfaction, but instead to the means or instruments by which satisfaction can be achieved. If income is the means, then the principle states that income should be distributed so that the individual with the least income has as much income as possible. The principle refers to the effective distribution of income after economic incentives are considered. Rawls' theory avoids two inherent problems in classic utilitarianism, in that it is based on observable characteristics of individuals, such as income, rather than inter-personal comparisons of welfare. Rawls' principle also avoids the ethical problem of benefitting the many at the expense of the few.

Dissatisfaction with these three classical approaches has led to other approaches to distributive justice. Related to utilitarianism and Rawls' difference principle are prioritarianism (Parfit, 1991) and leximin (Sen, 1997). Prioritarianism holds that welfare is an outcome of the overall welfare across all individuals with extra weight given to worse-off individuals. Prioritarianism resembles utilitarianism as aggregate consequentialism, but it differs in that all individual welfare is not equally weighted. Instead, prioritarianism prioritizes worse-off individuals. Prioritarianism differs from egalitarianism, since egalitarianism values equality as a relation between individuals whereas in prioritarianism value is not a relation but absolute levels of individual welfare rather than their relative standing (Holtug, 2006; Adler, 2019). Leximin aims to maximize the welfare of the worst-off party, then the second worst-off, etc. Subject to debate is the weight given to individuals, notably worst-off, next worst-off, etc. The leximin theory gives absolute priority to those who are worst off, whereas prioritarianism gives less priority to the worse-off.

A very different new approach is that distribution should be envy-free. An envy-free distribution occurs if no one prefers another's portion to one's own. Envy-free distribution does not require interpersonal comparisons of utility, because each individual evaluates every other person's share in terms of that individual's own utility function. Envy-freeness as a principle for equity thus states that global society is not in general envy-free, but that no individual prefers another portion of a particular allocation of goods or services. This idea requires that parties have equal claims on the goods and that the goods are divisible. While envy-free distribution does not require interpersonal comparisons of utility, it only applies when parties have equal claims on the good, which is often not the case. Most fair division problems resolve around the question of how differences in claims (due to disparities in merit, contribution, need etc.) should be considered, in which case the no envy principle becomes essentially irrelevant. Distributive decisions usually entail comparisons and value judgements, so the basis of these decisions must be considered. The judgements required to make distribution decisions are not made by consulting utility functions but upon objective measures of need, merit, contribution etc.

All of these distributive problems can be and are solved without invoking theories of social justice. Rather than developing and discussing the philosophical, ethical, and semantic meaning of equitable, fair or just distributions in the large, this report concentrates upon equitable sharing in the small. It is possible to analyse the meaning of equity in the small without resolving what social justice means in the large. In the case of DSM distribution,

equity in the small could be defined as a state in which each ISA member's welfare is increased to the maximum extent possible, without making any other ISA member worse off, given the limited resources in the Area and the deep-sea mining returns available for distribution, after taking proper account of the requirements of UNCLOS, the common heritage status of the resources being exploited, and the sharing rules ISA considers appropriate to its need. Alternatives are possible, such as, for example, equity with a stability property called "no justifiable envy". Equitable sharing has justifiable envy if a State party would prefer another allocation to that which it receives when a State party of higher income receives a larger allocation of proceeds.

Application to DSM

As ISA grapples with this challenge, several issues will need to be addressed. These include the principles to be used in determining the "claims" that different entities or groups (current or future) will have on the pool of resources that are generated, and the mechanisms to be used for distributing available funds among claimants, including whether distribution should be in the form of direct payments to States or funded projects. The first issue is, essentially, a question of what equitable sharing means for intergenerational equity in the context of DSM. The second is a question about how equitable sharing can or should be achieved.

As a general principle, the equitable sharing of resource rents can be based on two possible rationales. The first is simply the concept of shared ownership, while the second is that equitable sharing can reflect an implicit or explicit desire to redistribute income or wealth, presumably from wealthier States to poorer States.[22] In this case, shares should be distributed based on some indicator of a State's priority in the redistribution goal, and would, typically, embody some form of progressivity that favours poorer States in the distribution scheme.

Progressivity can be defined in various ways. For example, it can mean that the share of rents received by a low-income State is higher than the share received by a high-income State, or that the total amount received as a percentage of income is higher for low-income States than for high-income States. The first definition is more favourable to low-income States,[23] but either implies a redistribution of income or wealth relative to what would be required by a proportional distribution scheme based solely on ownership rights.

Revealed preferences and theory of allocations

Equitable sharing in this report refers to the sharing rules within and across generations that ISA considers appropriate to its needs rather than an abstract moral or ethical construct in the large. Appropriateness is shaped partly by principle, partly by precedent, and partly by what can be practically implemented. Appropriateness expresses what is reasonable and customary in a sharing situation. Appropriateness can be

[22] In the case of ISA, the "benefit of mankind" criterion implies a joint ownership rationale for equitable sharing. The requirement to take into particular consideration the interests and needs of developing States and of peoples who have not attained full independence or other self-governing status implies an income redistribution rationale as well.

[23] Technically, if s denotes the share of some fixed amount of revenue R that is distributed to a State with income of Y, then the first definition of progressivity requires that sR increases as Y decreases, which requires that s be inversely related to income. In contrast, the second definition requires that sR/Y increases as Y decreases. This can hold even if shares are the same or even increasing in income, i.e., higher-income States receive a greater share, as long as the percentage difference in the share is less than the percentage difference in income.

subjective through the stated preferences of ISA States parties or based upon the revealed preferences of policy makers.

The analysis developed in the present study uses the revealed preference of the highest possible global authority and representation of humanity, the UN General Assembly, to develop appropriateness and income progressivity as implied by the UN General Assembly's formula for assessed contributions in a manner consistent with UNCLOS.[24] This revealed preference is embodied in social distribution weights and the subsequent equitable allocation shares for States parties. This revealed preference, based upon decisions made independently of the allocation problem at hand, may come close to being "strategy proof" to the extent that each UN General Assembly member (with its own private information) honestly reveals its preferences on global progressivity in an action unrelated to the progressive distribution of the proceeds from deep-seabed mining to the States parties to UNCLOS. This UN General Assembly's revealed preference, by not being tied to deep-seabed mining, is neutral in incentives to seabed mining.

Aristotle's equity principle or proportionality principle states that the goods or services of concern should be divided in proportion to each's claimant's contribution (or claim). This approach requires that the good must be divisible and requires measuring each claimant's contribution (claim) on a cardinal scale that can be expressed in a common metric, which is sometimes clear and in other cases is not. When entitlement is created by verifiable and fungible claims, the proportional rule has the advantage through treating the units of claim equally, rather than the States parties which possess them. A division of resources in equal shares, which here is proportional, for all participants is non-envious, but it is generally inefficient. The fair share guarantee states that each State party should not strictly prefer the proportional share to the actual allocation and is an *ex-ante* lower bound on individual welfare in the sense that fair share does not depend on the preferences of some States parties rather than other States parties. Aristotle's equity principle can have an incentive effect through overbidding when parties claim for more shares than they really want (Moulin, 2003; Young, 1994).[25]

The theory of cooperative games has developed a theory of allocations. Some of the approaches may or may not face difficulty in practical operationalization, while others may be more tractable.[26] An

[24] Dietz et al. (2008, pages 7–8) observe that, "To deduce ethical values from preferences revealed by behaviour, at least four (non-trivial) conditions would be required: (i) a unique preference is revealed by the observed behaviour (the 'inverse optimum problem'); (ii) the preferences revealed are the 'true preferences' of the individual, based on full and correct information without any errors in decision-making; (iii) the preferences measured are contextually relevant to the ethical judgement at hand; and (iv) the preferences are appropriate for social decision making, and not merely individual decision making." Dietz et al. discuss these issues and problems with using market data to established revealed preferences in favour of stated preferences (and this approach's issues).

[25] As noted elsewhere, because exploration and production versus royalty allocation decisions are separable, Aristotle's equity principle applied to distribution is not expected to have an incentive effect upon exploration and production.

[26] A Shapley value is a systematic formula used to divide a joint cost or a jointly-produced output. It offers a reasonable definition and computation of the share of cost or surplus for which a user of the commons is deemed responsible. The Shapley value essentially weights States parties based upon their marginal contributions, such that each State party contributes more than they stand to gain. The Shapley value can yield inconsistent answers. The nucleolus is a unique solution that maximizes the benefits to the least-satisfied coalition and is thus comparable to the minimax principle of Rawls (1971). The Nash bargaining solution, an egalitarian approach, essentially assumes that all States parties in a coalition are equally important because full cooperation would not succeed without all of them, and thus the payoff should be shared equally. The Nash bargaining solution is thus closely related to Aristotle's equity principle.

allocation rule based on the "Contested Garment Principle" lies in the nucleolus.[27] In sum, allocations based upon cooperative solutions from game theory (along with allocations based upon welfare economics developed below) deserve attention.

Some allocation options are simply not tractable for various reasons. They may not be fair, efficient or homogeneous and divisible, or not be practicably applicable to the equitable distribution problem at hand. Auctions, divide-and-choose, lotteries, rotation, queuing or profit sharing cannot be practically operationalized. Auctions would likely be considered unfair by lower-income States parties (since auctions rely upon the ability to pay, which favors higher-income States parties), and in any case, lead to inequitable outcomes when the States parties have substantially different private endowments. Divide-and-choose "cake-cutting", queuing and lotteries could be used in allocating contracts.

Rotation (time sharing) of mining opportunities according to some rule presents another alternative but is inefficient (at a minimum) and not applicable to mining an exhaustible resource with large irreversible investments or to equitable division of mining royalties. Divide-and-choose, lotteries, rotations and queuing (likely first come, first served) fail to satisfy some notion of priority among claimants.[28] Priority methods of allocation are the only ones that allocate a good impartially and consistently over different situations, even though the criteria upon which priority is based may differ greatly from one situation to another.[29]

An allocation is a fair division, also called a fair bargain or fair share, when claimants decide directly rather than a third party (Young, 1992; Moulin, 2003). Hence, voluntary and self-enforcing international bodies and negotiations within these bodies will make the equitable allocation a fair division. From a procedural point of view, the decision must be unanimous. ISA States parties have impartiality and equal and identical entitlements, treatment and exogenous rights and claims in an involuntary, self-enforcing international organization. Such self-enforcing collective decision-making through "equal treatment of equals" (Aristotle, 2009) ensures a fair procedure and bargain, since sovereign States with legal personality, rather than a third party, unanimously decide issues (Young, 1993). We shall also assume that the good is divisible, or if it is not, that they divide chances at getting the good.

[27] The rule is based on allocation of the contested claim and meets the properties of the nucleolus. The claims problem is as follows: Several individuals (States parties) have claims on a common asset, and the claims exceed the amount available (here the asset is perfectly divisible). A solution to the claims problem is the division of the total amount among the various claimants, such that no individual receives more than that individual's claim and no claim is zero. Two claims are important to distinguish: (1) voluntary claims, when claims are created by voluntary actions, in which case the incentive impact can be important, and (2) involuntary claims, which involve no choice or effort on the part of the claimant, in which case the incentive impact may not be important. The Contested Garment Rule is then: Let two individuals have claims against a common asset, where the sum of the claims exceeds (or equal to) the total amount. Each claimant's uncontested portion is the amount left over after the other claimant has been paid in full in case that claim is less than the total, and zero otherwise. The contested garment rule gives each claimant his or her uncontested portion plus one-half of the excess over and above the sum of the uncontested portions. General rules are: (1) Equal amounts if the total is less than the smallest claim; (2) Equal loss if the total is more than the largest claim; (3) Half of the individual's claim to the smallest claimant and the rest to the other in all other situations. An allocation among a group of claimants is pairwise consistent with the Contested Garment Rule if every two claimants share the total allocated to them according to the Contested Garment Rule. Another rule is Maimonides's Rule, in which an equal amount is given to each claimant or the full amount of each individual's claim, whichever is smaller. See Young (1994), chapter 4.

[28] Divide-and-choose was operational for deep-seabed mining claims because the Area was owned by humanity as a whole under the common heritage of mankind concept and deep-seabed mining had no history of actual mining. Divide-and-choose is envy-free.

[29] Young (1994). Distribution based upon the priority principle is particularly applicable when the "good" to be divided is lumpy and indivisible, heterogeneous, and not readily cardinally measured by a single metric.

An allocation is envy-free if no individual prefers another's portion to one's own (Foley, 1967). Envy-freeness as a principle for equity states that global society is not in general envy-free, but envy-freeness exists where no individual prefers another portion of a particular allocation of goods or services. An equitable sharing would also be Pareto efficient, which arises if other feasible allocations do not make at least one individual better off without making at least one other individual worse off.

Envy-free distribution only applies when parties have equal claims on the good to be distributed, which is not strictly true here due to UNCLOS articles 140 and 82 (even though the status of the resources as the common heritage of mankind and Aristotle's proportionality principle would suggest equal claims on a per capita basis as the initial basis of the distribution).

Because the equitable sharing allocation is made after, and independent of, the decision of the amount and type of contractor payment to ISA, there is including no impact upon the supply of contractor effort. Inter-generational not an equity-efficiency trade-off in this dimension, equitable sharing, as discussed previously, can be addressed through measures such as the Seabed Sustainability Fund (which could also be considered as an updated version of the Common Heritage Fund first proposed in the 1970s).[30]

Such equitable sharing is also Pareto efficient because there is a single good (royalties), every party prefers a larger share than a smaller one, and the only way to increase a party's share is to reduce another party's share. Another way of stating this is that allocation is efficient (i.e., Pareto optimal) in that none of the good (royalties) is thrown away and royalties have zero opportunity cost.

[30] During UNCLOS III, the establishment of a Common Heritage Fund was proposed by a group of nine States (Afghanistan, Austria, Bolivia, Lesotho, Nepal, Singapore, Uganda, Upper Volta (Burkina Faso) and Zambia), but specifically in relation to funds to be received pursuant to Article 82, and not in connection with funds paid for activities in the Area. The Group for the Common Heritage Fund advanced the proposal in the Second Committee in "… an effort to strengthen those provisions of the Law of the Sea draft treaty which try to implement the vision of the oceans beyond national jurisdiction as the common heritage of mankind." See Virginia Commentary (Nordquist et al., 1985–2011), Vol. II at 945. Also, NG6/13 (1979, mimeo.), reproduced in IX Platzöder 383.

PART IV: ALTERNATIVE APPROACHES TO EQUITABLE SHARING CRITERIA

Rather than developing and discussing the philosophical, ethical and semantic meaning of equitable, fair or just distributions in the large, as discussed above this report concentrates upon equitable sharing in the small. This sharing follows UNCLOS as well as the procedures and norms of ISA and largely focuses upon the more practical discussions of how the equitable sharing of DSM royalties, received by ISA, will be defined, measured and implemented in the small.

Equity (in the small) could be defined as a state in which each ISA member's welfare is increased to the maximum extent possible, without making any other ISA member worse off, given the limited resources in the Area and the DSM returns available for distribution, after taking proper account of UNCLOS, the common heritage of mankind status of the resources, and the sharing rules ISA considers appropriate to its needs. Alternatives are possible, such as, for example, equity with a stability property called "no justifiable envy". Equitable sharing has justifiable envy if a State party would prefer another allocation to that which it receives when a State party of higher income receives a larger allocation of proceeds.

Equitable sharing in this section refers to sharing rules that ISA considers appropriate to its needs rather than an abstract moral or ethical construct in the large. Appropriateness is shaped partly by principle, partly by precedent, and partly by what can be practically implemented. Appropriateness expresses what is reasonable and customary in a sharing situation. Appropriateness can be subjective through the stated preferences of ISA States parties or based upon the revealed preferences of policy makers.

This section of the report develops three alternative permanent formulae (algorithms) to equitably allocate States parties' shares of benefits (proportions of the total benefit to be distributed in a time period) that are multiplied by the deep-sea mining proceeds and other benefits to be distributed to each State party in a distribution time period. The shares formula is predicated upon each State party's share of total population of all States parties, consistent with Aristotle's proportionality principle, adjusted by social distribution weights that can be used to account for either the Article 140 or Article 82 criteria by giving greater weight, as appropriate, to States parties that are low-income or low-income and landlocked, respectively, compared to higher-income and coastal beneficiaries.

The empirically estimated social distribution weights fall intermediate between those of utilitarianism and the maximin principle that maximizes the welfare of those who are worst off. The share of total population of all States parties adjusted by these social distribution weights yields greater benefits to those beneficiaries with larger

social distribution weights and hence a progressive allocation. These social distribution weights are further developed below. Appendix 1 comprehensively reports the empirical analysis of the UN General Assembly's revealed preference on progressivity that forms the basis of the social distribution weights.

Proportionality as a starting point

Each of the equitable sharing metrics developed in this report begins with Aristotle's equity or proportionality principle. This initial equitable distribution is trivially envy-free, since everyone has the same distribution.[31] The proportionality principle is then modified by a standard income measure of progressivity, which in turn is weighted by a parameter incorporating the revealed preferences about progressivity of the UN General Assembly (as revealed through the estimated progressivity of its member assessments for its budget under the assumption of equal sacrifice). As a result of this composite social distribution weight (income progressivity weighted by the progressivity parameter), dollars of proceeds to low-income recipients count more highly for social welfare than dollars to high-income recipients.[32]

Progressivity is defined to mean that the shares of proceeds received by low-income States parties for Article 140 proceeds and low-income landlocked States parties in the case of Article 82 proceeds are higher than the shares received by higher-income States parties and high-income landlocked coastal States parties, respectively. The reference point is given by mean global per capita income.

Strictly speaking, the distribution is not an envy-free distribution, since envy-free distribution only applies when parties have equal claims on the divisible good (here DSM royalties), which is not strictly true due to the priorities outlined in UNCLOS articles 140 and 82. Because most equitable and fair division problems revolve around the question of how differences in claims (due to disparities in merit, contribution, need etc.) should be considered, and since the degree of progressivity as agreed upon by ISA States parties in principle resolves differences in claims, the issue of envy-free equitable royalty distribution should become of little or no relevance.[33]

Revealed preferences

The analysis uses the revealed preference of the highest possible global authority and representation of humanity, the UN General Assembly, to develop appropriateness and income progressivity as implied by the UN General Assembly's formula for assessed contributions in a manner consistent with UNCLOS.

This revealed preference is embodied in social distribution weights and the subsequent equitable allocation

[31] An allocation is envy-free if no individual prefers another's portion to one's own (Foley, 1967). Envy-freeness as a principle for equity states that global society is not in general envy-free, but rather that no individual prefers another portion of a particular allocation of goods or services. An equitable sharing would be Pareto efficient if other feasible allocations do not make at least one individual better off without making at least one other individual worse off.

[32] Social distribution weights indicate the marginal social value of an extra unit of income to individual country *i*. They represent the value that society places on providing an additional dollar of income or consumption to any given individual. These weights directly reflect society's concerns for fairness. The weight attached to each country *i* when it receives an extra unit of income is positive, and the more income a country receives, the smaller the relative social weight becomes. (Little and Mirrlees, 1974; Adler, 2016).

[33] Envy-free distribution only applies when parties have equal claims on the good, which is not strictly true here due to UNCLOS articles 140 and 82 (even though the distribution starts with equal claims on the DSM proceeds due to the status of the resources as the common heritage of mankind and per capita distribution, given Aristotle's proportionality principle, as the initial basis of the distribution).

shares for States parties. This revealed preference, based upon decisions made independently of the allocation problem at hand, may come close to being "strategy proof" to the extent that each UN General Assembly member (with its own private information) honestly reveals its preferences on global progressivity in an action unrelated to the progressive distribution of the proceeds from deep-seabed mining to the States members of ISA.

ISA States parties have the option to use these revealed preference social distribution weights and resulting equitable allocation shares to States parties as a focal point, with starting values to develop their own stated preference normative values and resulting distribution weights and allocated shares for equitable sharing. Appendix 2 reports summaries of the different allocated shares by country, calculated with increasingly progressive allocations compared to the base case (reported below) revealed by the UN General Assembly's preferences on progressivity in the annual assessment.

Social welfare function

The social welfare function of economics is used to develop the equitable sharing algorithm (see Appendix 3 for a full explanation). The social welfare function represents some ethical judgement about the appropriate distribution of social welfare across people affected by a policy change, here the distribution of proceeds. It allows quantitative evaluations of outcomes to determine whether social welfare increases. A social welfare function cannot be observed. The social welfare function is normative and must instead be specified according to a particular ethical view. This social welfare function approach has the advantage of quantification according to well-developed principles of economics that captures ethics and allows either revealed or stated preferences for quantifying the ethical view that is assumed through the form of the social welfare function. The social welfare function approach is a consequentialist moral theory. As such, it says that policies should be judged only in terms of their consequences, and the only relevant consequences are to individual well-being.

The social welfare function used in this report is a constant-elasticity iso-elastic function that values both equality and high total social welfare (utility), is common across countries, and is a function of real (inflation-free) per capita Gross National Income (GNI) of States parties. The constant-elasticity iso-elastic social welfare function gives increasing priority to utility changes the lower the per capita GNI of a State party.

Social welfare functions from economics allow developing the social distribution weights that implement progressivity. These social distribution weights, based upon either stated or revealed preference, quantitatively weight individual well-being and allow cardinal comparisons between States parties. Through such normative social distribution weights, dollars to low per capita GNI States parties count more highly for social welfare than dollars to high per capita GNI States parties. With the iso-elastic social welfare function, the distribution weights tend to become very large as GNI per capita disparities increase among States parties.

Well-established and long-standing economics approaches allow the revealed preference approach to derive a quantitative measure of progressive income distribution for the social distribution weights from individual countries' income tax programmes (the

equal-sacrifice income tax approach).[34] In a comparable manner, the UN-assessed contributions are treated as a UN income tax to which the equal-sacrifice income tax approach is applied and that has a progressive structure determined by the revealed preferences of the UN General Assembly (and which the analysis recovers as discussed in Appendices 1 and 2).

Several criteria can be devised to distribute the net benefits to governments of States parties, all of which start with the principle that the mineral resources of the deep seabed are the common heritage of all mankind. This status of the resources as common heritage implies that any proceeds could be based, in part, upon each country's population as a percentage of the world's total (consistent with Aristotle's equity principle), and Article 140 states that this distribution should be adjusted in such a way as to favour the developing countries, giving progressivity. Extending this further to Article 82(4) implies that any proceeds from the outer continental shelf would be similarly based, and in addition would be further adjusted to favour low-income landlocked countries, also giving progressivity.

Equitable sharing formulae

1. Original (2019) formula

Initially, we developed a proposed formula based on readily accepted and accessible measures of States parties' income and populations, adjusted by a social distribution weight to achieve a progressive allocation.[35] This formula is written:

$$S_i = \frac{P_i \left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta = 1}}{\Sigma_{i=1}^{N} P_i \left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta = 1}}$$

where S_i denotes the allocated share of State party i in a time period, $\overline{GNI}$ denotes the average per capita Gross National Income (GNI) of all States parties, GNI_i denotes the per capita Gross National Income of State party i, and N denotes the total number of States parties that receive an allocation ($N = 167$). It may be noted that replacing GNI with the median GNI does not change S_i (because the value appears in both the numerator and denominator of the formula for S_i).[36]

Following the 1971 UN Report,[37] the distribution of income is considered according to the reference point of global per capita income, measured as global mean per capita GNI in US dollars adjusted

[34] Revealed preference estimation of η from income taxes operates under two assumptions: the income tax structure reflects the equal absolute sacrifice equity principle, and the social welfare function takes a known form, which is almost invariably iso-elastic (Groom and Freeman, 2019). The equal absolute sacrifice principle implies that in any given "tax" (UN assessment) year, the "tax" taken from each member represents the same sacrifice of utility or satisfaction, i.e., the marginal utility burden of the tax should be equal for all members (Young, 1994).

[35] Agreement on such a formula would also imply that the allocation as between claimant States is also a fair division. Allocation is fair division when claimants decide directly through a process of direct bargaining rather than through a third party (Young, 1994, 116–117). Moreover, since the UN General Assembly makes unanimous decisions through one-State, one-vote for the annual membership assessment rather than decisions by a third party, the decision-making process of the UN General Assembly as a voluntary, self-enforcing institution potentially confers fair preferences and distribution and facilitates procedural equity and fairness.

[36] Either mean or median global per capita GNI can serve as the reference point and will give the same results. In US$2017, the 2015–2017 mean global per capita GNI is US$14,359.49 and the median global per capita GNI is US$5,659.31. More States parties would be classified into the low-income category with the mean baseline and the distribution weights between the mean and median approaches would vary. However, when applying the algorithm for States parties' shares developed above, $S_i = \frac{\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta} * P_i}{\sum_{i=1}^{N}\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta} * P_i}$, the shares do not change. As this formula shows, GNI is a constant and changing its value in both the numerator and denominator of the equation does not alter the relative or proportional values, i.e., does not alter S_i (although the distribution weights change).

[37] A/AC.138/38, *supra* note 2.

for inflation to 2017 value (expressed as "US$2017"). As explained below, global median per capita GNI gives the same allocation. The discussion and metrics are framed in terms of States parties' income rather than wealth for a variety of reasons. These reasons include readily accepted and accessible measures of States parties' income as opposed to the more complex question of country wealth and the relationship with States parties' income (low-wealth States parties may have low incomes or vice versa, etc.). In addition, international discussions are typically framed in terms of income,[38] including classifications of States parties and the UN General Assembly's formula for assessing Member States' contributions to the budget.[39]

National income is better measured by Gross National Income (GNI) rather than Gross Domestic Product (GDP). GNI measures all income of a country's residents and businesses, regardless of where it is produced. GDP measures the income of anyone within a country's boundaries, and measures production whereas GNI measures income. The UN General Assembly uses GNI when deciding upon individual member contributions to the budget.[40]

This report uses a three-year (2015–2017) mean per capita GNI for each State party, primarily sourced from the World Bank Development Indicators, averaged to smooth out annual and potentially random fluctuations that can impact GNI (e.g., drought, weather, conflict, business cycle). The year 2017 is the latest year for which complete data are available. Population data are from the World Bank indicators and the UN Population Division, Department of Economic and Social Affairs.[41]

In a few instances, per capita GNI data were not directly available from the World Bank. In these instances, UN data were first consulted.[42] In turn, if these data were not directly available, then the World Atlas Data from Knoema.com were consulted.[43] The Knoema.com data could vary slightly from the World Bank data (when there was overlap), and in these instances, for consistency the Knoema.com data were used. Nominal GNI per capita data (i.e., data in existing prices) were deflated to US$ values for 2017 (US$2017) using the GDP implicit price deflator from the U.S. Federal Reserve Bank of St. Louis, Economic Research Division.[44] Population data in addition to the World Bank and the UN World Population prospects are also available.[45] Niue presented a special case, as GNI information is unavailable

[38] Income is a flow variable that changes the stock of wealth through savings from income that is invested in physical, human, social or natural capital (through reduced exploitation), whereas wealth is a stock variable. Inter-generational equity discussions are typically framed in terms of the flow that changes wealth over time. Moreover, consumption comes from the part of income that is not saved.
[39] United Nations General Assembly Report of the Committee on Contributions, 2001-2018.
[40] *Ibid*.
[41] United Nations Population Division Department of Economic and Social Affairs World Population Prospects, The 2017 Revision. Available at (accessed December 20, 2018): https://population.un.org/wpp/Download/Standard/Population/.
[42] Available at (accessed December 20, 2018) http://data.un.org/Data.aspx?q=GNI+PER+CAPITA+2010&d=SNAAMA&f=grID%3A103%3BcurrID%3AUSD%3BpcFlag%3A1%3Byr%3A2010.
[43] Available at (accessed December 20, 2018): https://knoema.com/atlas.
[44] Available at (accessed December 20, 2018): https://fred.stlouisfed.org.
[45] Available at (accessed December 20, 2018): https://population.un.org/wpp/Download/Standard/Population/.

although GDP per capita for 2013 of $12,945 is available from the Government of Australia.[46] This number was converted to US$2017 and assumed to grow at a 3% growth rate. The Cook Islands population data were from the Cook Islands Ministry of Finance and Economics.[47]

GNI is used rather than more complex but comprehensive indicators of a State party's socio-economic development, such as the Human Development Index. In contrast to such indices, GNI is widely used to classify countries' socio-economic development, including by the UN General Assembly when calculating its annual member assessment to the budget, and for UN and World Bank classification of countries into various income levels.

GNI measured in US$ and market exchange rates is used rather than GNI measured in purchasing power parity (PPP).[48] GNI measured in US$ and market exchange rates is consistent with the method to estimate the parameter measuring progressivity of income distribution (discussed below) used in the distribution (social welfare) weights from the UN General Assembly's assessment of member contributions to the annual budget (which is assessed in US$ and market exchange rates). GNI measured in US$ and market exchange rates is also consistent with how the mining royalties are measured and avoids any measurement error associated with PPP. States parties' imports and exports are valued in US$ and market exchange rates. Moreover, empirical evidence has shown that for many goods and baskets of goods, PPP is not observed in the short-term, and there is uncertainty over whether it applies in the long-term.

The algorithm for States parties' shares generalizes the 1971 UN Report's Criterion A, paragraph 56. Per capita proceeds are inversely related to States parties' per capita GNI. The States parties' shares are obtained by: (1) calculating the ratio of the world per capita GNI over each State party's per capita GNI; (2) raising this ratio to a power η, which then forms the social distribution weight:

$$\omega_i = \left[\frac{\overline{GNI}}{\overline{GNI_i}}\right]^{\eta}$$

for State party i (the weight ω_i is a hyperbolic function of GNI_i, with a value of one at GNI; see Figures A.2.1.–A.2.16); (3) multiplying each State party's share of the total population of all States parties by the distribution weight ω_i obtained in (1) and (2); and (4) reducing the values derived in step (3) to percentage form, i.e., dividing each State party's figure by the sum total of the figures for all countries in stage (3). The allocation calculations exclude all States that are not a State party to UNCLOS.

The formula for States parties' shares can be written for each time period t:

$$S_i = \frac{\left[\frac{\overline{GNI}}{\overline{GNI_i}}\right]^{\eta} * P_i}{\sum_{i=1}^{N} \left[\frac{\overline{GNI}}{\overline{GNI_i}}\right]^{\eta} * P_i},$$

where S_i denotes each State party $i's$ share (proportion) of proceeds, P_i is each States party $i's$ share (proportion) of the total population of all States parties (averaged over three years), $\overline{GNI_i}$ is the per capita Gross National Income of States party i (averaged over three years), GNI (the numerator of the GNI ratio) is the world

[46] Available at (accessed March 21, 2019): https://dfat.gov.au/trade/resources/Documents/niue.pdf.
[47] Available at (accessed March 21, 2019): http://www.mfem.gov.ck/statistics/134-economic-statistics/national-accounts.
[48] PPP provides an alternative to using market exchange rates. The actual purchasing power of any currency is the quantity of that currency needed to buy a specified unit of a good or a basket of common goods and services. Purchasing power is determined in each country based on its relative cost of living and inflation rates. PPP allows estimating what the exchange rate between two currencies would have to be to equate the purchasing power of the two currencies. Essentially, GNI measured at PPP controls for different costs of living and price levels, usually relative to US$.

per capita GNI (averaged over three years), and $\sum_{i=1}^{N} S_i = 1$. The total amount of DSM royalties to be distributed among States parties in any given time period is multiplied by each State party's S_i to give that State party $i's$ actual distribution.

The ratio $\frac{\overline{GNI}}{GNI_i}$ makes the social distribution weight $\omega_i = \left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta}$ inversely proportional to a State party's per capita GNI relative to global per capita GNI, i.e., $\frac{\overline{GNI}}{GNI_i}$, and thus makes the distribution progressive. The parameter value η further contributes to or reduces the progressivity, where a value $\eta = 1$ leaves progressivity unchanged, a value $\eta < 1$ reduces progressivity, and a value $\eta > 1$ increases progressivity, and a value $\eta = 0$ makes all social distribution weights equal and equal to 1.[49]

The parameter value η affects the progressivity of the distribution weight inversely proportional to a State party's per capita GNI.[50] This approach gives greater weight to beneficiaries the lower their per capita GNI relative to mean global per capita GNI. Separate values of η may be estimated for Article 140 and Article 82 proceeds based upon the UN General Assembly preferences revealed through their progressive "tax structure", i.e., its annual assessment schedule for the budget (see Appendix 1) under the assumption of equal sacrifice (Appendix 2). For Article 140 proceeds, the UN General Assembly revealed preference indicates that $\eta = 1$, giving a distribution parameter $\omega_i^{140} = \left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1}$.[51] This result means that per capita proceeds are inversely and directly proportional to the level of per capita GNI (unless $GNI_i = GNI$). States parties whose GNI is above (below) global per capita GNI will receive a weight less (greater) than unity.

The parameter η, called the elasticity for the social marginal welfare of income, is derived from the UN General Assembly's revealed preferences by treating the UN assessment and subsequent contribution to budget as a progressive tax scheme and applying the normative equity principle of equal absolute sacrifice. The implicit marginal and average tax rates can be determined from these assessments,

[49] The parameter η, called elasticity for the social marginal welfare of income, captures the change in social welfare for an increase in an individual's consumption or income due to the decline in social weight as utility increases and the declining marginal utility of income as consumption or income increases. In this exercise, η can also be interpreted as a measure of global society's aversion to inequality. The value for η incorporates attitudes to risk, inequality within generations, and inequality between generations. Higher η implies: (1) greater risk aversion, and/or (2) greater social inequality aversion (increasing the relative weight placed on changes in the consumption or income of the lower income, increasing the overall gain in social welfare), and/or (3) if we also assume, as is standard, that aggregate consumption and income will continue to grow, then the overall gain in social welfare increases with higher η because it reduces the weight placed on future consumption, and increases the weight placed on present consumption (because the present is poorer than the future). This report assumes that ISA has already made the intra-generational and inter-generational decision (so that reason #3 is irrelevant) and that there is minimal or no risk to ISA States parties since the distribution of royalties is separate and follows mining, and that price and revenue volatility are addressed in a previous step (so that reason #1 plays a minimal role). Spreading risk among all States parties also minimizes any residual risk. Annex 4 provides further discussion.

[50] The value for η captures attitudes to risk, inequality within generations and inequality between generations. Higher η implies: (1) greater risk aversion, and/or (2) greater social inequality aversion (increasing the relative weight placed on changes in the consumption or income of the lower income, increasing the overall gain in social welfare), and/or (3) if we also assume, as is standard, that aggregate consumption and income will continue to grow, then the overall gain in social welfare increases with higher η because it reduces the weight placed on future consumption, and increases the weight placed on present consumption (because the present is poorer than the future). This report assumes that ISA has already made the intra-generational and inter-generational decision (so that reason #3 is irrelevant) and that there is minimal or no risk to ISA States parties since the distribution of royalties is separate and follows mining and that price and revenue volatility are addressed in a previous step (so that reason #1 plays a minimal role). Higher η in this analysis largely implies greater social inequality aversion or increased social welfare for more progressive distributions of DSM proceeds.

[51] The value $\eta = 1$ as an exponent leaves the ratio $\frac{GNI}{GNI_i}$ unchanged.

as fully developed in Appendix 1. Each member's GNI is the income, and each member's contribution is the tax. These values were converted to per capita values by dividing by the corresponding member's population. The marginal tax rate is $\frac{\partial T(GNI)}{\partial GNI}$, where the symbol ∂ denotes the first partial derivative, and the average tax rate is $\frac{T(GNI)}{GNI}$ These tax rates enter into a formula that gives the elasticity of the marginal utility of income $\eta = \frac{ln(1-MTR)}{ln(1-ATR)}$, which in turn enters into the above formula that gives welfare weights, $\omega_i = \left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta}$ (Evans 2005).

To support the reader's review of this chapter and related appendices, a web-based country comparison model was developed by the secretariat and made available on the website of the Authority. The model allows output of the results of a notional distribution of any given sum of money according to the various alternative formulae presented in this report. Outputs include a country's relevant demographics including the resulting GNI-based distribution weight, expected distribution shares under three proposed distribution functional forms and three comparison forms, total and per capita pay-outs for the selected hypothetical total pay-out, the relevant group's Gini coefficient and Atkinson inequality index under each distributional form and Lorenz curves under each distributional form. All calculations in the web-based model are based on five-year averages of population and GNI data unless otherwise noted. The data are also available from the World Bank, United Nations and other sources. A user manual for the web-based model is included in Appendix 10.

Box: Ghana

The following example for Article 140 distributions to Ghana illustrates the calculation of shares using the formula $S_i = \frac{\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta} * P_i}{\sum_{i=1}^{N}\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta} * P_i}$ and $\eta = 1$. Mean global per capita GNI over 2015–2017 in US$2017 is $14,359.49, i.e., GNI = $14,359.49. Suppose State party i has a proportion (share) of the total population that are States parties to UNCLOS, which is 0.00436531, i.e., P_i = 0.00436531, and State party i has a mean per capita GNI over 2015-2017 in US$2017 of $1,488.18, i.e., GNI_i = $ 1,488.18. The distribution weight is $\omega_i^{140} = \left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1} = \left[\frac{\$14{,}359.49}{\$1{,}488.18}\right]^{1}$ = 9.64905648. The numerator of S_i is then $\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1} * P_i = \left[\frac{\$14{,}359.49}{\$1{,}488.18}\right]^{1}$ 0.00436531 =9.64905648*0.00436531=0.04212115. Suppose $\sum_{i=1}^{N}\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1} * P_i$ = 6.766. Then $S_i = \frac{\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1} * P_i}{\sum_{i=1}^{N}\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1} * P_i} = \left[\frac{0.04212115}{6.36198253}\right]$ = 0.00662076.

Table 2. Summary statistics of States parties' shares of total population of all States parties, per capita GNI, social distribution weights, equitable allocation shares: all States parties

Variable	Mean	Standard Deviation	Minimum	Maximum
Share of Global Population P_i	0.005988	0.0233317	2.51E-07	0.21395
Mean per Capita Gross National Income $\overline{GNI}$	14,359.49	22,096.00	120.14	171,966.70
Median per Capita Gross National Income	5,659.31			
Article 140 Distribution Weight ω_i	6.466751	11.92674	0. .0835016	119.5277
Article 82 Distribution Weight ω_i	6.981965	12.90973	0.0835016	119.5277
Article 140 Equitable Allocation Shares S_i	0.005988	0.0256045	3.77E-08	0.3078352
Article 82 Equitable Allocation Shares S_i	0.005988	0.0247329	3.63E-08	0.2961013
Sample Size N	167	167	167	167

The previous table for Article 140 and Article 82 distributions summarizes all States parties' share of the total population of all States parties (averaged over 2015–2017), per capita GNI (averaged over 2015–2017), social distribution weights using values of η as discussed above, and equitable allocation shares.

The following table for Article 140 and Article 82 distributions summarises the 20 low-income landlocked States parties' share of total population of all States parties (averaged over 2015–2017), per capita GNI (averaged over 2015–2017), social distribution weights using values of η as discussed above, and equitable allocation shares.

Table 3. Summary statistics of States parties' shares of total population of all States parties, per capita GNI, social distribution weights, equitable allocation shares: only low-income landlocked States parties

Variable	Mean	Standard Deviation	Minimum	Maximum
Share of Global Population P_i	0.0018385	0.0016175	0.0000662	0.0064217
Mean per Capita Gross National Income $\overline{GNI}$	2,389.54	2,042.64	357.90	6,899.99
Article 140 Distribution Weight ω_i	12. 80847	11.11525	2.081087	40.12125
Article 82 Distribution Weight ω_i	17.11051	16.19458	2.239336	58.03792
Article 140 Equitable Allocation Shares S_i	0.0054164	0.0069979	0.0000752	0.021559
Article 82 Equitable Allocation Shares S_i	0.0071158	0.0094419	0.0000820	0.0281649
Sample Size N	20	20	20	20

2. Alternative formulae

Review of the potential distributions for any given sum of money indicates a highly skewed distribution, with the median well below the mean. Most allocations are comparatively small, but some large distributions, especially that to India, create a long tail of distributions to the right. The distribution becomes somewhat more compact and less skewed as the allocation becomes more progressive through higher values of the elasticity of marginal social utility of income η.

To attempt to resolve the distributive problems associated with the original formula (a wide dispersion between States parties in the amounts received), and in response to discussions within the Finance Committee in 2019, two additional formulae were developed. These aim *ex ante* (prior to the allocation to each State party) to incorporate elements to achieve a more equitable allocation when compared to the original formula, by addressing the following variable elements within the formula:

1. Variables within the allocation formula
2. Functional form of the allocation formula
3. Allocation floor (minimum allocated share to each State party i, min S_i) and allocation ceiling (maximum share to each State party i, max S_i)
4. Value of η (which contributes to the degree of progressivity in the social distribution weight $\omega_i = \left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1}$)

As a result, the additional alternative formulae provided for consideration are:

1. Original formula with floor and ceiling (original formula with minimum and maximum allocated shares S_i)
2. Geometric mean functional form

Several alternative variables in the allocation formulae were considered, but rejected, for the reasons discussed in Appendix 4.

The impact of values for η greater than $\eta = 1$ (and hence more progressive in an *ex-ante* sense) was also evaluated, and while these values $\eta > 1$ impacted the distribution of allocation shares to States parties, S_i, the relative impact for values of η was less than the change in distribution of S_i required to address concerns raised by the Finance Committee in July 2019. Nonetheless, Appendix 2 *ex post* evaluates the relative equality and impact upon global social welfare of allocated S_i by formal inequality measures for $\eta = 2$ with the original and geometric mean formulae.

The three alternative allocation formulae differ by the functional form and whether or not there is an explicit floor and ceiling for the resulting allocated shares (S_i) to each State party, i.e., min S_i and max S_i. The two variables within the allocation formulae remain the same as the original formula: (1) Aristotle's equity principle represented by share of global population P_i; and (2) P_i weighted for progressivity by the social distribution weight $\omega_i = \left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1}$.

All three formulae are related in their basic functional form, since they are versions of a multiplicative functional form called a Cobb-Douglas aggregator function.[52] The three formulae impact the equity of the distribution of the allocated shares S_i as measured by the distribution's overall skewness, minimum and maximum values of the allocated shares S_i, and the equity of the distribution as measured by formal measures of relative inequality, several of which also measure the impact upon global social welfare (in terms of a social welfare function) and have been developed in the economics literature on income inequality (briefly summarized in Appendix 7).

3. Original formula with floor and ceiling

It will be recalled that in the original formula, the share of total population of each States parties, P_i, adjusted by the social distribution weight, $\omega_i = \left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1}$, yields greater benefits to those beneficiaries with a larger share of total population P_i (and thereby satisfying Aristotle's Equity Principle) and populations with per capita GNI less than the mean per capita GNI through larger social distribution weights ω_i (and thereby creating a more progressive allocation as required by UNCLOS).

The original allocation formula adjusted by a floor and ceiling for the allocated shares S_i ensures a minimum allocated share for each State party, notably States parties with small populations (and hence small values of share of total population P_i) and ensures a maximum allocated share for each State

[52] The numerator in the original formula is multiplicative, because P_i and ω_i are multiplied together. The original formula corresponds to a Cobb-Douglas aggregator function of: (1) Aristotle's equity principle represented by P_i; and (2) progressivity represented by ω_i, with exponents of one for each of these two variables in the numerator for each State party. Appendix 7 discusses the nature of the Cobb-Douglas and other potential aggregator functions in greater detail. Appendices 3 and 8 discuss the aggregation issue if additional criteria C_{ij} are added. Appendix 8 discusses how relative weights can be developed for the additional criteria C_{ij} (through, for example, voting or points systems, or choice experiments). These weights could conceivably replace the weights of the three alternative formulae developed in this report, in which the original formula and original with ceiling and floor have equal weights of one and the geometric mean formula has relative weights (exponents) of one-half (since there are two variables to be aggregated, P_i and ω_i). Two variables, P_i and ω_i multiplied together, with an exponent of one-half creates a geometric mean.

party. Ensuring a maximum allocated share S_i precludes any individual State party *i* from receiving what could be viewed by some States parties as a disproportionate share.

A floor and ceiling for S_i can also be thought of as creating a hybrid of Aristotle's Equity Principle applied to individual persons and individual States parties. The floor or minimum allocated share, i.e., min S_i, is determined from the revealed preference floor from the annual UN General Assembly minimum amount paid by States parties: S_i = 0.00001, i.e., S_i = 0.001%. The ceiling or maximum allocated share, i.e. max S_i, is determined from the revealed preference ceiling of the ISA maximum amount paid by States parties for their annual contributions to the overall budget:[53] S_i = 0.1631, i.e. S_i = 16.31%.[54] Using a floor and ceiling allocated share, along with the social welfare weight ω_i, create a less skewed distribution and more equitable distribution for States parties (as evaluated *ex post* by formal inequality measures) for the allocated shares and contribute toward equity among States parties with a stability property called "no justifiable envy".[55]

4. Geometric mean functional form

The geometric mean functional form for the allocation formula is written:

$$S_i = \frac{\left[\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1} * P_i\right]^{\frac{1}{2}}}{\sum_{i=1}^{N}\left[\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1} * P_i\right]^{\frac{1}{2}}} = S_i = \frac{\left[\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1} * P_i\right]^{\frac{1}{2}} * P_i^{\frac{1}{2}}}{\sum_{i=1}^{N}\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1} * P_i^{\frac{1}{2}}}$$

The difference between the geometric mean formula and the original formula is that each term P_i and ω_i is raised to the power ½ rather than 1. Generally speaking, the exponent ½, compared to 1, creates a more compact distribution among States parties of allocated shares, which includes less extreme minimum and maximum values. Appendix 6 discusses functional form in greater detail.

Ex post evaluation of equity of the allocation shares from each formula

Equity of allocated shares S_i among States parties i for each of the three allocation formulae is evaluated by *ex post* analysis using empirical and formal measures of inequality and global social welfare. These measures include:

1. Gini coefficient, Lorenz curves and Pen's Parade
2. Atkinson inequality measures
3. Generalized entropy measures

The Gini coefficient, Lorenz curve, and Pen's Parade primarily assess relative inequality per se, but the Gini coefficient and Lorenz curve can be related to social welfare functions under certain conditions. Two measures assess both relative inequality and global social welfare (as determined from a social welfare function): (1) Atkinson inequality measures; and (2) Generalized Entropy measures. Appendix

[53] For the Authority, as with the UNGA, the ceiling assessment rate is 22 per cent, and the floor rate is 0.01 per cent. However, since no State party currently reaches the ceiling rate, the actual ceiling for the Authority from 2021 will be 16.31 per cent. For the purposes of the illustrative analysis in this report, the ceiling rate of 16.31 per cent is used.

[54] S_i was increased to slightly more than the floor amount of S_i = 0.00001 for all States parties for which initially S_i < 0.00001. Due to additional redistribution of shares, the actual floor amount became S_i = 0.0000112. S_i = 0.1631 was allocated to the single large State party with S_i>0.1631. S_i in excess of S_i = 0.1631 was redistributed from this State party with S_i> 0.1631 to all other States parties, including those at the floor of S_i = 0.00001. The redistribution was according to the original formula for all States parties except the State party with S_i = 0.1631 (which was held constant) and those with S_i < 0.00001 which now started from a base of S_i = 0.00001. Thus, all States parties except the one with S_i = 0.1631 received a larger share using the recalculated original formula (and starting from S_i = 0.00001 for relevant States parties).

[55] Equitable sharing has justifiable envy if a State party would prefer another allocation to that which it receives when a State party of higher income receives a larger allocation of proceeds.

7 explains in greater detail the Atkinson and Generalized Entropy measures of relative inequality and social welfare.

Empirical results

1. Summary of empirical results

The primary empirical results can be summarized as follows (with $\eta = 1$, where results for $\eta = 2$ can be reviewed in the web-based model):

1. The allocated shares S_i from the geometric mean allocation formula have the greatest global social welfare and give the most equitable distribution (the lowest relative inequality) among States parties of the three formulae when considering all shares for all States parties (globally).

   Thus, the ranking of the three formulae in terms of equitable distribution among States parties and global social welfare is from highest to lowest: geometric mean > original with floor and ceiling > original.

2. The geometric mean allocation formula is relatively most equitable among States parties and has highest social welfare when per capita GNI < mean per capita GNI, i.e., when $\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1} > 1$, as determined by the Gini coefficient, Lorenz curve, and Atkinson and Generalized measures of relative inequality.

   Thus, the ranking of the three formulae in terms of equitable distribution among States parties and global social welfare when $\omega_i>1$ is from highest to lowest: geometric mean > original with floor and ceiling > original.

3. The geometric mean formula has a minimum allocated share S_i ($minS_i$=0.0000272) that exceeds the minimum S_i of the original ($minS_i$=3.77e – 08 = 0.0000000377) and exceeds the original with floor (minimum, ($minS_i$=0.0000112) and ceiling (maximum) formulae.

   Thus, the minimum shares $minS_i$ for the three formulae ranked from largest to smallest is: geometric mean > original with floor and ceiling > original.

4. The geometric mean formula has a maximum allocated share S_i ($maxS_i$=0.0778) that is less than the maximum S_i of the original ($maxS_i$=0.3078) and the original with floor (minimum) and ceiling (maximum,) ($maxS_i$=0.1631) formulae.

   Thus, the largest shares $maxS_i$ for the three formulae ranked from smallest to largest is: geometric mean > original with floor and ceiling > original.

5. The geometric mean formula has more allocated shares S_i that are "bunched together" in the "middle" of the distribution and is less skewed than the original and the original with floor (minimum S_i) and ceiling (maximum) formulae.

   Thus, the skewness for the three formulae ranked from least skewed to most skewed is: geometric mean (3.92) > original with floor and ceiling (5.82) > original (10.11).

6. The ranking of the original and geometric mean formulae for values of $\eta = 1$ and $\eta = 2$ in terms of most equitable among States parties and

highest social welfare from highest to lowest is geometric mean $\eta = 1$ > geometric mean $\eta = 2$ > original with floor and ceiling $\eta = 1$ > original $\eta = 1$ > original $\eta = 2$. The Atkinson and Generalized Entropy (Theil) Inequality Measures, Gini Coefficient and Lorenz Curve results reinforce the conclusions of the histograms and kernel density estimators that raising η from $\eta = 1$ to $\eta = 2$ paradoxically creates more losers than gainers and decreases equity among States parties and global social welfare when reallocating proportions or shares of a fixed amount on the basis of η. A limited number of States parties enjoy exceptionally large gains in allocated shares regardless of the formula.

7. The equity of distribution to ISA regions depends upon heterogeneity of each region's States parties by population share P_i and to a lesser extent the magnitude of each State party *i's* social distribution weight $\omega_i = \left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1}$. The ranking of equitable distribution among States parties by ISA region from the most to least equitable distribution (where relative equity is determined by the Atkinson and Generalized Entropy measures) is:

    1. Eastern European Group
    2. Western European and Others Group
    3. Africa Group
    4. Latin American and Caribbean States
    5. Asia Pacific Group

8. The same ranking of the distribution for social welfare among States parties is found as with the ranking of relative inequality, i.e., the EEG group receives highest social welfare relative to others, WEOG next most etc.
9. Changing the distribution formula is the best way to alter the equitable distribution of allocated shares S_i among States parties. Paradoxically, raising the progressivity parameter η, the elasticity of the social marginal utility of income, from $\eta = 1$ to $\eta = 2$ lowers rather than raises the distribution of allocated shares' equity among States parties and social welfare. Raising the value of η creates proportionately more losers than gainers among States parties and a limited number of gainers enjoy considerable gains in allocated share S_i.
10. Although not reported here, there is a very similar and consistent pattern for both Article 140 and Article 82 distributions.
11. A statistical (generalized linear model regression) analysis shows that share of population P_i has several orders of magnitude greater impact upon S_i than does the social distribution weight $\omega_i = \left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1}$ for all formulae.
12. Even when excluding P_i from the formula for S_i, so that the formula depends only upon $\omega_i = \left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1}$, the statistical analysis gave the same result (that P_i's impact upon S_i is orders of magnitude larger than ω_i). Similarly, the correlation coefficient between P_i and S_i is substantially larger than the correlation coefficient between ω_i and S_i (both are always statistically significant at 5 per cent or higher).

2. Empirical results in detail

The balance of this discussion now examines the relative inequality among States parties and the impact upon global social welfare of the distribution of the allocated shares S_i from the three different allocation formulae in terms of an *ex-post* analysis using measures of relative inequality and impact upon global social welfare.

Table 4 reports summary statistics for the three allocation formulae. Tables

Table 4. Summary statistics of allocated shares for the original, geometric mean and original with floor and ceiling formulae

Type of Allocated Shares S_i	Mean $\eta = 1$	Skew-ness $\eta = 1$	Skew-ness $\eta = 2$	Minimum Share $\eta = 1$	Mini-mum Share $\eta = 2$	Maxi-mum Share $\eta = 1$	Maxi-mum Share $\eta = 2$	More or Less Compact with Larger η?
Original	0.0060	10.11	7.82	3.77E-08	3.72E-10	0.3078	0.2833	More
Geometric Mean	0.0060	3.92	4.11	2.72E-05	3.44E-06	0.0778	0.0948	More
Original with Floor (0.00001) and Ceiling (0.1631)	0.0060	5.82		0.0000112		0.1631		

Note: A blank cell for the original formula with a floor and ceiling arises since the allocated share S_i was not calculated for η=2. Mean share values (column 2) are arithmetic means.

A.2.2.–A.2.4. in Appendix 2 provide detailed summary statistics by percentile of recipient States Party for each of the three allocation formulae for Article 140 allocations.

Table 4 also evaluates the distribution of the allocated shares among States parties when $\eta = 2$ rather than $\eta = 1$ to assesses the sensitivity of the distribution to a higher value of the progressivity parameter η. Appendix 2 Tables A.2.46.-A.2.48. for Article 140 allocations provides more detail upon the distribution of the allocated shares for $\eta = 2$.

The geometric mean formula (with η=1) has a minimum allocated share S_i ($minS_i$=0.0000272) that exceeds the minimum S_i of the original ($minS_i$=3.77e-08=0.0000000377) and exceeds the original with floor (minimum, $minS_i$=0.0000112) and ceiling (maximum) formulae. Thus, the minimum shares $minS_i$ for the three formulae ranked from largest to smallest is: geometric mean > original with floor and ceiling > original.

The geometric mean formula (with η=1) has maximum allocated share S_i ($maxS_i$=0.0778) that is less than the maximum S_i of the original ($maxS_i$=0.3078) and the original with floor (minimum) and ceiling (maximum, $maxS_i$=0.1631) formulae. Thus, the largest shares $maxS_i$ for the three formulae ranked from smallest to largest is: geometric mean > original with floor and ceiling > original.

Larger skewness values correspond to a more skewed distribution of the allocated shares S_i, notably a longer tail for larger values. Conversely, a less skewed distribution is more compact than a more skewed distribution. Thus, the skewness for the three formulae (with η=1) ranked from least skewed to most skewed is: geometric mean (3.92) > original with floor and ceiling (5.82) > original (10.11).

The distribution among States parties of the allocated shares S_i for the three formulae (with η = 1 can be visually displayed by the histogram in Figure 1. In the figure, the original formula is depicted by red, the original with floor and ceiling is depicted by orange, and the geometric mean formula is depicted by blue. Appendix 2, Figures A.1.17.–A.1.19. have histograms and kernel density estimation figures[56] (essentially a smoothed histogram) for each individual formula.

[56] Kernel density estimation smooths a discrete histogram to better display the underlying shape of the data through nonparametric regression smoothing (Härdle 1990). Rather than the step function of the histogram, the kernel density plot connects the histogram's midpoints, as well as giving more weight to data that are closest to the point of evaluation rather than equally weighting each data point in a bin.

Figure 1 clearly shows that the order of most skewed to least skewed distribution of allocated shares S_i is original (red) > original with floor and ceiling (orange) > geometric mean (blue). The original formula (red) has the lowest shares (S_i = 3.77e-08 or 0.0000000377) of the three formulae, although that cannot be seen from the histogram due to the degree of resolution. The original with floor and ceiling formula (orange) has the highest frequency of minimum shares at the floor level, followed by the geometric mean formula (blue), in turn followed by the original formula (red). The original formula (red) has a maximum value share of 0.3078 which exceeds the maximum value of the original with floor and ceiling formula (orange) of 0.19, which in turn exceeds the maximum value of the geometric mean formula (blue) of 0.0778. The original formula (red) and the original with floor and ceiling formula (orange) both have a higher frequency of high-valued shares allocated among States parties than the geometric mean formula (blue).

Kernel density estimators, which are essentially smoothed histograms, give essentially the same results as for the histograms.

Figure 1. Histogram of allocated shares among States parties for the original, geometric mean and original with floor and ceiling formulae

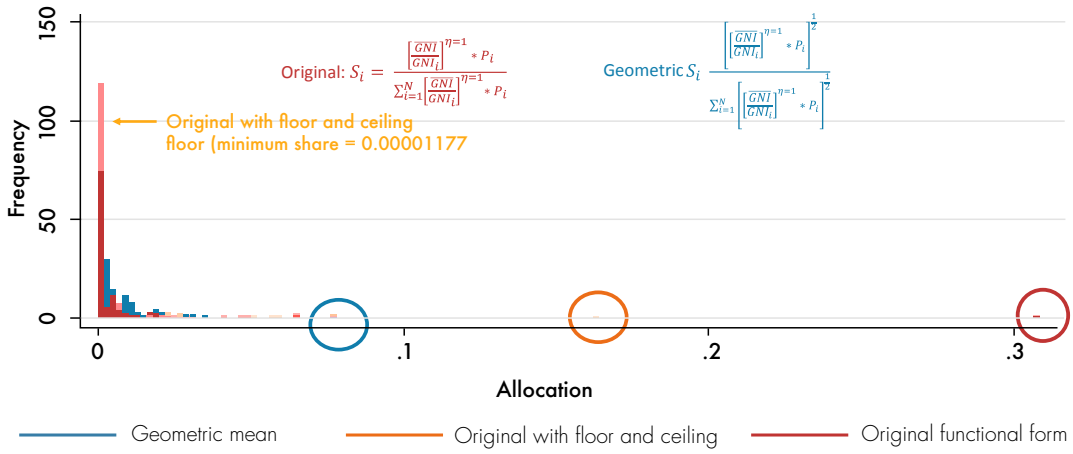


Figure 2. Kernel density of allocated shares among States parties for the original, geometric mean and original with floor and ceiling formulae

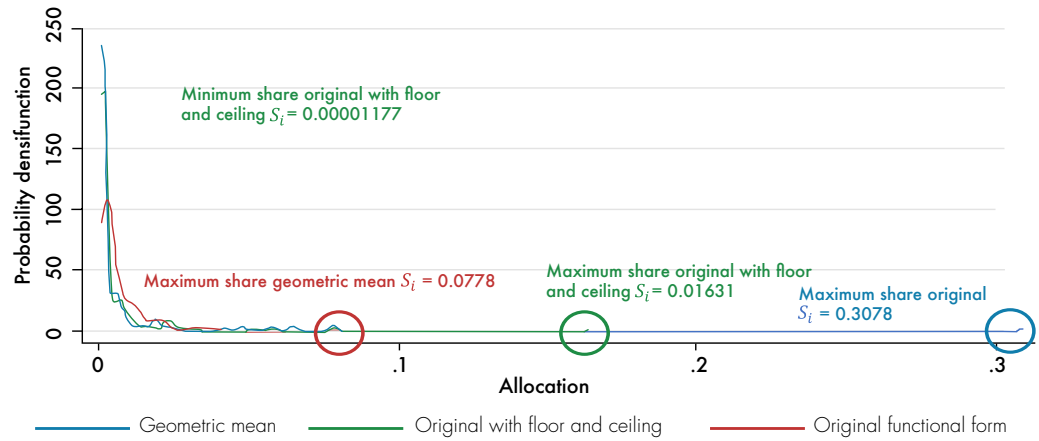
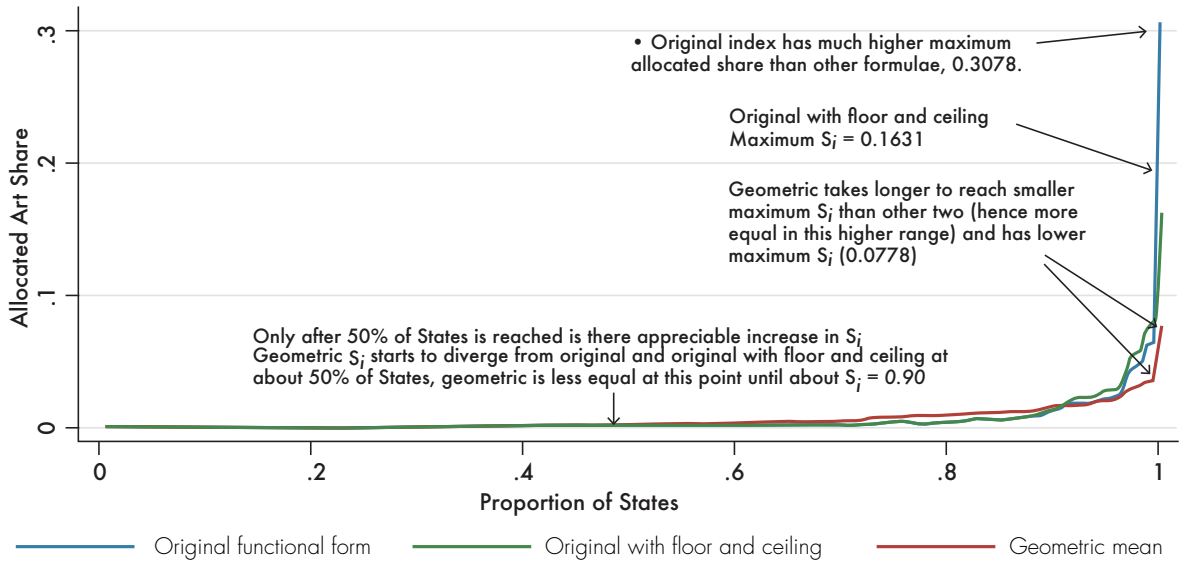


Figure 3. Pen's parade of allocated shares among States parties for the original, geometric mean and original with floor and ceiling formulae[57]

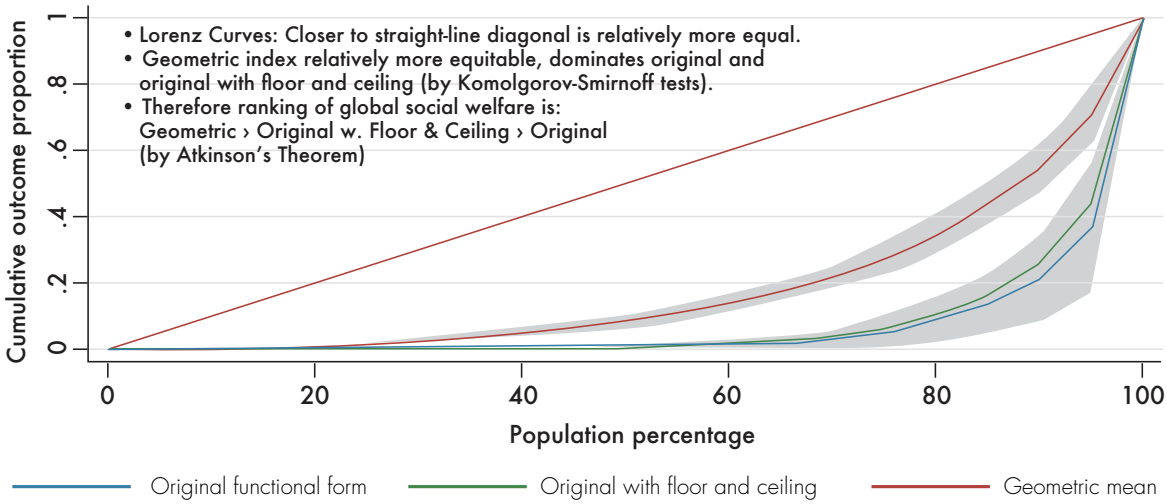


Looking at the lower end of the distribution (small number of States parties with small allocated shares), it is hard to see a great divergence of the allocated shares for the three formulae due to the low degree of resolution. After about 50 per cent of the States parties have been allocated shares, a divergence is depicted in Figure 3. That is, the geometric mean formula starts to diverge from the original and original with floor and ceiling formulae. After around 90 per cent of the States parties have received allocated shares, the original and original with floor and ceiling formulae receive larger allocated shares than the geometric mean formula. That is, as depicted by the histogram (Figure 1) and kernel density estimator (Figure 2), the geometric mean takes longer to reach smaller large shares. In this sense, the geometric mean formula is more equitable. After almost all States parties have been allocated shares (the far right-hand side of the figure), the original formula clearly has the highest allocated share followed by the original with floor and ceiling formula followed by the geometric mean formula (i.e., the original formula has the highest height, with the floor and ceiling formula shorter, and the geometric mean formula the shortest).

The Lorenz curve in Figure 4 clearly shows that the geometric mean formula (red) has the most equitable distribution among States parties followed by the original

[57] Pen's Parade depicts the succession of every State party with each State party's "height" (vertical height or location on the vertical axis) proportional to its allocated share S_i, and ordered from the lowest to highest. States parties are thus lined up in order of their "height" or magnitude of S_i from "shortest" to "highest". States parties with the smallest allocated share S_i are first in line (furthest to the left and lowest in "height" in the parade) and States parties with the highest allocated share S_i are last in line (furthest to the right in the parade). The State party with the average S_i is endowed with average "height" or average allocated share S_i, 0.005988. The States parties in the parade march past in some given time interval and the sight we see is depicted by the curve in Figure 3. The parade shows a parade of States parties with small distributions, and then some giants (large shares) toward the very end of the parade.

Figure 4. Lorenz curve for allocated shares among States parties for the original, geometric mean and original with floor and ceiling formulae[58]



with floor and ceiling formula (green) followed by the original formula.[59] The geometric mean formula allocation begins to diverge from the other two formula after around 10–12 per cent of the States parties receive an allocation. The original with floor and ceiling formula allocation begins to diverge from the original formula allocation only after about 55 per cent of the States parties receive an allocation. The divergence between the original and original with floor and ceiling formulae allocations narrows after almost all of the States parties receive allocations.

Table 5 measures the relative inequality of distributed shares S_i among States parties for the three alternative allocation formulae using the Atkinson and Generalized Entropy (Theil) inequality measures, the Gini coefficient, the ratio of the 90th to 10th percentiles and skewness measure for the distributed S_i. Appendix 5 discusses each of the relative inequality measures in detail. The Atkinson measure ranges between 0 and 1, with lower values indicating greater equality and social welfare. The Generalized Entropy (Theil) measures range between 0 and infinity, with lower values indicating greater equality and greater social welfare. The Gini coefficient ranges between 0 and 1, with lower values indicating greater equality.

Table 5's rows correspond to the three different types of allocation formulae: (1) the original; (2) geometric mean; and (3) original with floor and ceiling. Each column gives a type of relative inequality measure and the ranking of each allocation formulae by that measure of relative inequality among States parties. For example, the second row is for the original allocation formula and the second

[58] The Lorenz curve depicts income inequality by comparing it to the straight diagonal line, which represents perfect equality among States parties in allocated share S_i distribution. The Lorenz curve, which lies beneath the diagonal line, shows the actual distribution. The wider the disparity between the diagonal line and the Lorenz curve, the greater the disparity in allocated shares among States parties. Appendix 2 provides more discussion of the Lorenz curve.

[59] A Kolmogorov-Smirnov type test statistic based on the largest positive difference shows that the geometric mean Lorenz Curve differs from the original Lorenz Curve (KS Test Statistic [p-value] = 6.52e+00 [0.0000]). The same test shows that the original and original with floor and ceiling differ (KS Test Statistic [p-value] = 6.52e+00 [0.0000]). The same test shows that the geometric mean Lorenz Curve differs from the original with floor and ceiling Lorenz Curve (KS Test Statistic [p-value] = 6.32e+00 [0.0000]).

column is for the Atkinson inequality index with the inequality aversion parameter γ = 0.5. The geometric mean formula has the lowest relative inequality of the distributed S_i (indicated by the number 1 in parenthesis under the actual Atkinson measure of 0.33077), the original with floor and ceiling formula has the second lowest relative inequality (indicated by the number 2 in parenthesis under the Atkinson value of 0.64778), and the original formula has the most inequitable distribution (indicated by the number 3 in parenthesis under the Atkinson value of 0.69352).

Every single measure of relative inequality with $\eta = 1$ indicates that the geometric mean formula is the most equitable among States parties, followed by the original formula with floor and ceiling, and followed by the original formula. The same values and results are obtained whether the inequality measures are applied to allocated shares S_i or an actual allocation, i.e., $F_i = S_j E$, where F_i the actual dollar amount allocated to State party i and E is the total amount of royalties to be allocated among the 167 States parties. This result is consistent with the Lorenz curve depicted in Figure 4.

Table 5. Measures of relative inequality and social welfare for the allocated shares or actual allocation for the original, geometric mean and original with floor and ceiling formulae[58]

Type of Allocated Shares S_i	Atkinson Inequality Index $A(\gamma) = 0.5$	Atkinson Inequality Index $A(\gamma)$ $\gamma = 1$	Atkinson Inequality Index $A(\gamma)$ $\gamma = 2$	Gini Coefficient w. Standard Error	Theil's First (T) Inequality index GE (1)	Theil's Second (L) Inequality index GE (0)	Percentile Ratio p90/p10	Skewness
Linear	0.69532 (3)	0.94910 (3)	0.99948 (3)	0.8694 (3)	1.97984 (3)	2.97793 (3)	2385.228 (3)	10.11 (3)
Geometric	0.33077 (1)	0.59128 (1)	0.87892 (1)	0.6264 (SE=0.0285) (1)	0.71947 (1)	0.89472 (1)	48.839 (1)	3.92 (1)
Linear with Floor (0.00001) and Ceiling (0.1631)	0.64778 (2)	0.92465 (2)	0.99063 (2)	0.8431 (SE=0.0249) (2)	1.62406 (2)	2.58561 (2)	1454.887 (2)	5.82 (2)

Notes: Each column includes the relative inequality measure and inequality rank for that column (given in parenthesis below the relative inequality measure).
Atkinson: Lower values are more equal, $0 \leq A(\gamma) \leq 1$. Higher γ denotes higher inequality aversion.
Generalized Entropy:
Theil T = GE(1) & Theil L = GE(0): $0 \leq GE(0), GE(1) \leq \infty$, lower values are more equal.
GE(1) is more sensitive to higher income than GE(0).
With positive and large α, the index G*E* will be more sensitive to what happens in the upper tail of the income distribution.
With positive and small α, the index G*E* will be more sensitive to what happens at the bottom tail of the income distribution.
Gini coefficient: Lower values are more equal, $0 \leq G \leq 1$. Standard error given in parentheses.
All values equivalent for allocated share $0 \leq S_i \leq 1$ and allocated share of notional sum of US$500 million.

Equitable distribution for States parties with per capita *GNIs* less than mean per capita *GNI* for all ISA States parties

Table 6 and Figure 5 below examine the relative inequality of the three allocation formulae for States parties with per capita GNIs that are less than the mean per capita GNI for all ISA States parties with η=1. This criterion is equivalent to a social distribution weight greater than one: $\omega_i = \left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1} > 1$.

The results in Table 6 and Figure 5 show that the geometric mean allocation formula provides the most equitable allocation among States parties when η =1.

Table 6 evaluates the relative inequality of the three allocations for the States parties with per capita GNIs that are less than the mean per capita GNI for all ISA States parties with η =1. The results are consistent with the relative inequality calculated over all States parties, presented in Table 3. Hence, the geometric allocation formula is most equitable for any degree of inequality aversion.

Table 6. Measures of relative inequality and social welfare for the allocated shares or actual allocation for the original, geometric mean and original with floor and ceiling formulae: per capita GNI < global mean per capita GNI (ω_i>1), η=1

Formula/ Measure	Atkinson Inequality Index A(y) γ=1	Atkinson Inequality Index A(y) γ=2	Theil´s Second (L) Generalized Entropy Inequality Index GE(0)	Theil´s First (T) Generalized Entropy Inequality Index GE(1)	Gini Coefficient
Original	0.91637 (3)	0.99827 (3)	2.48130 (3)	1.69906 (3)	0.8295325 (3)
Geometric	0.52667 (1)	0.83916 (1)	0.74796 (1)	0.58325 (1)	0.5716104 (1)
Original with Floor and Celling (0.1631)	0.88677 (2)	0.99021 (2)	2.17833 (2)	1.34792 (2)	0.7951952 (2)

Notes: Each column includes inequality measure among States parties and inequality rank for that column.
Atkinson: Lower values more equal, 0≤ A(γ) ≤1. Higher γ is higher inequality aversion.
Generalized Entropy:
Theil T = GE(1) & Theil L = GE(0): 0 ≤ GE(0), GE(1) ≤ ∞, lower values are more equal.
GE(1) more sensitive to higher income than GE(0).
With positive and large α, the index G*E* will be more sensitive to what happens in the upper tail of the income distribution.
With positive and small α, the index G*E* will be more sensitive to what happens at the bottom tail of the income distribution.
Gini coefficient: Lower values are more equal, 0 ≤ G ≤ 1. Standard error given in parentheses.
All values equivalent for allocated share $0 \leq S_i \leq 1$ and allocated share of notional sum of US$500 million.

Figure 5. Lorenz curve for shares allocated among States parties for the original, geometric mean and original with floor and ceiling formulae η=1: per capita GNI < global mean per capita GNI.

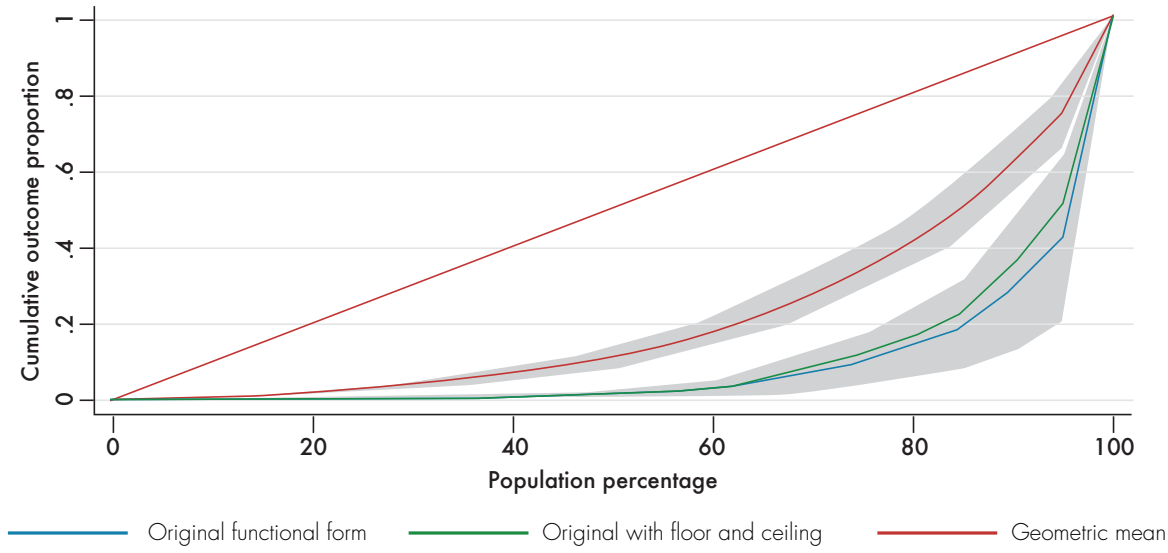
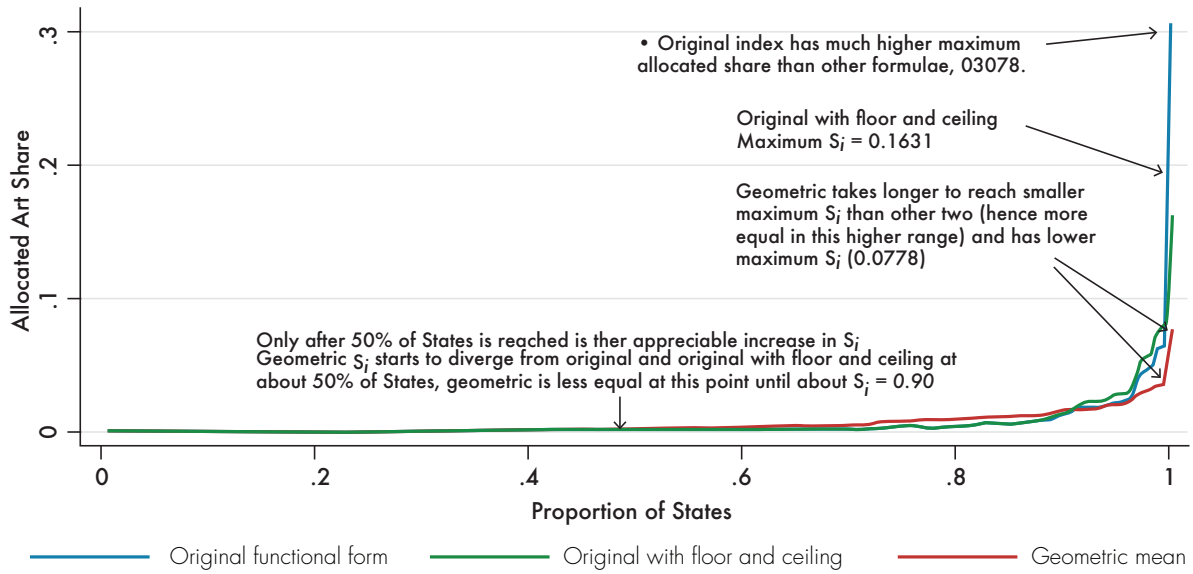


Figure 6. Pen's parade for shares allocated among States parties for the original, geometric mean and original with floor and ceiling formulae η=1: per capita GNI < global mean per capita GNI.



The Lorenz Curve for the three allocation formulae for the States parties whose per capita GNI is less than the mean global per capita GNI for all States parties shows that the geometric mean index clearly gives a more equitable distribution among these States parties and that the original and original with floor and ceiling give very close results to one another except at the lowest allocation shares (as expected due to the floor and the inapplicability of the ceiling).[60] Note that because η=1, the analysis and results are equivalent to evaluate on the basis of the social distribution weights ω_i.

Pen's Parade in Figure 6 clearly shows that the geometric mean allocation formula allocates larger shares to more States parties with per capita GNI less than the mean per capita GNI than do the original formula or the original with floor and ceiling.

Distribution of shares allocated among States parties by ISA regions

The shares allocated among States parties S_i for the original formula η=1, ranked by size from largest to smallest is, as indicated by Table 4, is:

1. Africa Group (Africa) 28.144%
2. Asia-Pacific Group (APG) 26.946%
3. Latin American and Caribbean Group (GRULAC) 17.356%
4. Eastern European Group (EEG) 13.722%
5. Western European and Other Group (WEOG) 13.722%.

Table 7. Summary statistics of allocated shares by region for original formula η=1

REGION	Popn. share	Mean	--00000F	Income share	log(mean)
APG	0.26946	0.01282	2.14122	0.57697	-4.35662
Africa	0.28144	0.00803	1.34067	0.37731	-4.82482
EEG	0.13772	0.00064	0.10756	0.01481	-7.34773
GRULAC	0.17365	0.00092	0.15406	0.02675	-6.98837
WEOG	0.13772	0.00018	0.03009	0.00414	-8.62167

[60] A Kolmogorov-Smirnov type test statistic based on the largest positive difference shows that the geometric mean Lorenz Curve differs from the original Lorenz Curve (KS Test Statistic [p-value] = 6.52e+00 [0.0000]). The same test shows that the original and original with floor and ceiling differ (KS Test Statistic [p-value] = 6.52e+00 [0.0000]). The same test shows that the geometric mean Lorenz Curve differs from the original with floor and ceiling Lorenz Curve (KS Test Statistic [p-value] = 6.32e+00 [0.0000]).

Tables 8–13 provide Atkinson and Generalized Entropy (Theil) and Gini Coefficient values for the equity of allocated shares to each ISA regional group for the original formula (Tables 8–9), geometric mean formula (Tables 10–11), and original with floor and ceiling formula (Tables 12–13) with η =1. The relative rankings for each measure are given in parenthesis and outlined by red (on a column-by-column basis, for each measure, where rows give ISA regional group). The relative rankings of equitable distribution among States parties are consistent across the Atkinson and Generalized Entropy (Theil) and Gini Coefficient values.

The equity of distribution to ISA regions depends upon heterogeneity of each region's States parties by population share P_i and to a lesser extent the magnitude of each State party i's social distribution weight $\omega_i = \left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1}$. The ranking of equitable distribution by ISA region from the most to least equitable distribution (where relative equity is determined by the Atkinson and Generalized Entropy measures) is:

1. Eastern European Group
2. Western European and Other Group
3. Africa Group
4. Latin American and Caribbean Group
5. Asia Pacific Group

The same ranking of the distribution for social welfare is found as with the ranking of relative inequality among States parties, i.e., EEG group States parties receive highest social welfare relative to other States parties, WEOG next most, etc. with η =1.

Table 8. Atkinson inequality values of shares allocated among States parties by region: original formula, η=1

	Less Inequality aversion.			More inequality aversion.
REGION	A (0.5)	A (1)		A (2)
APG	0.75846	0.98411	(5)	0.99990
Africa	0.38204	0.74293	(3)	0.98895
EEG	0.40294	0.63592	(1)	0.83009
GRULAC	0.50896	0.86709	(4)	0.98700
WEOG	0.34305	0.69423	(2)	0.99087
Pacific Island Developing P-SIDS	0.69532	0.94910		0.99948

Atkinson: Lower values more equal, $0 \leq A(y) \leq 1$.

Table 9. Generalized entropy (Theil) inequality values and Gini coefficient of shares allocated among States parties by region: original formula, η=1

	More sensitive to low income					More sensitive to high income		
REGION	GE (-1)	GE (0)		GE (1)		GE (2)	Gini	
APG	5.20E+03	4.14187	(5)	2.06716	(5)	6.59926	0.89425	(5)
Africa	44.73293	1.35840	(3)	0.76718	(2)	1.09034	0.64294	(2)
EEG	2.44274	1.01038	(1)	0.98184	(3)	1.76314	0.68547	(3)
GRULAC	37.95828	2.01812	(4)	1.04958	(4)	1.50736	0.73359	(4)
WEOG	54.26158	1.18492	(2)	0.65766	(1)	0.72040	0.60414	(1)
P-SIDS	961.13738	2.97793		1.97984		9.08714	0.86938	

Gini coefficient: Lower values more equal, $0 \leq G \leq 1$.
Theil T= GE(1) & Theil L = GE(0): $0 < GE(0), GE(1) \leq$, lower values more equal.
With positive and large a, the index GE will be more sensitive to what happens in the upper tail or the income distribution.
With positive and small a, the index GE will be more sensitive to what happens in the bottom tail or the income distribution.

Table 10. Atkinson inequality values of shares allocated among States parties by region: geometric mean formula, η=1

	Less Inequality aversion.			More inequality aversion.
REGION	A (0.5)	A (1)		A (2)
APG	0.44150	0.74349	(5)	0.94780
Africa	0.16616	0.35502	(3)	0.70472
EEG	0.11976	0.21911	(1)	0.36744
GRULAC	0.24701	0.47975	(4)	0.75054
WEOG	0.14500	0.31777	(2)	0.70734
P-SIDS	0.33077	0.59128		0.87892

Atkinson: Lower values more equal, $0 \leq A(y) \leq 1$.

Table 11. Generalized entropy (Theil) inequality values and Gini coefficient of shares allocated among States parties by region: geometric mean formula, η=1

	More sensitive to low income					More sensitive to high income		
REGION	GE (-1)	GE (0)		GE (1)		GE (2)	Gini	
APG	9.07877	1.36057	(5)	0.97262	(5)	1.57007	0.71252	(5)
Africa	1.19331	0.43853	(3)	0.30831	(3)	0.30912	0.42591	(3)
EEG	0.29044	0.24732	(1)	0.26041	(1)	0.33743	0.38097	(1)
GRULAC	1.50434	0.65345	(4)	0.47993	(4)	0.51824	0.53108	(4)
WEOG	1.20844	0.38239	(2)	0.26810	(2)	0.26109	0.39939	(2)
P-SIDS	3.62952	0.89472		0.71947		1.14107	0.62635	

Gini coefficient: Lower values more equal, $0 \leq G \leq 1$.
Theil T= GE(1) & Theil L = GE(0): $0 \leq GE(0), GE(1) \leq$, lower values more equal.
With positive and large a, the index GE will be more sensitive to what happens in the upper tail or the income distribution.
With positive and small a, the index GE will be more sensitive to what happens in the bottom tail or the income distribution.

The next two tables, Tables 12–13, present the Atkinson, Generalized Entropy (Theil), and Gini Coefficient inequality measures for the original with floor and ceiling formula with η=1. The results are consistent with the original and geometric mean formulae with η=1.

Table 12. Atkinson inequality values of shares allocated among States parties by region: original with floor and ceiling formula, η=1

	Less Inequality aversion.			More inequality aversion.
REGION	A (0.5)	A (1)		A (2)
APG	0.71150	0.96787	(5)	0.99673
Africa	0.38150	0.73567	(3)	0.97622
EEG	0.40294	0.63592	(1)	0.83009
GRULAC	0.49765	0.83461	(4)	0.96901
WEOG	0.31409	0.57418	(2)	0.81667
P-SIDS	0.65558	0.92691		0.99089

Atkinson: Lower values more equal, $0 \leq A(y) \leq 1$.

Table 13. Generalized entropy (Theil) inequality values and Gini coefficient of shares allocated among States parties by region: original with floor and ceiling formula, η=1

	More sensitive to low income					More sensitive to high income		
REGION	GE (-1)	GE (0)		GE (1)		GE (2)	Gini	
APG	142.15783	3.37551	(5)	1.67107	(5)	3.42355	0.85827	(5)
Africa	20.61012	1.33073	(3)	0.76704	(2)	1.09028	0.64291	(2)
EEG	2.44274	1.01038	(2)	0.98184	(3)	1.76314	0.68547	(3)
GRULAC	15.68981	1.80056	(4)	1.04133	(4)	1.50189	0.73150	(4)
WEOG	2.24184	0.85519	(1)	0.63137	(1)	0.70553	0.59507	(1)
P-SIDS	52.87832	2.58561		1.62406		4.16830	0.84305	

PART V: SEABED SUSTAINABILITY FUND[61]

As we have seen from the previous chapters of this report, there are various options for distributing the net financial benefits generated by seabed minerals exploitation in the Area.

First, one could consider the simple **financial distribution** of the net benefits based on rules or formulae. By calling this form of distribution "simple" we do not pretend that it would be easy to agree upon or to set up. This option is elaborated in detail in Part 3 and 4 of the present report. The sophisticated formulae described in Parts 3 and 4 capture multiple dimensions of fairness leading to a calculated outcome (i.e., a formula to distribute money). The formula must be applied dynamically and be recalculated on a regular basis to adapt to the changing parameters (e.g., evolution of population, economic performance etc.). In any case, the idea is to collect the net financial benefits and to transfer the monetary proceeds to the pool of qualified beneficiaries.

A second option, as an adjunct or an alternative, could be to make a **qualitative distribution**. The financial benefits would be wisely used to generate qualitative benefits that would be made available to mankind. The qualitative benefits would take the form of knowledge and competence related to the Area and of physical improvements to the Area.

In other words, the financial benefits would be used to invest in people and in preserving and developing the Area sustainably so that it truly becomes a cherished heritage that maintains its inherent value for the generations to come rather than a mere exploitable, and possibly depletable, source of immediate financial gain. In this scenario, the main objective is to seek a balance between two extremes, viz., not touching the heritage at all and alternatively using it rather blindly for immediate financial return. It seeks to establish a true appreciation for the value of the heritage. If, after having made all effort to keep the heritage intact and having given the opportunity to all inheritors to benefit from it qualitatively, surplus financial gains remain, then these could possibly be distributed as under the first option.

Arguably the second option is more in line with the precautionary approach than the first one. Considering that resources will be needed to further advance the general understanding and knowledge of the deep sea and its ecosystems with a view to ensuring rigorous and sound management of the Area, it might be unwise to collect financial resources and then to create "financial entropy" by simply distributing these resources again. Evidence provided by multilateral institutions with global conservation objectives shows how difficult it is to

[61] This part was prepared for ISA by Stefan Depypere and Heleen Raat of SDP-Consult (De Pinte, Belgium).

mobilize financial resources for a common purpose.[62]

In this particular case, it will be nearly impossible to "re-collect" the funds in a second stage to finance worthwhile collective goods related to the seabed. It is worth considering that the seabed, being "terra communis",[63] is an orphan with only one true foster parent, viz., ISA, and that the foster parent, whilst having built a considerable centre of competence and being a proficient advocate, can presently only mobilize modest financial resources.[64] ISA acts as a custodian for the seabed but, considering that there is more seabed than dry land on the planet, the custodian must act with very limited resources.

It is needless to remind the reader of the vast array of natural services provided by the ocean – whether in the Area or in the Exclusive Economic Zones (EEZs) and Continental Shelf (CS) – for the benefit of mankind, including oxygen production, heat capture, carbon capture and other services such as quality food production.[65] It must be clear that a well-managed ocean is of tremendous benefit, not only for the countries that are closely connected to it because they are islands or coastal states, but also for landlocked countries. The latter might a priori prefer immediate financial returns, but ultimately, they also depend on the ocean for the supply of the services just mentioned. It is the long-term interest of mankind as a whole to invest enough in the ocean.

We see only one practical possibility to achieve this, and that will be through the creation of a Seabed Sustainability Fund, using the financial benefits from seabed mining to stock up this fund. It would of course be of the utmost importance to set it up properly.

Overview of the Seabed Sustainability Fund (SSF)

Scope

The objective of the Fund would be to invest in knowledge and competence related to the Area. As such, it would bring about a practical solution to the precondition for actually starting the exploitation in the first place, i.e., a precautionary and sustainable approach. Brought together in broad categories, the fund could thus finance:

Research

Promotion of research to develop and monitor the necessary technology and to ensure the acquisition of marine scientific knowledge.[66] It is useful to refer to the conclusion on the purpose of the sustainability fund, discussed during the preparations of the mining code: "The promotion of research into methods of marine mining engineering and practice by which environmental damage or impairment resulting from Exploitation activities in the Area may be reduced".[67]

Research would involve the entire range from basic research to applied research and innovation. A concern from conservationists and some scientists is that finalizing the Mining Code will encourage mining before enough information is gathered about how mining operations

[62] E.g., the Global Environment Facility (GEF) mentions the difficulty to collect the required funding for its seventh round of funding (GEF7). Description in Annex 1, and see, for that matter, the experience of ISA itself, namely that "no contribution was received from international organizations" for the EFMSR.
[63] In the minds of some, it might even still be considered "*terra nullius*". In any case, no individual State has or feels any particular responsibility for the Area (de Borchgrave, 2019).
[64] As an example, ISA's Endowment Fund relies on a total capital of US$3.5 million (24/04/2020).
[65] It has been amply shown that fishery products supply essential nutrients than cannot easily be found in other foodstuffs.
[66] 1994 Agreement, Annex, section 1(5)(i).
[67] ISBA/26/C/IWG/ENV/CRP.1, May 2020.

can avoid environmental harm (Heffernan, 2019; Van Poppel, 2020; Rossi, 2010). There is a demand for more robust risk assessments, especially those that bring together science, conservation, industry and regulators. The SSF, due to its possibility to generate liquidity streams upfront, would offer a unique opportunity to scale up this effort at an earlier stage, which would be a logical step in the concept of the evolutionary approach, and would allow the undertaking of more types of research and make it even more inclusive. In this way, ISA could further develop in its role as a platform for research and cooperation and fasten the roll-out of existing initiatives such as DeepData.[68] This would allow ISA to pre-empt and counter possible residual criticism and assert its approach of moving forward in an evolutionary way without neglecting its precautionary approach, while maintaining a high level of trust among the stakeholder base.

This objective should be pursued in close connection with a strategy to carry out the research in a decentralized manner and to put in place technology transfer so as to foster maximum involvement of all parties.

Capacity building

This element should aim at developing tools of inclusivity, offering an opportunity to all people of the entire planet (in particular those of vulnerable communities and relevant stakeholders) to take part through basic or advanced seabed education and specific technical training.

It is suboptimal to set up governance tools or to generate scientific knowledge unless a wide group of participants from all member countries are capable of fully understanding and using the outcomes. Moreover, if we wish the seabed to be properly managed, then pure scientific knowledge will not suffice. There will also be a major need for technicians, verifiers, auditors, observers etc. At present, there are virtually no generally accessible possibilities to build these competences. Apart from capacity building aimed at highly skilled professionals, there could also be an effort to create awareness and offer basic technical insight for the general public of interested citizens.

The inclusivity toolbox would also contain a proactive information system, rolled out in all member countries, about the opportunities offered by the SSF. As the seabed and its wealth are the common heritage of mankind, everybody should feel involved, or at least have the opportunity to become involved. Clearly, the inclusivity objective aims particularly at attracting a high number of participants (agencies, universities, companies and individuals) from developing states. One would naturally expect a high interest from Small Island Developing States (SIDS) but also all other developing States and, in particular, Landlocked Developing Countries (LLDCs) and less-technologically advanced States should look carefully into what the SSF could offer.

This information system could also include a platform where former participants of the programmes could share their experiences, which could improve the visibility of these programmes. Based on these shared experiences, adaptations could be made to the programmes to increase long-term impact.

The clear objective would be to bring a high number of participants up to the highest level of knowledge and competence and to create the conditions for retaining and using these competences on a local basis. Therefore, it is also important to encourage capacity building on an institutional level. Retaining the trained manpower allows institutions to further develop and forge cooperation internationally.

[68] https://www.isa.org.jm/index.php/deepdata.

Endowment Fund for Marine Scientific Research

ISA is already mandated under UNCLOS to promote and encourage the conduct of marine scientific research in the Area for the benefit of mankind as a whole. The Endowment Fund for Marine Scientific Research (EFMSR) was established by ISA's Assembly in its decision ISBA/12/A/11 in order to implement this obligation. The purpose of the Fund is in particular "supporting participation of qualified scientists and technical personnel from developing countries in marine scientific research programmes and providing them with opportunities to participate in international technical and scientific cooperation, including through training, technical assistance and scientific cooperation programmes". The total capital of this fund in April 2020 was US$3.5 million, of which only the accrued interest can be used, limiting its potential. In addition, this limitation leads to difficulties attracting interest from potential donors to contribute to the EFMSR. Hence, it is fair to say that the EFMSR could potentially be the appropriate qualitative solution, although some adjustments should be made in the way it operates and its financial resources should be fundamentally increased.

Training programmes with contractors

Offering dedicated training programmes is obligatory for all entities engaged in deep-sea exploration. Accordingly, the modalities through which such trainings are implemented are fully part of the contract signed between ISA and the Contractors. The objective of these Contractor Training Programmes (CTPs) is to increase capacity building of nationals of developing member States and ISA's personnel. As the number of contracts signed has recently increased, it is expected that 300 training opportunities will be available in the period 2020–2024. Thorough review of these training programmes indicated that they are considered to be successful based on feedback of Contractors and participants. However, it is again fair to say that 60 training opportunities per year is too modest quantitatively. Issues relating to these training programmes are that benefits to ISA and to participants are not clear in the long-term. The review suggested to establish a capacity building and training division within the Secretariat and to increase the outreach of these programmes by developing regional centres. These programmes could continue as before and, for that matter, be expanded to include staff of the Authority itself.

See: Workshop on Capacity building, needs and resources assessment: "Key findings of the assessment of the Contractor Training Programme", ISA, February 2020

The SSF would have a sufficient critical mass to guarantee participants from all over the globe a long-term opportunity to use their acquired knowledge and competence without having to travel outside of their region. By anchoring seabed-related activity locally, one could achieve a high sense of ownership and interest in all member countries. The importance of inclusivity has been identified by major economists as a basis for economic prosperity.[69]

Fostering other public goods related to the seabed

Besides research and capacity-building, consideration should also be given to use the proceeds of DSM for the protection and/or sustainable management of other

[69] E.g., Acemoglu and Robinson (2012). This book underlines the importance of good governance and inclusivity.

Statement of purpose of a sustainability fund

"The main purposes of the [Sustainability Fund] [Environmental Research and Training Fund] include:

(a) The promotion of research into methods of marine mining engineering and practice by which environmental damage or impairment resulting from Exploitation activities in the Area may be reduced.

(b) Education and training programmes in relation to the protection of the Marine Environment with particular regards to vulnerable communities and relevant Stakeholders.

(c) The funding of research into Best Available Techniques and Best Environmental Practices for the restoration and rehabilitation of the Area.

(d) The restoration and rehabilitation of the Area as well as of the maritime zones of coastal States when technically and economically feasible and supported by Best Available Scientific Evidence; and

(e) The funding of research into the environmental values of the Area, with special focus on the deep-sea benthic habitats, as well as on migratory species which are present in the Area, to provide good quality information for the review of Regional Environmental Management Plans, as well as for the Environmental Impact Assessments that should be based on the best available knowledge."

public goods that benefit humanity (climate change, epidemiology surveillance etc.). This is also reflected in the statement of purpose of the SSF from the draft Mining Code[70] (points (c) to (e) in particular; see box below).

Basic set-up of the SSF

Arguably, most, if not all, of the actions described under "scope" will have to be undertaken. These are not just options. The view is regularly expressed that without these actions it would probably be irresponsible to allow actual large-scale mining to proceed.[71] On the other hand, with these actions, it seems perfectly appropriate to start mining operations. So, a significant funding need will exist in any case.

The advantage of setting up a fund that is financed by a steady autonomous flow of revenue, as opposed to calling on budgetary contributions or pledges, lies in the stability and the predictability of the financial resources. The terms under which the fund is set up and its governance mechanisms can enhance these features.

A first basic approach could be to collect the revenue and spend it directly. To the extent that the underlying economic activity is perfectly stable and predictable, this might work. Yet, it is evident that this basic assumption might not always remain valid, which might create problems to the extent that a predefined spending commitment would need to be met with an uncertain income pattern.

A second option would therefore be to collect the revenue, invest the principal and use the financial return to finance the projects.[72] The disadvantage here lies in the long period needed to create enough spendable revenue. Moreover, applied in its purest form, this option also generates an uncertain income because the return on the invested principal will necessarily also be variable.

[70] ISBA/26/C/IWG/ENV/CRP.1, May 2020.
[71] See, e.g., Van Poppel (2020) and Heffernan (2019).
[72] This method is used for the EFMSR.

A combined method seems advisable in generating resources quickly enough and yet offering a predictable financial flow. The exploitation income of the SSF would be invested until a decent buffer is created (a number of years of revenue) and then an amount equal to the revenue on the principal plus a percentage of all new proceeds would be available for commitments. Simulations would need to be made to align the revenue and the spending patterns (see Table 14 below). An avenue to be explored, once the SSF is set up, is whether other financing pools would be willing to provide a starting capital. It should be possible to convince funds or donors to make a financial effort, be it through a grant or through a soft loan.

It would be worthwhile indeed to start the activities mentioned under the scope not later than the time when the exploitation starts.[73] Ideally, they would start ahead and, to some extent, they have already started on a modest scale, thanks to ISA. We note in passing that article 174 of UNCLOS foresees the possibility for ISA to borrow funds (except for financing its administrative budget).[74] Also, this option could be used to frontload the SSF. In other words, once it is set up, the SSF could even borrow the required funds to start its operations. Because borrowing would be secured by a steady flow of income and because, *ultima ratio*, donors can be found to provide guarantees, favourable borrowing conditions can be expected.

Table 14. Liquidity analysis of potential SSF

Year	1	2	3	4	5	6	7	8	9	10	11
Liquidity driver											
Incoming benefit stream	50	100	150	200	250	300	350	400	450	500	550
Spending of projects	30	46	61	79	99	120	144	169	198	228	261
Donor contribution/Co-financing	20	22	24	27	29	32	35	39	43	47	52
Market borrowing	40										
Reimbursement loans				10	10	10	10				
Invested fund (stock value)	80	160	280	430	620	850	1120	1440	1800	2200	2640
Investment income											
Net Liquidity	80	80	120	150	190	230	270	320	360	400	440
Control: net liquidity= increase fund		80	120	150	190	230	270	320	360	400	440
Spending on projects 20% of incoming benefits+ co-financing or donors+ return on investment assest											
Flow in											
Flow out											
Stock value											

[73] If the participatory research and the inclusivity actions start late, many interested participants from developing countries will have incurred (again) arrears and will have great difficulty catching up.
[74] 1994 Agreement, Annex, section 1, para. 14.

Investment policy

We assume that the SSF could collect a considerable amount of resources and be capable of seeking a balanced long-term high yield on its investment. This implies investing in assets that yield a high long-term return, inter alia, equity, high-yield bonds and real estate. It would thus follow the example of a respectable institution like the UN Pension Fund, which is capable of realizing a 4.5 per cent annual return net of inflation (invested capital of around US$75 billion in 2019, but provisional figures indicate that the capital has accrued to US$80 billion by the end of 2020). Somehow the SSF would be a Sovereign Wealth Fund (SWF) set up at the level of the entire planet, probably the first such fund. In a way, one could consider that mankind presently owns a natural asset (the seabed) and would, through its exploitation, be capable of transforming this immobilized asset into a more active portfolio of productive assets. Mankind would maintain its principal but would be in a position to use the return on this investment. It would use its capital in a productive manner. The archetype of the Norwegian SWF springs to mind as an example of how the exploitation of natural resources was used cleverly to build real asset reserves to the benefit (in this case) of the entire Norwegian population.

Positive side effect 1: Leverage through investment policy
There is a possible attractive side effect in setting up an investment fund in this manner. Through its investment policy, the fund could exert investor pressure by being selective in its investable objects or even by being active as a bondholder or shareholder. It could nudge companies or governments into more sustainable behaviour. In doing so, it would adhere to a practice followed by major national SWFs and by the UN Pension Fund.

Positive side effect 2: Becoming a serious partner
A fund could leverage its activity and cooperate with other institutions that have similar objectives such as GEF, GCF etc., and with national or international organizations (e.g., the EU). By having its own pool of resources, ISA, through its SSF, could become a key partner for financing environmental projects. Being capable of offering innovative finance and combining with offers by others would greatly enhance the effectiveness of ISA and SSF.

Governance of the SSF

In terms of economy of governance systems, consideration should be given to establishing the SSF as a tool for ISA rather than a new body. This being said, we would be speaking of a new dimension of ISA's work in line with the higher level of economic activity, i.e., ISA would need to scale up tremendously and develop a set of operational rules. In the next section, we first define some theoretical ideas and then test them against reality, meaning that we check whether the present structures and procedures can perform these functions.

A number of **structures and procedures** will need to be defined. These would aim at being very precise on the objectives and operational targets, on efficiency and effectiveness, on avoiding wasteful action and on pursuing zero tolerance with regard to financial mismanagement and fraud.[75] A balance would need to be found between the cost of governance – be it the financial cost or the bureaucratic inertia – and the benefit of developing new governance tools. As a fairly decentralized set-up would be one of the basic objectives, careful attention to these aspects will be required.

[75] This is easier to maintain, as it has been until now, for a smaller institution like ISA in its present format. If the organization needs to scale up, it will need to have a fresh look at the existing procedures.

In terms of structure, it may be worthwhile to consider establishing the SSF around four functional bodies:

A body responsible for setting general policy and objectives (including the investment policy), endorsing major decisions and arbitrating in case of internal conflict. We could call this the Management Board (MB). The MB could report annually to the Assembly of ISA, which is ultimately in charge of considering and approving rules, regulations and procedures on equitable sharing of benefits (UNCLOS, article 160 (2)(f)(i)). The MB could consist of a chair, one (or more) vice chair(s) and a number of other stakeholder seats, which could be elected by the Assembly for a dedicated period. There would probably be an agreed rule on geographical rotation of the (vice) chair(s) of the MB and on the equitable geographical distribution of its members amongst regional groups and representation of special interests. Attention would be paid to geographical representation and to the presence of specific stakeholders such as SIDS, coastal states, landlocked countries and those actively involved in sponsoring mining operations.

Basically, there seem to be two options for the MB:

Option 1: Create a new body. However, this might complicate matters as it would give rise to various questions around composition and balance.
Option 2: Use the Finance Committee as the MB. Prima facie, this appears to be a very practical and straightforward solution and is more in keeping with the evolutionary approach.

A body responsible to advise the MB on all scientific matters. We could call this the Scientific Guidance Board. This body would identify scientific issues for the MB to reflect on and would translate the overall objectives of the MB into scientific objectives and further give guidance for the evaluation of the results so the MB can focus on strategic and financial management decisions. It could consist of limited number of elected members, e.g., eminent scientists with a recognized experience in a certain domain. It would preferably set up a wider network of correspondent scientists to support its thinking.

The Legal and Technical Commission appears to be the ideal precursor of the Scientific Guidance Board.

A body responsible for organizing performance audits, reporting directly to the Assembly of ISA. We could call this the Performance Audit Board. It would act independently from the other bodies and be separate from the existing financial audit.

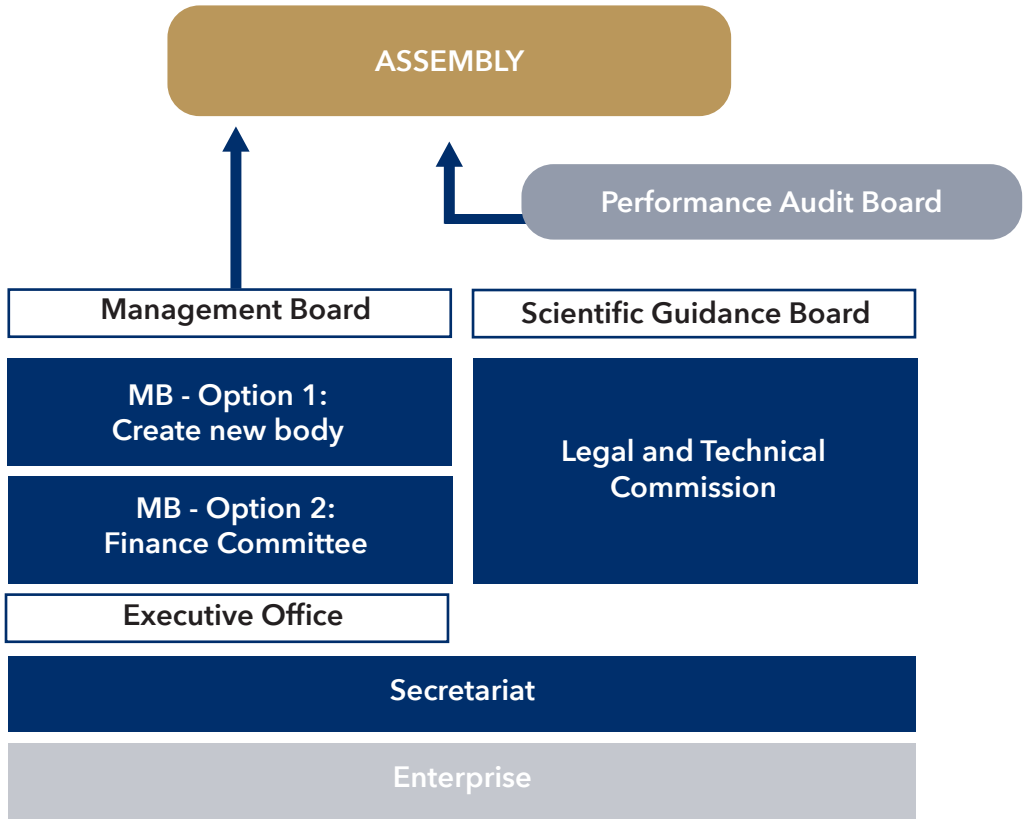
This role could be taken by an ad hoc group of experts or be outsourced to an existing organization such as the UN Board of Auditors or World Bank. It would need to focus its attention on performance management, beyond financial matters.

An Executive Office (EO) that would manage the fund on a daily basis. Together with an executive support staff, and relying on a network of regionally spread-out offices, the EO would carry out practical execution. A regional set-up (see further) would allow it to follow a deliberate policy of proximity to the local stakeholders and inclusiveness.

There is a natural correspondence between the role of the EO and that of the present Secretariat (see further).

The integration of the SSF's structure into the existing structure of ISA is visualized in the organigram below.

Figure 7. Organigram



Internal rules of procedure would need to be established for each of the functional bodies. Especially for the Executive Office, this will involve defining a set of good managerial practices adapted to the new scale of operations in each of the functional domains (project management, resources planning, human resource management, financial management, permanent quality management and organizational development, performance management and definition of Key Performance Indicators). The Executive Office[76] would then be responsible for submitting detailed proposals aligned to the ISA Strategic Framework (e.g., Strategic Plan, High-Level Action Plan, ISA MSR Action Plan etc.) to be formally endorsed by the MB.

[76] The present study does not allow us to elaborate these points, but it should be underlined that good procedures and managerial practices might matter even more than structural aspects.

Nature of the activities financed by the SSF

We envisage that the SSF would essentially support three types of projects:

1. **Projects needed to implement specific actions identified by ISA members, for instance through the Strategic Plan and High-Level Action Plan, as well as any other strategic frameworks endorsed by the ISA Assembly:** There will be a number of projects that should be defined by ISA itself drawing on its own experience and inspiration. ISA has already formulated numerous ideas for research projects and for capacity building.[77] As mentioned, the SSF will allow it to scale up its present level of activity and its policy of global communication and information to the general public.

2. **Projects proposed by ISA members and third parties:** There should also be a large part of the funds reserved for co-financing projects proposed by third parties and deemed worthwhile to be co-financed. ISA/SSF would lay down desired outcomes and qualitative criteria and allow third parties to propose concrete projects. Validation could be done according to thresholds. For instance, projects up to US$ 1 million require a decision by the EO, projects up to US$ 10 million require a decision by the MB upon recommendation by the EO, and projects of a higher amount require a decision by the Assembly on the basis of the recommendations of the MB and the EO. An extensive communication policy would need to be set up so that the outside world would be aware of the nature of eligible projects.

Which third parties would be eligible to present projects?

The nature of the users would probably vary in line with the type of activity defined under the scope of the SSF. The EO would need to propose a set of guidelines to be approved by the Management Board. They would contain indications about the desired nature of projects (serving the purpose of the fund) and the quality norms. It is suggested to keep a wide perspective and to keep the fund open to individuals (e.g., for competence building), private entities (including civil society organizations) and public bodies. It worth noting that ISA has already made a "demand analysis" in April 2020, so ISA does possess an initial list of desired initiatives. One would imagine that the acceptance of projects would fall within the remit of the EO up to a certain threshold and that a non-opposition procedure could be introduced for larger projects (EO proposes, and these are deemed approved unless the MB opposes within a certain timeframe).

3. **Co-financing the Enterprise:** When exploitation starts, or presumably before it actually starts, the Enterprise will have to be established and be made operational. If ISA wants the Enterprise to be a serious player, it will require a considerable amount of financial and technical resources, as well as knowledge and competences. It is open for discussion whether investing in the Enterprise could be regarded as an investment for the fund as part of the investment portfolio or a project that falls under the special assignment of ISA. The latter would be the more obvious choice. In any case, the Enterprise will need to avail itself of a considerable number of

[77] See also contributions at the ISA High-Level Webinar to introduce ISA Action Plan in support of the UN Decade of Ocean Science for Sustainable Development (17 November 2020), during which Vladimir Ryabinin (Executive Secretary of IOC-UNESCO) mentioned that "there are many ideas for an as-yet-unfunded activity".

financial resources for engaging in the activity for which it is mandated.[78] The SSF could be a good source of such funds.[79]

It would be for the Scientific Guidance Board to endorse and enrich the list above. Apart from these initiatives on content, there would need to be a series of projects on activity monitoring and economic analysis. There could be another demand analysis with stakeholders and parties regarding this set of tools. The Performance Audit Board could give its input for this new demand analysis and thus could contribute to the definition of the eligible common goods.

Nature of the support

For its own initiative activity, the SSF could rely on in-house staff or outsource the activity by contracting external expertise.

For activities that it does not organize itself, the SSF could intervene through a variety of instruments such as grants, loans, guarantees, co-financing and blended finance. The type of instrument should be adapted to the nature of the project and the third-party user. The SSF should always make sure that the users maintain their own commitment and that there is "incentive compatibility". The structure of the assistance should be such that the users feel an important incentive to attain the defined goals of the project and not be motivated by the financial support per se. This does not mean that the own commitment should always be financial. A number of users will prefer to contribute in kind.

Case example: JPI Oceans

(This project is covered by the European Horizon 2020 suite of research projects. We wish to bring it to the fore because it is the project which most closely connects to what could be undertaken by the SSF).

- JPI Oceans is an Intergovernmental platform (2011) striving to increase impact of national investments by aligning national priorities and allowing Member States to set up and implement joint actions within this framework.
- One or more member countries must take the lead and be supported by at least three other countries. This allows for countries with fewer resources to take leadership roles (one country has the primary lead, however, to avoid decision deadlocks).
- A proposal is discussed by the JPI Oceans Management Board and, if approved as a JPI Oceans Action, it is defined in greater detail, also enabling other countries to join.
- The financial structure is based on the principle of variable geometry. Member states decide whether they wish to participate and how much to contribute, according to the relevance of the action to their national priorities. Types of contributions are national research budgets, shared infrastructure (e.g., ship time), EC's framework programmes, institutional contributions, knowledge hubs and regional initiatives (JPI Oceans toolkit).
- The SSF could develop or co-finance similar projects. This would open a window for many parties in the member countries to participate in larger-scale projects. The SSF would then act as what is known in the financial industry as a "feeder fund". Such funds are used to syndicate the interest of large numbers of smaller parties so that they also have access to large-scale projects.

[78] 1994 Agreement, Annex, section 5(1a): "The Enterprise, and developing States wishing to obtain deep seabed mining technology, shall seek to obtain such technology on fair and reasonable commercial terms and conditions on the open market, or through joint-venture arrangements."

[79] For instance, by indirectly funding the Enterprise through loans or investments from the SSF to the Enterprise.

Regional set-up

Inclusivity would be a major objective, so it would be important to bring the SSF close to its potential beneficiaries. This could be achieved in various ways, and there exist various examples, such as:

- National Designated Authorities (used by the Green Climate Fund)
- Local UN offices (whom UNEP can work with)
- The "national authorizing officer" function, used by the European Union in the framework of its cooperation policy

Such arrangements clearly have the advantage of a firm local rooting. Yet, they also generate other problems. They may be fairly costly to set up and to maintain, and there is a need for firm control as local representatives may develop discretionary behaviour with ensuing reputational damage.

Risks when setting up a system:

- Centralized system: risk of disconnecting from real world, little inclusiveness
- Decentralized system:
  - Tight control: excessive bureaucracy, appropriation by the in-crowd of specialists
  - Loose control: risk of emergence of local baronies, loss of consistency, risk of fraud

We should attempt to combine structural and process elements to mitigate these risks.

A first option would be to set up a few regional ISA offices hosted by regional institutions. Conceptually, this is fairly straightforward. As a second option, one can also imagine that ISA/SSF could set up a network of local franchisees, where ISA would be more flexible and less financially engaged. These franchisees would receive an instruction set on how to represent ISA/SSF locally. They could be compensated by a fee, depending on the activity generated. This is probably much more cost-efficient than setting up a local branch. The franchisees would be subject to a performance audit by the Performance Audit Board, which could even be organized remotely. There exist many local organizations with an "ocean mission", e.g., chairs at universities, civil society initiatives or public initiatives. The members of the Assembly of ISA are very well placed to make suggestions. If ISA could, through its SSF, become the world-wide coordinator and facilitator, it could

Case example: JTRC

The concept of local franchisees fits the recommendations made in the international workshop on capacity development, resources and needs assessment, viz., that ISA should consider forming partnerships with existing national and regional institutions instead of establishing new regional centres in each region.

A recent case example of local presence can be found in the ISA-China Joint Training and Research Centre (JTRC). The Centre is affiliated with and hosted by the National Deep-Sea Centre of China in Qingdao. Its Steering Committee is comprised of seven members nominated jointly by ISA and China. The aim of the Centre is to stimulate capacity-building and technology transfer. It is established under a memorandum of understanding to offer training to aspiring professionals from developing countries in deep-sea related science. The experiences of this centre could be used as guidance to set up similar centres in more regions in the future.

enhance global efficiency considerably. ISA could organize a call for proposals and, in parallel, support the organization of seabed scientific faculties (or local chairs) on a regional basis. The same is true for technical training. The notion of "science" should not be limited to physical marine sciences and engineering. Legal faculties (e.g., those working with the Law of the Sea), economics faculties etc. should also be encouraged to remain involved.

Institutional regulations and other considerations

The SSF would develop from a modest size with a specific focus on seabed-related issues. It could expand its focus over time to include building **strategic reserves** or **remedies** and perfecting governance and stewardship tools.

Building strategic reserves or remedies would be for repairing general environmental damage that has occurred in the Area, not necessarily linked to a particular mining operation. Metaphorically, this could include actions like cleaning the bottom of the sea of all plastics or cleaning up the plastic soups. One must expect that the availability of a mechanism to finance remedial action will set people thinking creatively. Obviously, the Executive Office and the Scientific Guidance Board will need to be very critical about the technical feasibility of projects. The scope of this work would be broader than the Environmental Compensation Fund (ECF) under the Mining Code, which is focusing on damage and compensation that cannot be recovered through other sources.

Such a system will need to be science-based, and hence the scope of the SSF comprises research and competence building.

To the extent that it is not already done by ISA, one could also imagine that the SSF could add to the more expeditious development of **governance and stewardship**[80] tools, including at regional or local level. Besides decision-making and regulation, these should include monitoring and enforcement mechanisms. They would also aim at regulating (and possibly limiting or stopping) the forms of human activity which are found to be more damaging for the ocean. The need to develop appropriate governance tools is regularly underlined in various fora. For an activity as important as the mining of the seabed, it is worth spending much effort to developing the right tools. These will need to be closely aligned to the mining code and the Draft Exploitation Regulations.

Lessons learned from other funds, organizations and agencies

Having defined what would be needed to guarantee sustainable use of the wealth available on the seabed, a pertinent question is to check if no existing institution is already offering the required services.

There is a wide range of institutions that could be considered:

- The World Bank or Regional Development Banks (EBRD, EIB, ADB, IADB)
- UN agencies (UNEP, UNESCO)
- Large environmental funds (GEF, GCF)
- Large private funds (Nippon Foundation, Nature Conservancy)
- Regional institutions (CGIAR, RFMOs)

[80] The importance of a well-developed governance system cannot be sufficiently underlined. In a recent study carried out for the European Commission, it is found that "below standard policy frameworks, regulations and codes of conduct for specific activities/markets" constitute a major hindrance to finding sustainable finance (Ecorys et al., 2020).

The short and not entirely unexpected answer is that ISA is offering the service but with a modest budget and that many of the other institutions have much larger budgets but no focus on the Area. In a number of cases, we found some provisions (e.g., GEF7 is planning to spend 0.6% on an ABNJ project, although we are unsure for that matter if this relates to the seabed at all), and surely various institutions could be nudged into spending more. However, this is unlikely ever to become proportionate to the development of seabed mining activity.

Some programmes, such as the JPI Oceans programme of the European Union, do focus on the seabed and have set up significant activities. Even if they share their results widely, however, they remain confined to the participating countries. Other programmes, by national authorities, also doubtlessly offer some degree of insight and participation to non-nationals.

However, it is fair to conclude that setting up an SSF would not create a redundancy or major overlap with an existing institution or fund. In fact, it is the only practical option to direct a meaningful financial and intellectual effort towards the seabed. This is not surprising because, after all, the ABNJ and the seabed in particular are orphan domains. In broad terms, the trend of environment-related funds is that they gradually become more specific. UNEP, created in 1972, was broad based, while GEF, created in 1991, was a bit more specific, and GCF, set up in 2010, focused (mainly) on climate change. In this evolution, SSF would fit well with its main focus on the seabed.

Still, it is worth looking at what can be learned from other experiences in terms of how funds are governed and administered by their organizations and best practices. An overview of the reviewed organizations and take-aways can be found in Annex 1. Below, we give some recommendations for the SSF based on the experience of others.

Performance evaluation: self-learning

We think it is crucial for the SSF to have a continuously evolving funding model based on needs, learning and realities assessed by the proposed Performance Audit Board. GCF's independent evaluation unit (IEU) faced criticism at the time of establishment that its creation came too soon and that it would have nothing to evaluate yet.[81] The head of the IEU, Dr. Jyotsna Puri, countered this by saying that it is an important opportunity to be able to correct early in order to be able to make processes better, smarter and faster. We are of a similar opinion and assess it as crucial to be able to adapt the funding model from early on.

We note that several organizations have similar independent evaluation units, which are a recognized part of the organizations' structure. Throughout the different organizations, the units have in common that they are independent. This is crucial to the credibility of the units' work and credibility towards partners. In most cases there is also a need for a management response for every evaluation. As mentioned earlier, the proposed Performance Audit Board would act independently under the oversight of the Secretary-General, who would report on the results of the Performance Audit Board to the ISA Assembly under article 166(4) of UNCLOS.

Some organizations make use of specific tools to facilitate structured and

[81] "'The Evaluator' Episode 4: Dr Jyotsna Puri (Jo) on the past, present and future of the IEU", https://ieu.greenclimate.fund/podcast/evaluator-episode-4-dr-jyotsna-puri-jo-past-present-and-future-ieu. Accessed 21 July 2021.

standardized evaluation of projects. WHO is one example and has developed balanced scorecards called "Output Scorecards" as a measurement system for the outputs.[82] This tool uses six assessment parameters, or dimensions, which are assessed at the delivery of each output. These dimensions have been chosen based on what is strategically important for WHO. We are advocates of using a similar system for the SSF.

Tuna RFMOs have a policy of carrying out independent performance reviews, inspired by the review process under the Fish Stocks Agreement. This is done in principle every five years. They have organized between them a form of loose cooperation and exchange of best practices (through the so-called KOBE process). The performance reviews have been inscribed, e.g., in ICCAT, as a fixed item on the agenda of the Annual Meeting. In ICCAT, two reviews took place. On each occasion they were carried out by three independent experts. Their reports were very detailed. The first review was very critical, even devastating. The organization took the review and its manifold recommendations to heart and was relieved to learn after the second review that its performance had improved tremendously. This was very encouraging and shows that international organizations can be learning organizations.

Supporting capacity building

In April 2020, the ISA secretariat made a "demand analysis" in the form of a questionnaire, in which 96 per cent of the respondents indicated that there is a need for qualified deep-sea science professionals. Respondents identified that establishment of higher education programmes, organizing workshops and establishing training and research centres could be various tools to achieve this. We looked at capacity-building initiatives in other organizations. There exist several teaching initiatives as outlined below.

IOC-UNESCO established an Ocean Teacher Global Academy. This is a platform providing web-based training and supporting face-to-face learning (in regional and specialized training centres).[83] This academy might be a good partner for a similar ISA Academy.

WHO is creating the WHO Academy to support lifelong learning in health. Their training centre will consist at the beginning of an online learning experience platform (from May 2021 onwards) and later will be extended to onsite training at a campus in France (around 2023) and at regional facilities around the world. The focus is on learning for impact and building

Performance review

Every five years a Performance Review of ISA is carried out (UNCLOS, article 154). The first (and only so far) review dates from 30 December 2016 and was carried out by independent consultants appointed by a Review Committee (comprised of President and Bureau of Assembly and President of Council with Chairs of regional groups able to participate as observers). This Performance review could in the future be extended to reviewing the operations of the SSF as well. However, for SSF, we suggest a more permanent performance evaluation mechanism instead of only evaluating once every five years. As suggested, this could be done by the Performance Audit Board.

[82] The "Balanced Scorecard" is a management tool developed by Robert Kaplan and David Norton. Its main objective was to report on various critical aspects of a company's performance over and above the financial bottom line. It also pays attention, for instance, to the evolution of the human capital and customer satisfaction.
[83] https://classroom.oceanteacher.org/.

competence. The goal is to reach 10 million people by 2023.[84] It will not be a separate legal entity, but an integral part of the WHO under management authority of its Director-General.

We are of the opinion that an on-line academy would be an interesting tool for the SSF, both in outreach and inclusivity, and in the creation of a community. In addition, through this academy, the SSF could contribute to the SDGs. Although the WHO Academy has not started yet, it shows that it is a scalable tool, starting on-line and gradually increasing its onsite training capacity. This on-line academy could be governed by the Executive Office of the SSF. The concept of an online academy fits the recommendations made in the international workshop on capacity development, resources and needs assessment, viz., that ISA should consider establishing an online training platform which would enable information sharing and research outcomes in addition to training individuals.

Transparency

With a number of agencies and funds, it is not clear who is eligible to propose projects and what is the decision flow for such projects. It is not clear at all either if there is an explanation for why projects are turned down or if there is any form of appeal. However valuable a project might be, if it falls outside of the detailed strategic choice of the fund or if it does not use, in its formulation, the appropriate jargon of the fund, it stands no chance of attracting finance.

We would emphasize that the SSF should be more transparent about its decisions, explaining why certain projects were approved or refused.

It appears to be challenging to work with certain institutions. Over and above the administrative challenges and the use of jargon there exists little flexibility within these institutions. One has to adapt strictly to their preferences and visions, not only in terms of content but also in terms of formalities. As a consequence, an intermediary layer of in-crowd has emerged that has developed a capacity to have projects approved. This creates alienation with the ultimate users. Furthermore, the system is sometimes so complex that functional specialism inside the organization leads to inertia. Internal specialists steer projects into the topics they technically know best and where their expertise enhances their personal reputation.

Interesting take-aways: tool for upscaling investments and increased involvement of the private sector

Blended finance is used by GEF and GCF to create leverage to mobilize private-sector funds. By using non-grant instruments (i.e., debt, equity and guarantees), risks are reduced, and opportunities are created for private investors. A lesson learned from GEF's experience is that this approach enables multi-stakeholder platforms to be created around specific issues, enhances knowledge and idea-sharing as an additional benefit and increases predictability.[85] This method could be used for the SSF to scale up investments and increase the involvement of the private sector and non-State actors.

Using blended finance as an instrument will require good and sensible project preparation in order to make the project attractive for investors and match the

[84] https://www.who.int/about/who-academy.
[85] "Advances in Blended Finance: GEF's Solutions to Protect the Global Environment" (27/11/2019) 49 http://www.thegef.org/topics/blended-finance.

right non-grant instrument with the right investor and project. GEF's experience has shown that blended finance is a potent instrument. In 2013–2014, GEF provided US$175 million for blended finance, mobilizing US$1.1 billion from the private sector. In order to support technical and financial assistance during the preparation of project and programme funding proposals, GEF has a Project Preparation Facility. This facility mainly assists developing countries with their proposals as they may face capacity constraints. Funding is available up to US$1.5 million for project help and increases inclusiveness for these countries.

Conclusion

The exploitation of the seabed could be a source of much needed qualitative economic growth. In general, "blue growth", the sustainable use of the oceans, holds an important promise of wealth creation for the world economy. This new frontier should be explored prudently. Deep-sea mining should generate an important sum of financial benefits that should be, as agreed in UNCLOS, made available for mankind. However, this can be achieved in various manners. One solution could be to invest in human potential and aim for qualitative growth in knowledge, competence and capacity development, which is a priority identified by Member States and is the key to unlocking the objectives of equal participation and benefit of mankind in UNCLOS, article 150.

On the other hand, significant amounts of money will still be needed to finance the research and the competence building that will be necessary for exploitation to take place in acceptable sustainable conditions. Similarly, more resources will be needed to finance the Enterprise under the conditions set for its future operation under the 1994 Agreement.

ISA will probably find it very difficult to mobilize the required resources. A quick analysis of existing possible external sources of funds shows that it is unlikely that enough funds will be found.

An elegant technical solution to address all the above problems would be to create a Seabed Sustainability Fund (SSF). Such a fund would be used to invest the seabed exploitation revenue for the benefit of mankind instead of simply distributing the money. This would be a precautionary solution.

Such a technical tool would allow management of the liquidity perfectly in line with needs, including by frontloading it. It would allow ISA to fully play and further develop its unique role as guardian of the Area. Gradually, an important reservoir of wealth would be built up, belonging to mankind and usable for its benefit. In this sense, the SSF would be an important innovation. It would allow the pursuit of various SDGs.

Obviously, the adequate structures and procedures would need be adopted to govern such a Fund. Analysis shows that it would not be necessary to create expensive new institutions or adopt expensive new procedures. In fact, the evolutionary approach that underlies UNCLOS can continue to be followed. The SSF would fit perfectly into the existing structures if they are further developed and scaled up for a much larger level of activity. In terms of processes, much inspiration can be drawn from existing agencies and funds. It is highly recommended to take the basic decision of setting up an SSF and to work out all practical arrangements to make it a success.

PART VI: DISTRIBUTION UNDER ARTICLE 82(4)

Article 82 provides for a system of revenue sharing between coastal States and the international community. It provides that payments or contributions in kind are to be made by coastal States in respect of the exploitation of the non-living resources of the continental shelf beyond 200 nautical miles. Those payments or contributions in kind are to be distributed by the ISA to developing States, "particularly the least developed and the land-locked amongst them". UNCLOS provides little guidance as to how Article 82 might be implemented in practice.

The concept of revenue sharing, or the imposition of an international royalty, derived from Malta's Draft Ocean Space Treaty, submitted to the Seabed Committee in 1971, which proposed that a coastal State should contribute to the International Ocean Space Institution a percentage of the revenue received from exploitation of living and non-living resources within its jurisdiction.[86] Article 82 in its present form thus represents a compromise between various national positions. Coastal States with a continental shelf extending beyond 200 nautical miles must make annual payments or contributions in kind when exploiting the non-living resources beyond that distance after the first five years of production at a site. The rate of payments or contributions will annually rise from 1 per cent at the beginning to 7 per cent of the value or the volume of production at the site as of the twelfth year after the commencement of exploitation.[87] A developing State which is a net importer of a mineral resource produced from its continental shelf is exempt from making such payments or contributions with respect to that resource. Production does not, however, include resources used in connection with the exploitation.

Provisions concerning the equitable sharing of payments and contributions derived from the exploitation of resources on the continental shelf beyond 200 nautical miles are contained in articles 82(4), 160(2)(f)(i) and 162(2)(o)(i) of the Convention. A key point is that the role of ISA under Article 82(4) is fundamentally different to its role under Article 140. In the case of Article 82, the function of ISA is to serve as a conduit for transmissions of payments and contributions in kind to States parties in accordance with Article 82(1). The destination of the payments and contributions is the States parties, and ISA's role is purely instrumental.

An international workshop on the implementation of Article 82 convened by ISA in 2012 considered that there would be a need for the ISA to establish a mechanism for collecting payments and contributions and then distributing them in a timely and efficient manner to States

[86] Nordquist et al. (1985–2011), 930–947 contains a thorough analysis of the negotiating history of Article 82. An interesting analysis of the negotiating history is also presented in Chircop and Marchand (2003).
[87] Proposals were made ranging between 5 and 15 per cent. As a compromise, Austria suggested a rate of 7 per cent.

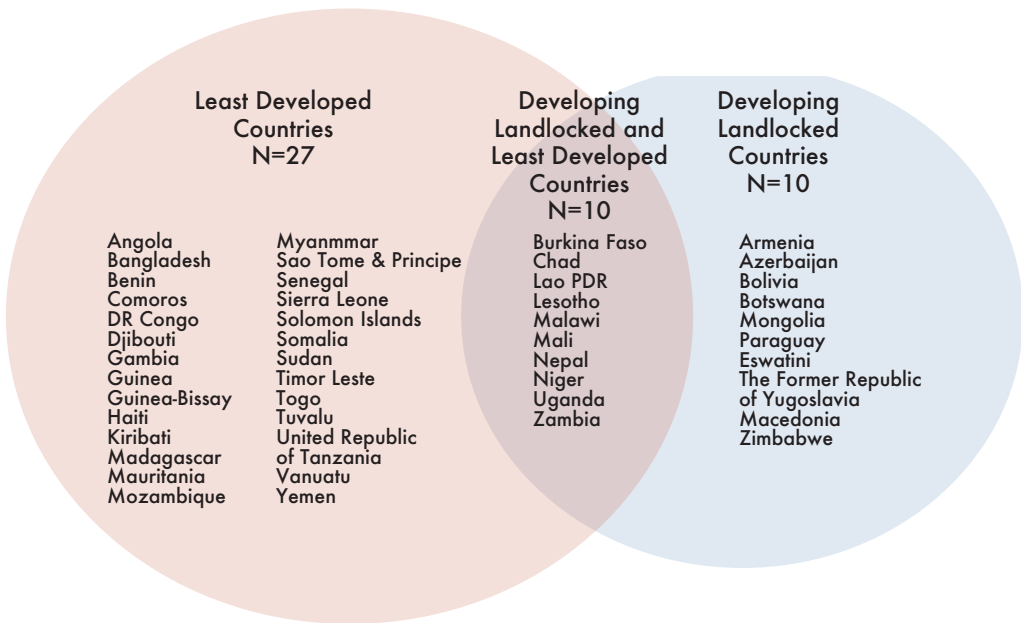
parties.[88] The workshop noted that the establishment of such a mechanism may entail additional costs for ISA, which could be recovered from the amounts collected. Whether this would be on a strict cost recovery basis, or through an agreed percentage overhead charge, remains to be considered. A possible role for the Finance Committee was also identified in determining what should be a reasonable overhead charge for this purpose.

Difficulties of interpretation in Article 82(4)

As noted above in Part II, the text of UNCLOS suffers from considerable ambiguity. For example, what are "interests and needs" in relation to both Article 140 and Article 82(4), and how are they to be assessed and measured? Does the language of "taking into account" imply a preferential consideration for such States? How should the reference to "States parties" in Article 82(4) be reconciled with the generic reference to "States" in articles 140 and 162(2)(o)(i)? Overall, it seems reasonable to assume that although the objectives of both Article 82(4) and Article 140 include distributive justice or "correction of inequalities", the remedial rationale is not the same. In the case of Article 140 and associated provisions in Part XI, the remedial effect is broadly socio-economic, geographical and political. In the case of Article 82(4), the remedial effect is geographic and socio-economic, hence the highlighting of the needs and interests of landlocked States, which have no entitlement to a continental shelf.

Another difficulty for Article 82(4) will be to identify more precisely which States should receive preferential treatment. The provision refers to developing States in general, but particularly the "least developed and land-locked among them". This categorization is not necessarily straightforward. Among the Member States of ISA there are "Least Developed States" (27), developing States that are also landlocked (10) and States that are both landlocked and Least Developed (10). It is unclear from the language of Article 82(4) which category of these States should be favoured in terms of any distribution. The relationship between these potential groups of States is shown in Figure 1.

Figure 8. Least developed and landlocked developing countries



[88] International Seabed Authority (2013).

Adapting the distribution formula for Article 82(4)

Notwithstanding the definitional difficulties identified above, provided that the preferred class(es) of beneficiaries can be identified, any of the distribution formulae developed in Part III can easily be adapted for Article 82(4) distribution by adjusting the social distribution weights derived from revealed preferences in order to make a preferential distribution. If the basic methodology is accepted, the tables and weightings can be manipulated to give preference to any group of States.

The discussion in Part III, and the relevant tables in Appendix II (Sections A.2.1, A.2.5 and A.2.6) are relevant to Article 82(4) distributions and show in detail the relationships between the various parameters in the distribution formulae and the weights assigned for purposes of Article 82(4). In essence, we assume that, for Article 82 proceeds, UN General Assembly revealed preference indicates that η=1.1 for low income and landlocked States parties and η=1 for all other States parties, giving a distribution parameter $\omega_i^{82} = \left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1.1}$ for i= low income and landlocked States parties and $\omega_i^{82} = \left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1.1}$ for i= all other States parties. This result means that per capita proceeds are inversely related to the level of per capita GNI in a somewhat more progressive relationship for low-income landlocked States parties compared to all other States parties and compared to Article 140 proceeds.

The impact of applying increasingly progressive values of the elasticity of marginal social utility of income η for all States parties and for developing landlocked States parties can be seen in Tables 15 and VI.2, which both use a notional sum of US$500 million as the basis for a distribution. Table 15 indicates a highly skewed distribution, with the median well below the mean. Most allocations are comparatively small, but some large distributions, especially that to India, create a long tail of distributions to the right. The distribution becomes somewhat more compact and less skewed as the allocation becomes more progressive through higher values of the marginal social utility of income η.

Table 15. Summary statistics of increasingly progressive distribution of US$500 million Article 82 payments (increasing values of η): all States parties

	η=1	η=1.1	η=1.2	η=1.3	η=1.4	η=1.5
Mean	2,994,012	2,994,012	2,994,012	2,994,012	2,994,012	2,994,012
Median	166,673	160,320	159,808	169,000	168,461	168,453
Standard Deviation	12,802,250	12,366,431	11,857,813	11,305,917	10,774,027	10,773,450
Minimum	19	18	17	16	15	15
Maximum	153,917,620	148,050,629	140,658,250	131,583,521	120,800,700	120,794,668
Skewness	10.20	10.06	9.77	9.26	8.42	8.42

Note: US$2017

Table 16 shows that increasing values of the elasticity of marginal social utility of income up to η=1.4 progressively increase the allocation to landlocked developing States parties, but those further gains are minimal beyond η=1.4.

Table 16. Summary statistics of increasingly progressive distribution of US$500 million Article 82 payments (increasing values of η): low income landlocked States parties

	η=1	η=1.1	η=1.2	η=1.3	η=1.4	η=1.5
Mean	2,708,190	3,557,903	4,628,538	5,942,826	7,504,497	7,505,370
Median	702,254	817,992	941,720	1,068,216	1,189,900	1,189,841
Standard Deviation	3,574,377	4,826,122	6,446,917	8,494,463	11,002,979	11,001,531
Minimum	37,614	44,097	51,063	58,221	59,935	59,932
Maximum	10,779,515	14,082,452	18,171,483	23,093,933	30,380,644	30,379,127
Total	54,163,804	71,158,068	92,570,758	118,856,526	150,089,934	150,107,407
Skewness	1.28	1.31	1.34	1.39	1.44	1.44

Note: US$2017

The key finding of the report is that any of the distribution formulae developed in relation to Article 140 could also be applied to distributions under Article 82(4). If the basic methodology is accepted, the social distribution weights can be easily manipulated to give preference to any group of States. It would simply be necessary to determine which States should receive preferential treatment. Among the members of ISA, 27 States are least developed countries (including 10 that are landlocked) and 10 States are both developing and landlocked countries. It would be necessary to determine whether these should receive equal preference or whether there is a ranking of preference in the distribution.

APPENDIXES

Appendix 1: Revealed preference estimation of elasticity of social marginal utility of income and social welfare weights

Revealed preference through united nations general assembly revealed preferences

1. The literature that estimates the elasticity of marginal utility of income η provides several different approaches.[89] A revealed preference approach that is readily operationalized relies upon the social revealed preferences of the United Nations General Assembly through the UN's annual assessment of member countries for their contribution to the UN budget. This annual contribution, which is based upon a country's per capita GNI adjusted for debt burden and with a contribution ceiling and floor, implicitly forms a progressive income tax system. The social and ethical values of the UN are revealed through the structure of its implicit income tax rates. In this approach, the elasticity of social marginal utility of income η is interpreted as an income inequality aversion parameter, so the more progressive the "tax structure", the greater is the degree of income inequality aversion η from the UN General Assembly's perspective.

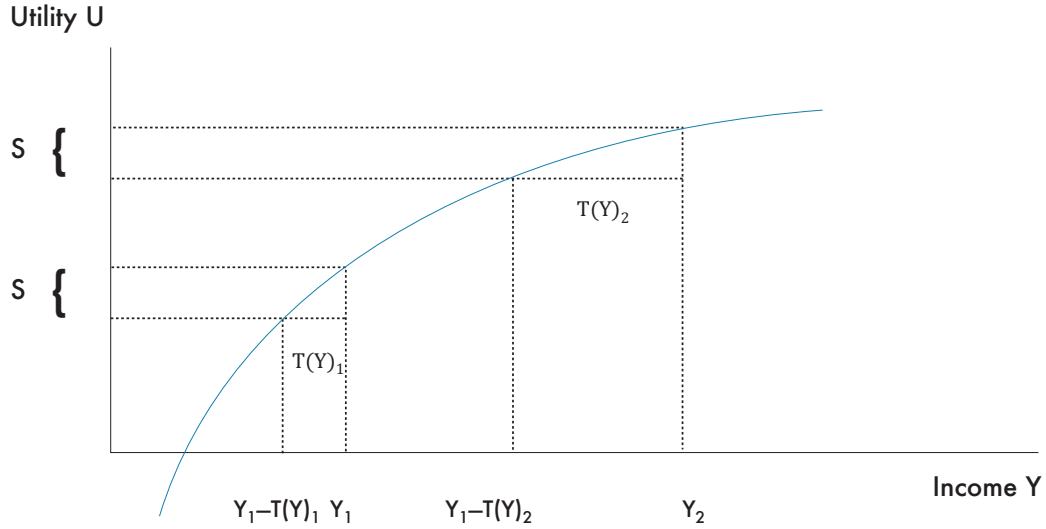
Assumptions: equal absolute sacrifice and iso-elastic utility functions

2. This approach operates under two assumptions: that the income tax structure reflects the principle of equal absolute sacrifice, and that the social welfare and utility function takes a known form, which is almost invariably iso-elastic. The equal absolute sacrifice principle implies that in any given "tax" (assessment) year, the "tax" taken from each country represents the same sacrifice of utility or satisfaction. If the UN has a high degree of GNI inequality aversion reflecting a high value of η, then the marginal social utility declines relatively quickly as GNI rises.

3. The analysis is conducted on an annual per capita basis for each UN member using member per capita assessment (contribution) and member per capita GNI rather than country values consistent with the UN analysis and methodology behind the UN member assessments. The analysis also expresses all monetary values in US$ consistent with the UN analysis and methodology behind the UN member assessments. Monetary values further control for inflation by using the US Implicit GDP Price Inflator, valuing all US$ of the year 2027 (US$2017).

[89] This section follows Young (1994), Evans (2005), Evans et al. (2005) and Groom et al. (2016).

Figure A.1.1. Principle of equal absolute sacrifice



Source: Young (1994)

4. The previous diagram (Figure 12 of Young, 1994) illustrates the equal absolute sacrifice principle. Let Y denote GNI (gross income), U denote utility, and $T(Y)$ denote the total tax liability (UN member country assessment) according to the income tax schedule (UN member country assessment schedule). Utility is concave, so that the marginal gain in utility from each additional unit of income decreases with higher levels of income.

5. Suppose that country 1 has a pre-tax income Y_1 and pays tax $T(Y)_1$, so that after-tax income is $Y_1 - T(Y)_1$. Before taxes, country 1's utility level is U. After the tax, country 1's utility level is $U(Y) - S$, where S is the loss in utility. Now consider higher-income country 2 with pre-tax income Y_2 and after-tax income $Y_2 - T(Y)_2$. As the figure shows, the tax $T(Y)_2$ on Y_2 must be larger than $T(Y)_1$ if both are to suffer the same loss in utility S. Thus, the equal absolute sacrifice principle states that the tax schedule $T(Y)$ equalizes absolute sacrifice if it imposes an equal loss of utility on all income classes of countries relative to some utility function $U(Y)$.

6. When the marginal utility of income is decreasing, equal absolute sacrifice implies that the tax increases with income, but it does not necessarily imply that the tax rate increases with income. With the logarithmic utility function, so that $Y = 1$, and $U(Y) = lnY$, a fixed percentage decrease in income represents the same loss in utility at every income level. Thus, each country sacrifices equally if it pays the per cent of its income in tax. Equal absolute sacrifice implies a strictly progressive tax schedule if the elasticity of marginal utility exceeds unity, i.e., $\eta > 1$.

7. Algebraically, the principle of equal sacrifice implies that for all income levels Y the following equation holds: $U(Y) - U(Y - T(Y)) = k$, where k is a constant, Y is GNI (gross income), U is utility, and $T(Y)$ is the total tax liability (UN member country assessment) according to the income tax schedule (UN member country assessment schedule). Let the social welfare function be iso-elastic, $W(U) = \frac{U_i^{\gamma}}{1-\gamma}$, and since $\gamma = 0$ with the isoi-elastic social welfare function, $W = \sum_{i=1}^{N} U_i = \sum_{i=1}^{N} Y_i$. Let each country have the same iso-elastic utility

function $U(Y_i) = \frac{Y_i^{1-\varepsilon}}{1-\varepsilon} = \frac{Y_i^{1-\eta}}{1-\eta}$ $\varepsilon = \eta \neq 1$ and $U(Y_i) = lnY_i, \varepsilon = \eta = 1$ The private and social elasticities of marginal utility with respect to income are the same in the iso-elastic case in which $Y = 0$, i.e., $\varepsilon = \eta$, since $\eta = \varepsilon + \gamma(1 - \varepsilon)$. Following Evans et al. (2004), substituting $(Y) = \frac{Y^{1-\varepsilon}}{1-\varepsilon}$ into $(Y) - U(Y - T(Y)) = k$ gives $\frac{Y^{1-\varepsilon}}{1-\varepsilon} - \frac{[Y-T(Y))^{1-\varepsilon}]}{1-\varepsilon} = k$ Taking the total differential gives: $Y^{-\varepsilon} - [Y - T(Y)]^{-\varepsilon}(1 - t) = 0$ where t is the effective marginal tax rate. Rearranging terms and simplifying gives: $(1 - t) = \left(1 - \frac{T(Y)}{Y}\right)^{\varepsilon}$ Taking natural logs of both sides of the equation gives: $ln(1 - t) = \varepsilon ln\left[1 - \frac{T(Y)}{Y}\right]$. Rearranging gives $\varepsilon = \frac{ln(1-t)}{ln\left(1 - \frac{T(Y)}{Y}\right)} = \frac{ln(1-MTR)}{ln(1-ATR)}$ where MTR = marginal tax rate and ATR = average tax rate.

8. Equal sacrifice combined with a smooth utility function would imply an MTR that continually varies (Groom, 2016). Hence, an income tax structure characterized by a limited number of tax thresholds cannot perfectly fit the equal sacrifice model. Furthermore, tests of the equality of sacrifice assumption are themselves impossible since they are necessarily based on a particular utility function.

Formula for the elasticity of marginal utility of income η

9. The empirical literature uses multiple values of marginal and average tax rates to provide the panel data and then directly estimates the equation $\varepsilon = \eta = \frac{ln(1-MTR)}{ln(1-ATR)}$, the elasticity of the marginal utility of income. This approach is not directly applicable since the UN annual assessment for each member to the UN budget does not explicitly provide marginal and average tax rates. However, from this tax schedule and using linear regression analysis, the marginal tax rate can be estimated by simply regressing all members' annual contribution per capita $T(Y)it$ upon annual GNI per capita $GNIPit$ and substituting the expression for the marginal tax rate for country i in time t, given by the derivative $\frac{\partial T(Y)_{it}}{\partial Y_{it}}$ into the formula from above, $\varepsilon = \frac{ln(1-MTR)}{ln(1-ATR)}$. That is, the following equation can be estimated by fixed effects linear regression: $T(Y)_{it} = \alpha_i + \theta_t + \beta Y_{it} + \mu_{it}$, where Yit is country i's per capita GNI in time t, α_i is country i's fixed effect, θ_t is the common time fixed effect (with one annual dummy variable omitted to avoid the dummy variable trap), and μ_{it} the standard error term assumed identically, independently and normally distributed. The coefficient of Yit gives the MTR of country i in time t (assumed constant across all countries and time periods), since $\frac{dT(Y)_{it}}{dY_{it}} = \beta$ and $ATR = \frac{T(Y)}{Y}$ (calculated as the grand mean of $\frac{T(Y)_{it}}{Y_{it}} = \frac{1}{N}\frac{1}{T}\sum_{i=1}^{N}\sum_{t=1}^{T}\frac{T(Y)_{it}}{Y_{it}}$.

10. The estimate of $\varepsilon = \eta$ then enters the formula for the relative social welfare weight: $\omega_i = \left[\frac{Y_j}{Y_i}\right]^{\eta} = \left[\frac{Y_j}{Y_i}\right]^{\varepsilon}$. A reference level of income is chosen for Yjt, typically the mean global per capita income (here GNI) or median global per capita income and the mean or median per capita income is used for each country, i.e., $\widehat{Y_i} = \frac{1}{T}\sum_{t=1}^{T} Y_{it}$. Then $\omega_i = \left[\frac{Y_j}{\widehat{Y_i}}\right]^{\varepsilon}$, where $\overline{Y} = \frac{1}{N}\frac{1}{T}\sum_{i=1}^{N}\sum_{t=1}^{T} Y_{it}$ if the mean global per capita income and $\overline{Y} = \frac{NT+1}{2}$ if the median global per capita income. Because the UN formula for calculating annual member shares of the UN budget uses global per capita GNI rather than GNI, this is the preferred approach.

The data

11. The UN bases members' contributions on member per capita GNI and then adjusts for debt burden and places a floor and ceiling on contributions for Least Developed Countries and a ceiling on contributions by high-income countries.[90] GNI is used rather than a broader measure such as the Human Development Index. GNI is used rather than Gross Domestic Product (GDP) because GNI is a more accurate measure of a member's national income. Per capita GNI with adjustments is averaged over three years and over six years, and then these averages are averaged to obtain an annual share (proportion) of contribution and actual contribution for each member. These assessments remain constant for three years and are then recalculated and updated (thus 2000–2003 through 2016–2018, each using the three previous years of data). The actual shares are quite stable, although they do change a bit over time, becoming very slightly more progressive as indicated by estimated values of η when using only the more recent years of data.

12. Because the UN's annual country contribution to the UN budget changes every three years, the marginal and average tax rates change slightly every three years. Hence, the estimated marginal and average tax rates estimated over multiple three-year budget cycles give a long-term social revealed preference for the value of η, as well as improved statistical properties of the estimate of η due to a larger sample size.

13. The basic steps undertaken by the UN General Assembly are as follows. By its resolution 70/245, the General Assembly decided that the scale of assessments for the period 2016–2018 shall be based on the following elements and criteria:[91]

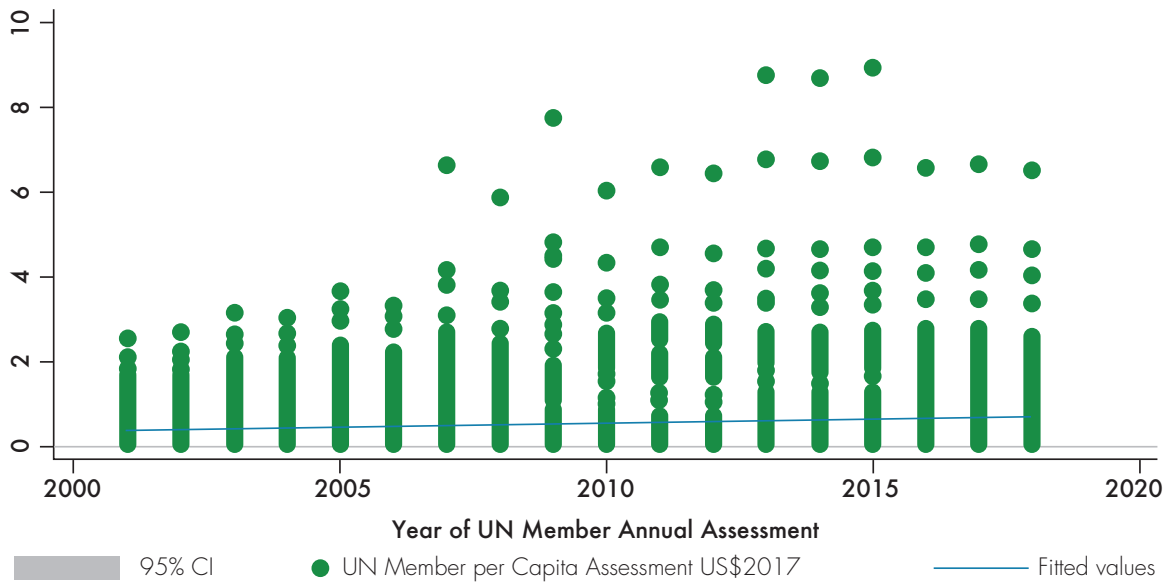
- Estimates of gross national income
- Average statistical base periods of three and six years
- Conversion rates based on market exchange rates, except where that would cause excessive fluctuations and distortions in the income of some Member States, when price-adjusted rates of exchange or other appropriate conversion rates should be employed, taking due account of its resolution 46/221B
- The debt-burden approach employed in the scale of assessments for the period 2013–2015
- A low per capita income adjustment of 80 per cent, with a threshold per capita income limit of the average per capita gross national income of all Member States for the statistical base periods
- A minimum assessment rate of 0.001 per cent[92]

[90] GNI is obtained by adjusting the Gross Domestic Product (GDP) with the income of residents from activities abroad and the income of non-residents from activities in the country: GNI = GDP - primary incomes payable to non-resident units + primary incomes receivable from non-resident units.

[91] The next step was the application of the low per capita income adjustment in each machine scale. This involved the calculation of the average per capita GNI during each of the base periods for the membership as a whole and the average per capita GNI for each Member State for each base period. The overall average figures for the current scale were $8,956 for the three-year base period and $8,338 for the six-year base period, and these were fixed as the starting points, or thresholds, for the respective adjustments. The share in GNI of each Member State whose average per capita GNI was below the threshold was reduced by 80 per cent of the percentage by which its average per capita GNI was below the threshold.

[92] The floor only applies to a limited number of countries in each assessment period. For example, in the scale of assessments for the 2013–2015 period, 30 Member States, of which 17 were included in the list of the least developed countries, had been raised to the floor. Based on its analysis of the updated data, the Committee noted that, for 2016–2018, the scale of assessments for 17 Member States, of which 10 were on the list of the Least Developed Countries, would be raised to the floor level. (UN Committee on Contributions, Report of the Committee on Contributions, 75th session (1-26 June 2015), A/70/11. Available at: https://digitallibrary.un.org/record/798683?ln=en).

Figure A.1.2. UN member assessments per capita by year, 2001–2018



- A maximum assessment rate for the least developed countries of 0.01 per cent[93]
- A maximum assessment rate of 22 per cent[94]

14. Annual member contributions assembled from the annual UN reports give each member's annual contribution. Annual member contributions are converted to annual member per capita contributions using annual country populations sourced from the World Bank Development Indicators database or the UN Population Division,[95] recognizing that a contribution in, for example, year 2018 should be divided by the 2017 population. Members' annual per capita GNIs were the World Bank Development Indicators assembled from the annual UN reports, the World Bank Development Indicators database, the UN Department of Economic and Social Affairs,[96] or the World Data Atlas (using World Bank data) from Knoema.[97] These values were in nominal US$. The US implicit GDP price deflator was used to convert all nominal values into real US$2017.

15. The raw data scatter plot of UN member assessments per capita by year for the years 2001–2018 (US$2017) with a fitted linear regression is depicted as follows in figure A.1.2.

[93] The ceiling applies only to a limited number of countries in each assessment period. For example, the least developed countries ceiling had applied to 7 of the 49 least developed countries for the 2013–2015 scale of assessments and would apply to 8 of the 48 least developed countries for the 2016–2018 period. (UN Committee on Contributions, Report of the Committee on Contributions, 75th session (1-26 June 2015), A/70/11. Available at: https://digitallibrary.un.org/record/798683?ln=en).

[94] The 22 per cent ceiling only affects the United States of America.

[95] United Nations Population Division Department of Economic and Social Affairs World Population Prospects the 2017 Revision. Available at (accessed December 20, 2018): https://population.un.org/wpp/Download/Standard/Population/.

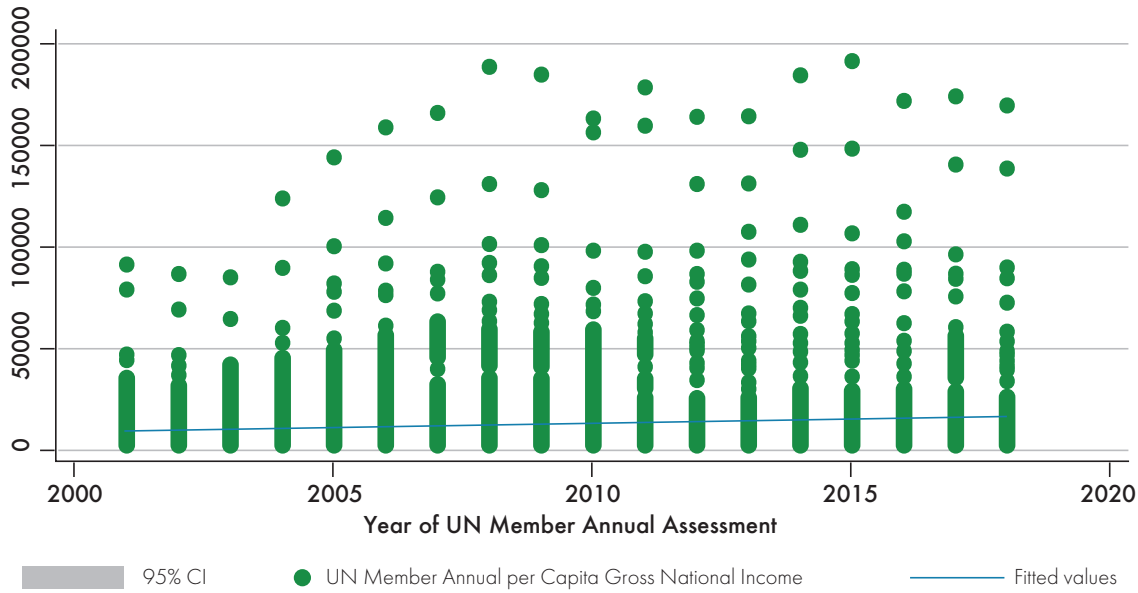
[96] UN Department of Economic and Social Affairs, National Accounts – Analysis of Main Aggregates. Available at (accessed December 20, 2018): https://unstats.un.org/unsd/snaama/Downloads.

[97] https://knoema.com/atlas.

16. Figure A.1.2. depicts each member's GNI per capita (US$2017) and the overall mean plotted against time (without member fixed effects). It shows a linear and upward-sloping relationship with variation around a simple linear trend line, due to adjustments for progressivity in GNI that vary by member and the assessment ceiling and floor, becoming slightly more progressive over time. Nonetheless, most assessments are quite stable. The difference between the two lines is slight, depicting a slight difference between the average and constant marginal tax rate (slope) and average tax rate (overall mean). The results show increasing dispersion between member annual UN contributions per capita from about the year 2007. This increasing dispersion reflects increasing progressivity of the contribution system starting in 2007. The fitted regression line shows a slightly increasing average relationship of member UN contribution per capita over time.

17. Figure A.1.3. plots each country's GNI per capita (in constant, inflation adjusted US$2017) against its contribution per capita (US$2017). The figure shows a linear and upward-sloping relationship with variation around a trend line due to adjustments for progressivity that vary by country and the assessment ceiling and floor. The figure depicts multiple prominent "outliers" for the contribution per capita at high GNI per capita. These "outliers" correspond to Monaco. The raw data also show that small countries, particularly Small Island Developing States, are assessed at a higher rate of contribution per capita corresponding to their GNI per capita. This higher assessment rate is due to the floor or minimum annual assessment (a "price floor"), below which assessments cannot fall. Some of these countries may also not benefit from assessment reductions due to debt relief. This annual assessment minimum leads to data "outliers" in the figure of a comparatively high contribution per capita corresponding to low GDP per capita. The ceiling or maximum annual assessment (a "price ceiling"), above which assessments cannot exceed, limits widening dispersion of data points between contribution per capita and GNI per capita as GNI per capita increases at the higher levels. Other outliers emerge for reasons other than a minimum or maximum assessment. Greece is a country with a comparatively high annual assessment per capita for its GNI per capita. The fixed effects estimation should control for these "outlier" cases.

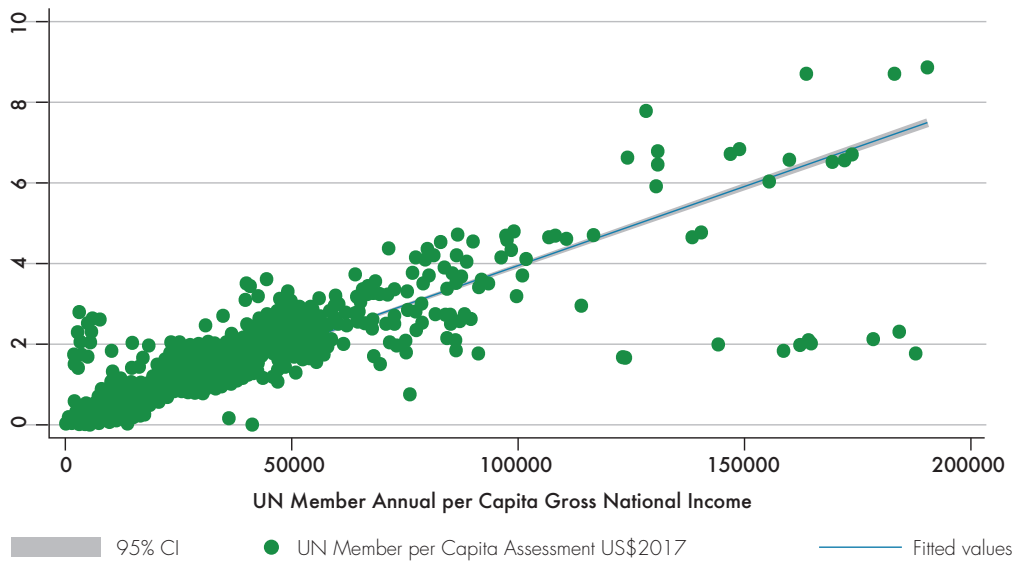
Figure A.1.3. UN member GNI per capita by year, 2001–2018



18. Figure A.1.3. further shows increasing dispersion among all members' annual contribution from about the year 2007, reflecting increasing progressivity of the contribution system (but heavily influenced by a small number of members). Each year also shows the contribution floor, most contributions clustered around a relatively small amount, and then a long tail of high contributors. The marginal tax rate (given by the slope of the trend line) is less than the average tax rate (given by the mean line) (the fitted line lies below the mean line) until about 2007, after which the marginal tax rate exceeds the average tax rate (the fitted line lies above the mean line), reflecting growing progressivity in income. Figure 1 also depicts multiple prominent "outliers" for each member's annual contribution at high per capita GNI. One of the largest "outliers" corresponds to Monaco. The raw data also show that small members, particularly small island developing States, are assessed at a higher rate of contribution per capita corresponding to their annual contribution due to the assessment floor, shown as data "outliers" of a comparatively high contribution per capita at very low annual contribution. Some members may also not benefit from assessment reductions due to debt relief. The assessment ceiling widens dispersion of data points between member annual contribution and member annual per capita GNI as member annual per capita GNI increases at higher levels. Other outliers emerge for reasons besides minimum or maximum member annual contribution. Greece is a country with a comparatively high annual contribution for its annual per capita GNI. The fixed effects estimation should control for these "outlier" cases.

19. The raw data scatter plot between the UN member annual contribution per capita and GNI per capita for the years 2001–2018 (US$2017) with the fitted linear regression for a linear trend line (without member fixed effects) is depicted in Figure A.1.4. below. The annual contributions are more compact at lower Y_{it}, with the exception of the lowest range as discussed above and are more dispersed at higher Y_{it} as discussed above. The number of complete observations (values for both member annual assessments and per capita GNI) is 3,447. There are 193 UNGA members and 18 years. Because of a limited number of missing observations (e.g., South Sudan was not a member in earlier years), the panel is slightly unbalanced, with an

Figure A.1.4. UN member assessments per capita and member contributions per capita, 2001–2018



average of 17.9 observations per member. The minimum number of observations in a panel is 6 and the maximum number of observations in a panel is 18.

20. This relationship solely for UN members that are both landlocked and low-income is depicted by the following Figure A.1.5.

21. Kernel density plots depict the distribution of data over a continuous interval over some time period. Kernel density plots are a continuous variation of

Figure A.1.5. UN member assessments per capita and member contributions per capita low-income landlocked members, 2001–2018

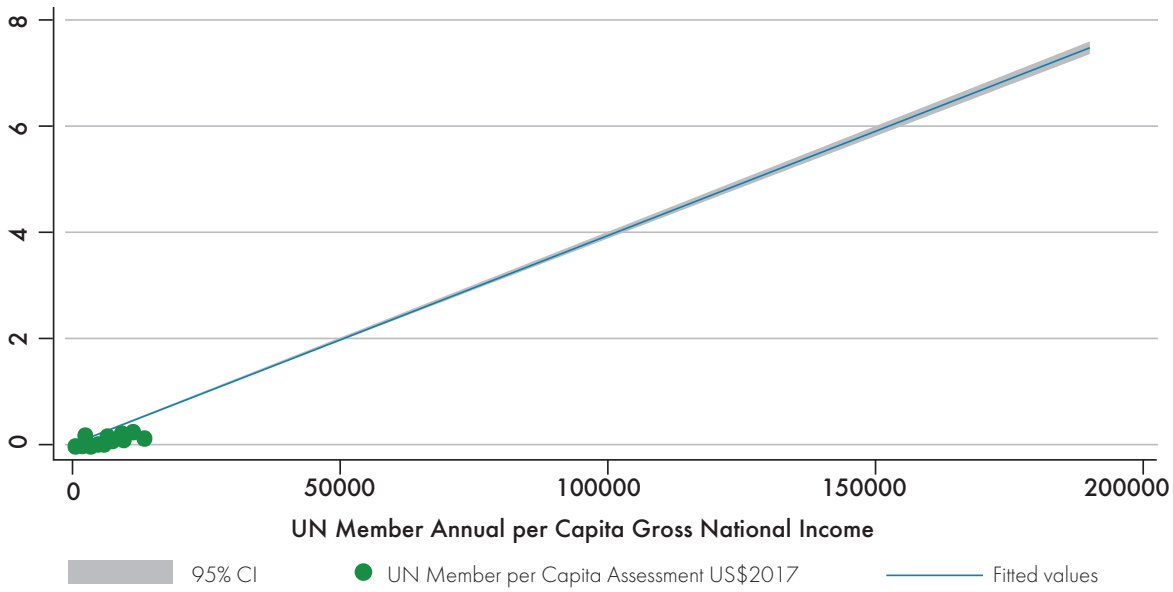


Figure A.1.6. Kernel density estimate of member annual UN assessment per capita

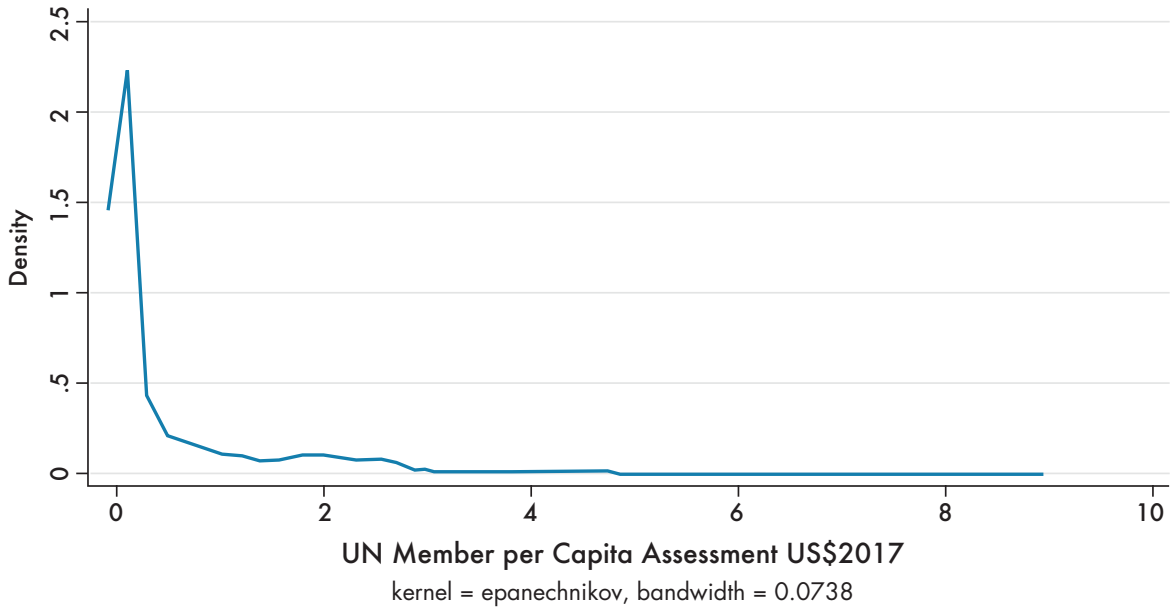
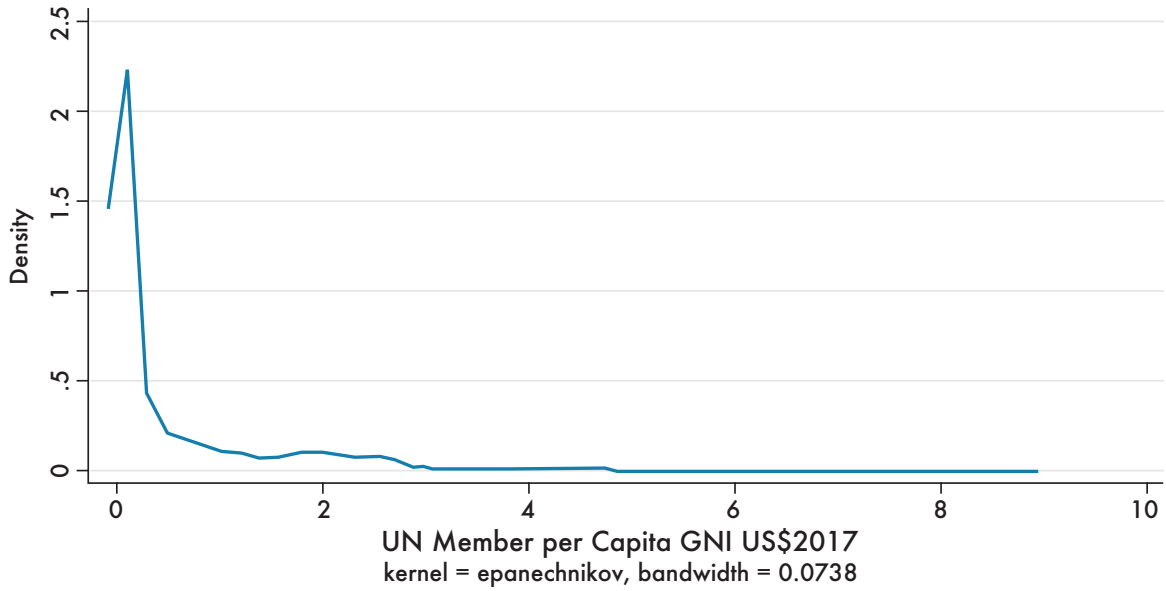


Figure A.1.7. Kernel density estimate of member GNI per capita



histograms that use kernel smoothing to plot values, thereby allowing for smoothing distributions by smoothing out the noise. Kernel density plots help visualize the "shape" of data.

22. Both kernel density plots show the large number of UN members with low member annual contributions and GNI per capita. The long right-hand tails of the distributions show the limited number of UN members with comparatively large annual per capita contributions and GNI.

23. Summary statistics of the data follow. The number of complete observations (values for both annual member contribution per capita and GNI per capita) for the analysis is 3,447. There are 193 UN members and 18 years. Because of a limited number of missing observations (e.g., South Sudan was not a member in the earlier years), the panel is slightly unbalanced, with an average of 17.9 observations per group. The minimum number of observations in a panel is 6 and the maximum number of observations in a panel is 18.

Panel data cointegration tests for long-term equilibrium relationship between contributions and *GNI*

24. Prior to estimating the linear regression to estimate the model parameter used to measure η used in the social welfare weight $\omega_i = \left[\frac{\overline{Y}_i}{\widehat{Y}_i}\right]^{\eta}$, panel data cointegration tests were conducted to determine if the members' annual contributions per capita are stationary without unit roots and integrated of order zero, and if nonstationary and with a unit root are then cointegrated with UN members' per capital GNI over the years of 2000–2017 for per capita GNI by UN member and per capita UN member contribution for the corresponding years 2001–2018. If these two variables are cointegrated, then they are in a long-term equilibrium (long-run stable) relationship and linear regression is not spurious. The Stata procedure allows for many different tests of cointegration with different specifications. Almost all of them uniformly rejected the null hypothesis of no cointegration between members' annual contributions per capita

Table A.1.1. Summary statistics of the data

Variable	No. Observations	Mean	Standard Deviation	Minimum	Maximum
Year of Contribution	3,474	2009.5	5.188874	2001	2018
GNI per Capita	3,461	12,915.21	22,001.72	91	190,723
Contribution Total	3,449	1.23E+07	5.30E+07	192	681,747,185
Contribution per Capita	3,451	0.5334244	0.9543737	0.001	8.89
Population	3,467	3.34E+07	1.33E+08	9,512	1.39E+09
Contribution Percentage by Member	3,450	0.5217383	2.159761	0.001	22
Dummy Low-income Member	48	0.2487	0.4323	0	1
Dummy Low-income Landlocked Member	31	0.1606	0.3673	0	1

are cointegrated with UN members' per capita GNI over the years of data. The results indicate long-term equilibrium and linear regression that is not spurious, i.e., there is a linear relationship between the two variables that is not due to some other, third and unaccounted-for factor.

25. For the panel data cointegration tests, rejection of the null hypothesis implies that it is stationary and that the series UN member contributions per capita and UN member GNI per capita are cointegrated. The alternative hypothesis of the Kao tests, the Pedroni tests, and the all-panels version of the Westerlund test is that the variables are cointegrated in all panels. The alternative hypothesis of the Westerlund test is that the variables are cointegrated in some of the panels. The number of panels in all tests is 193 (the United States of America is included as well as the 192 States parties).

26. The panel data cointegration results are as follows. For the Kao cointegration test the null hypothesis of no without a no time trend, the average number of periods is 15.798, the Kernel is Barlett, the number of lags (Newey-West) is 1.47, and the number of augmented lags is 1.

27. The Pedroni test for the null hypothesis of no cointegration without a time trend, 16.813 average numbers of periods, Bartlett kernel, 0.00 lags (Newey-West), and 1 augmented lag gives the following results (Table A.1.3).

28. The Pedroni test for the null hypothesis of no cointegration with the same specification but with an equal autoregressive parameter across all panels is (see Table A.1.4).

29. Finally, the Westerlund test for the null hypothesis of no cointegration, without a time trend and with 17.829 average numbers of periods, gives a variance ratio statistic of -8.16 and p-Value of 0.00.

30. In sum, almost all the cointegration tests reject the null hypothesis of no cointegration in favour of cointegration of

Table A.1.2. Kao panel cointegration test results

Test	Statistic	p-Value
Modified Dickey-Fuller	-6.53	0.00
Dickey-Fuller	-7.99	0.00
Augmented Dickey-Fuller	1.49	0.07
Unadjusted Modified Dickey-Fuller	-15.16	0.00
Unadjusted Dickey-Fuller	-12.03	0.00

Table A.1.3. Pedroni panel cointegration test results

Test	Statistic	p-Value
Modified Phillips-Perron	-2.58	0.05
Phillips-Perron	-11.25	0.00
Augmented Dickey-Fuller	-13.97	0.00

Table A.1.4. Pedroni panel cointegration test results with equal autoregressive parameter across all panels

Test	Statistic	p-Value
Modified Variance Ratio	7.92	0.00
Modified Phillips-Perron	-4.22	0.00
Phillips-Perron	-7.54	0.00
Augmented Dickey-Fuller	-8.64	0.00

all panels (with the Westerlund test some panels are cointegrated).

Models to estimate marginal tax rates used to calculate the elasticity of marginal social utility of income η

31. In Stata, the analysis regressed member annual contribution per capita upon annual member per capita GNI for the years 2000–2017 (UN member annual contribution reports for years 2001–2018). Per capita values rather than country values were used to adjust for variations in population among countries and because the individual's welfare is the ultimate focus in the approach of social welfare functions. All values were reported in US$2017 and were adjusted for inflation using the US implicit GDP price deflator.

32. The following linear regression model is used to estimate welfare weights for Article 140 countries:

$$C_{it} = \alpha + \beta_1 GNIP_{it} + \alpha_i + b_t + \mu_t,$$

where C_{it} denotes UN member annual contribution per capita in $US2017, GNI_{it} denotes annual UN member per capita Gross National Income ($US2017) in time t, α_i denotes member i fixed effect, b_t denotes annual fixed effects, and μ_t denotes an identically, independently and normally distributed error term. Fixed effects were chosen over random effects because the data represented the population of countries rather than a sample of countries from a much larger population of countries. The statistical analysis allowed for fixed effects among countries and over time (the latter with annual dummy variables and the former through mean differencing).

33. The empirical literature typically uses multiple values of MTR and ATR to provide the panel data and then directly estimates constant η (Groom and Freeman, 2019).[98] This approach is not directly applicable, since the UNGA annual member assessment does not explicitly provide marginal and average tax rates.[99] In addition, equal absolute sacrifice combined with a smooth utility function would imply MTR that continually varies (Groom and Freeman, 2019). Hence, an income tax structure characterized by a limited number of tax thresholds cannot fit perfectly the equal absolute sacrifice model. Tests of the equal absolute sacrifice assumption are themselves impossible since they are necessarily based on a particular utility function. Further, because the annual assessment changes every three years, the UNGA-wide MTR and ATR change slightly every three years. As a consequence, the estimated MTR and ATR estimated over multiple three-year budget cycles give a long-term average social revealed preference for inequality aversion represented by η's value (as well as improved statistical properties of η's estimate due to larger sample size). Below, the long-term average is compared to annual values.

34. The following linear regression model is estimated by ordinary least squares to obtain welfare weights for Article 82 States parties: $C_{it} = \alpha + \beta_1 GNIP_{it} + \beta_2 DLOWLAND*GNIP_{it} + a_i + b_t + \mu_t$ where DLOWLAND is a dummy (categorical) variable for UN members that are both low income and landlocked. The specification $\beta_1 GNIP_{it} + \beta_2 DLOWLAND*GNIP_{it}$ allows the welfare weights to differ between Article 140 and Article 82 countries by β_2.

Statistical estimation of models to obtain marginal tax rates for Article 140 and Article 82 payments

35. Both specifications may be subject to heteroscedasticity and serial correlation (concentrating upon first-order serial correlation). Scatter plots of the residuals and formal statistical tests for heteroscedasticity indicated that heteroscedasticity is present, so that the variance of β_1 and variances of β_1 and β_2 increase with UN member GNI per capita (also suggested by the raw data plots above). The Article 140 regression Breusch-Pagan (Cook-Weisberg) test for heteroscedasticity rejected the null hypothesis of homoscedasticity (constant variance) with a chi-square test (one degree of freedom) value of 17,035.4

[98] Groom and Freeman (2019), for example, regress $ln\ (1 - MTR_i)$ against $ln\ (1 - ATR_i)$ with the constant term suppressed. This accommodates a non-linear MTR schedule, but the estimated coefficient gives an average η value constant over time.

[99] In contrast to estimating revealed preferences from national income tax systems, and in common with revealed preferences from altruistic giving, there is not a ("highly") non-linear tax system with explicit or formal progressively higher marginal tax brackets in a given year (cross section). The UNGA estimates are the average MTR or average slope from a linear functional form for all observations, which, if the "tax" system was highly nonlinear, would lead η closer to 1 than it "should" be. Estimation of $C_{it} = \alpha + \beta_1 GNIP_{it} + \alpha_i + b_t + \mu_b$, quadratic in GNI_i GNI_i, i.e., with additional variable GNI_i^2, provides a robustness check discussed below. The authors are grateful to Jeff Shrader for raising these issues.

with a p-value of 0.00, i.e., $X_{df} = 1 = 17{,}035$ $(p = 0.00)$. The Article 140 regression Breusch-Pagan (Cook-Weisberg) test for heteroscedasticity rejected the null hypothesis of homoscedasticity (constant variance) with a chi-square test (one degree of freedom) value of 17,035.4 with a p-value of 0.00. The Article 82 regression Breusch-Pagan (Cook-Weisberg) test for heteroscedasticity rejected the null hypothesis of heteroscedasticity (constant variance) with a chi-square test (one degree of freedom) value of 17,057.93 with a p-value of 0.00.

36. Serial correlation was tested by the Woolridge test for panel data (command xtserial in Stata). The Article 140 null hypothesis of no first-order serial correlation was rejected with an F-statistic (1,192) value of 7.265 with a probability of exceeding F of 0.0077. The Article 82 null hypothesis of no first-order serial correlation was rejected with an F-statistic (1,192) value of 7.261 with a probability of exceeding F of 0.0077. The result is that standard errors of both the Article 140 and Article 82 regressions are subject to heteroscedasticity of some unknown form and first-order serial correlation.

37. This result of heteroscedasticity of an unknown form and first-order serial correlation was addressed through heteroscedastic and autocorrelation consistent standard errors. Three methods were applied: Newey-West (newey command in Stata), Driscoll-Kraay (xtscc command in Stata), and robust regression with cluster-specific standard errors (xtreg command in Stata, individual members is the cluster variable) that is robust to any form of serial correlation and heteroscedasticity and does not rely upon results as $T \rightarrow \infty$. All three-panel data fixed effect approaches accounting for unknown forms of heteroscedasticity, and first-order serial correlation gave the same parameter values although they, not surprisingly, gave slightly different standard errors. The Newey-West regression applied least squares with dummy variables for the country fixed effects and all three approaches applied least squares for dummy variables for annual fixed effects. The Newey-West method requires many time periods for asymptotic results. The cluster-robust approach requires many panel identifiers (here UN member countries), with the number in this study more than enough. The Driscoll-Kraay standard errors are more robust to cross-sectional dependence, with significantly better small properties when UN Member GNI per capita estimates and differ according to the standard errors of the coefficients.

38. The key empirical result with heteroscedastic and autocorrelation consistent (HAC) standard errors for the Article 140 regression is the parameter for GNI per capita, β_1, which gives the marginal tax rate, from the linear regression. The key empirical results with heteroscedastic and autocorrelation consistent (HAC) standard errors for the Article 82 regression is the parameter for GNI per capita, β_1, which gives the marginal tax rate for all UN members except the landlocked low-income members and the parameters $\beta_1 - \beta_2$ for the landlocked low-income members. In the regression results reported next, Wald tests always indicated that the member fixed effects and the year fixed effects were statistically significant as groups, and these member and year fixed effects were consequently always included.

39. The parameter results for the Article 140 members' linear regression by ordinary least squares of $C_{it} = \alpha + \beta_1 GNIP_{it} + \alpha_i + b_t + \mu_t$ with cross-sectional fixed effects and dummy variables for time fixed effects and without HAC standard errors is (see table A.1.8)

40. The parameter results for the Article 140 members' linear regression by ordinary least squares of $C_{it} = \alpha + \beta_1 GNIP_{it} + \alpha_i +$

b_t+ μ_t with cross-sectional fixed effects and dummy variables for time fixed effects and with HAC standard errors is (the R^2 values remain the same).

41. The constant term for the Newey-West estimation differs from the constant term for the robust and Driscoll-Kraay estimation because the former is estimated with dummy variables for members and the latter two through fixed effects (mean differencing). The constant term for the Newey-West and Driscoll-Kraay estimation is insignificant in each case.

42. Wald tests always indicate that member and year fixed effects are statistically significant as groups, and these fixed effects are always included.

43. Robustness of C_{it}= α+ $\beta_1 GNIP_{it}$ α_i+ b_t+ μ_t was verified by estimating this equation quadratic in GNI_i^2 (additional variable GNI_i^2).Newey-West estimation gave coefficients, standard errors, t-ratio and p-values for GNI_i of 0.0000208, 7.42e-06, 2.80, 0.005 and for GNI_i^2 7.97e-11, 6.82e-11, 1.17, 0.243. Driscoll-Kray estimation gave for GNI_i 0.0000208, 9.75e-06, 2.13, 0.035 and for GNI_i^2 7.97e-11, 7.95e-11, 1.00, 0.317. GNI_i^2 is not statistically significant at conventional levels in both cases.

Table A.1.5. Article 140 initial regression results

Variable	Coefficient	Standard Error	t-Value	p-Value
Member GNI per capita	0.0000327	8.46e-07	38.68	0.000
R^2 within	0.3900			
R^2 between	0.8850			
R^2 overall	0.8245			

Table A.1.6. Article 140 initial regression results

Variable	Coefficient	Standard Error	t-Value	p-Value
Member GNI per capita Newey-West	0.0000327	3.58E-06	9.15	0.000
Constant Newey West	-0.0300712	0.020453	-1.47	0.142
Member GNI per capita Robust	0.0000327	2.89E-06	11.34	0.000
Constant Robust	0.0911364	0.0265706	3.43	0.001
Member GNI per capita Driscoll-Kraay	0.0000327	2.89E-06	11.34	0.000
Constant Driscoll-Kraay	0.0919335	0.0505705	1.82	0.071

Note: Heteroscedastic Autocorrelation Standard Errors.

Table A.1.7. Article 82 initial regression results

Variable	Coefficient	Standard Error	t-Value	p-Value
Member GNI per capita	0.0000327	8.47E-07	38.59	0.000
DLOWLANDLOCKED* Member GNI per capita	-0.000208	0.0000101	-2.07	0.039
Constant	0.0934608	0.0201993	4.63	0.000
Within	0.3908			
Between	0.8859			
Overall	0.8254			

44. Substituting the estimated marginal tax rate β_1= 0.0000327 into $\eta = \frac{ln\,(1-MTR)}{ln\,(1-ATR)}$ gives $\hat{\eta}$ = 0 – 0.9987862 or effectively .[100] Average MTR is close in value to ATR (Figure A.4.3.). Figure A.4.3. does not account for fixed effects, so that closeness of average MTR to ATR after partialing out fixed effects is notable.

45. The parameter results for the Article 82 members' linear regression by ordinary least squares of $C_{it}= \alpha+ \beta_1 GNIP_{it}+ \beta_2 D\text{-}LOWLAND*GNIP_{it}+ a_i+ b_t+ \mu_t$ with cross-sectional fixed effects and dummy variables for time fixed effects and without HAC standard errors is:

46. The intercept α should be statistically insignificant for the assumption of equal absolute sacrifice and constancy of η over time to receive empirical support (Evans et al., 2005). In almost all instances, the intercepts are statistically insignificant, so that the regression line intercepts the origin (see also Figures 2 and 3, in which the estimated regression lines run through the origin).

47. Constant, average, long-run η=1 masks annual variability in UNGA ethical revealed preferences for inequality aversion represented by η. Figure A.4.8. depicts annual percentage MTR and ATR with the implied annual unweighted estimate of η over 2001–2017. Annual values are estimated as above but with an annual dummy variable interacting with Y_{it}. ATR declines, rises, then declines again. MTR rises but with annual variability, lies below ATR then rises above in 2013. Mean annual η is 1.0304 with standard deviation 0.0247, minimum 0.9880, maximum 1.0707. The mean value slightly exceeds η estimated over all the years but remains very close to η=1 as the conclusion, where a round, even number gives a more plausible and justifiable basis for agreement and coordination of States' expectations than one with additional significant digits. Table A.4.14. reports dummy variable regression results. MTR steadily declines 2001–2006 and then rises with annual variability. Inequality aversion η declines (rises) as the gap narrows (widens) between MTR and ATR. These results reinforce conclusions from Figure 1, with later-year values of

[100] The linearized standard errors are Newey-West 0.017672, Driscoll-Kray 0.0096311. Wald test of H_0: η = 0 gives X^2_{df}= 1= 10744.64 (p=0.0000) with Newey-West and X^2_{df} = 1= 10754.64 (p=0.0000) with Driscoll-Kray standard errors, rejected H_0 (under assumptions of constant elasticity and equal-absolute-sacrifice). Wald test of H_0: η = 1 gives X^2_{df} = 0.02 (p=0.8998) with Newey-West and (p=0.8997) with Driscoll-Kray standard errors, did not reject H_0. Linearized standard error by delta method with Newey-West is 0.0097013 with 95% Confidence Interval [0.9915384, 1.012149].

Table A.1.8. Article 82 final regression results

Variable	Coefficient	Standard Error	t-Value	p-Value
Member GNI per capita Newey-West	0.0000327	3.58E-06	9.14	0.000
DLOWLANDLOCKED* Member GNI per capita Newey-West	-0.0000208	3.56E-06	-5.86	0.000
Constant Newey-West	-0.0244898	0.0202354	-1.21	0.226
Member GNI per capita robust regression	0.0000327	2.88E-06	11.33	0.000
DLOWLANDLOCKED* Member GNI per capita robust regression	-0.0000208	5.97E-06	-3.49	0.001
Constant robust regression	0.0934608	0.0265451	3.53	0.001
Member GNI per capita Driscoll-Kraay	0.0000327	3.56E-06	9.17	0.000
DLOWLANDLOCKED* Member GNI per capita Driscoll-Kraay	-0.0000208	5.63E-06	-3.70	0.000
Constant Driscoll-Kraay	0.10057	0.0503668	2.00	0.047

Note: Heteroscedastic Autocorrelation Standard Errors and estimated by Ordinary Least Squares.

Figure A.1.8. Annual marginal and average tax rate per capita and inequality aversion (η)

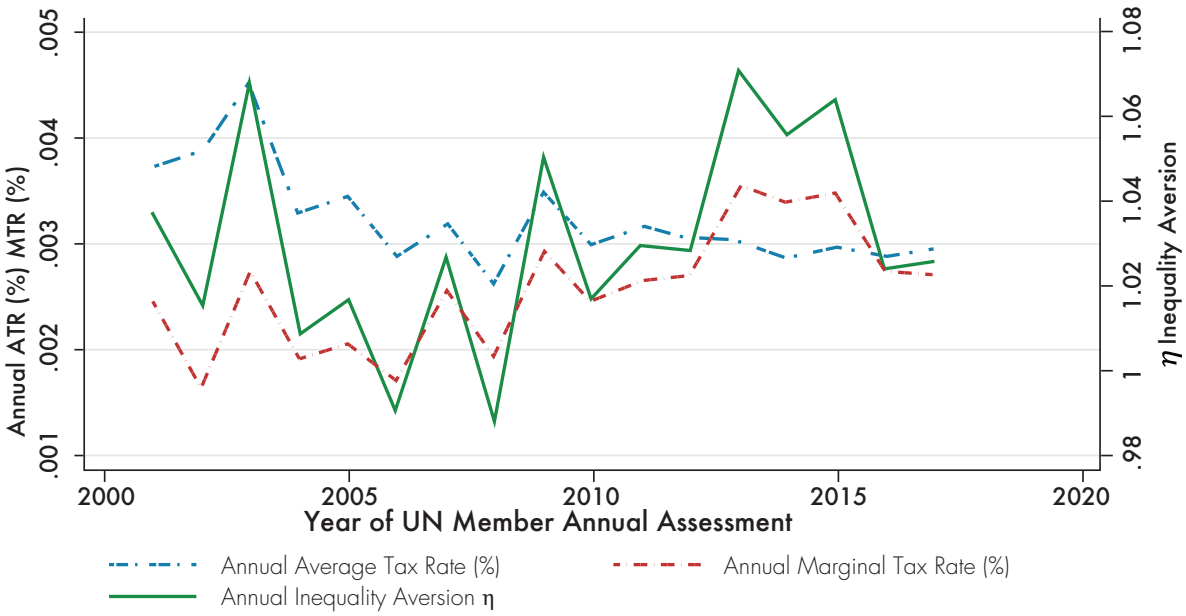


Table A.1.9. Article 82 final regression results

Variable	Coefficient	Standard Error	t-Ratio
Constant	-0.05226	0.0241318	-2.17
GNI per Capita	0.0000246	6.36E-06	3.86
Annual Dummy Variable Interacting with per Capita GNI			
2002	-8.17E-06	4.45E-06	-1.84
2003	2.89E-06	3.76E-06	0.77
2004	-5.36E-06	3.74E-06	-1.43
2005	-3.98E-06	4.21E-06	-0.95
2006	-7.48E-06	4.05E-06	-1.85
2007	1.16E-06	5.23E-06	0.22
2008	-5.31E-06	4.90E-06	-1.08
2009	4.73E-06	6.37E-06	0.74
2010	1.65E-08	4.70E-06	0.00
2011	1.93E-06	5.42E-06	0.36
2012	2.45E-06	5.15E-06	0.48
2013	0.000011	6.04E-06	1.83
2014	9.36E-06	5.64E-06	1.66
2015	0.0000104	5.40E-06	1.92
2016	2.71E-06	5.02E-06	0.54
2017	2.60E-06	3.75E-06	0.69

Notes: Dependent variable is annual country per capita contributions to UN General Assembly budget. Independent variables are constant, country per capita GNI, country and year fixed effects, and annual dummy variable interacting with each country's per capita GNI. Country fixed effects (F (192, 3220) = 24.51, p=0.0000)) and year fixed effects (F (17, 3220) = 1.63, p=0.0464)) are both statistically significant as a group. Interaction of annual time dummy variables and per capita GNI statistically significant as a group: F(16, 3220) = 5.07 (p = 0.0000). Newey-West standard errors. Overall regression F (226, 3220) = 204.28.

rising η driven by increasing annual MTR relative to ATR and increasing progressivity of a limited number of members' per capita contributions.

Weighted least squares estimation of models to obtain marginal ta rates for Article 140 and Article payments

48. The weighted regression is done by dividing all values for observation I by $\sqrt{w_i}$

This creates the matrix:

$$\tilde{x} = \begin{matrix} \frac{x_{1,1}}{\sqrt{w_i}} & \cdots & \frac{x_{1,k}}{\sqrt{w_i}} \\ \cdots & & \cdots \\ \frac{x_{n,1}}{\sqrt{w_n}} & & \frac{x_{n,k}}{\sqrt{w_n}} \end{matrix}$$

Call the diagonal matrix composed of $\sqrt{w_i}$ in the (i, i) element$\sqrt{w}$ Then the weighted least squares (WLS) estimator is given by:

$$\hat{\beta}_{WLS} = (\tilde{x}'\tilde{x})^{-1}\tilde{x}'\tilde{y} = \left[\left(\sqrt{w}x\right)'\sqrt{w}x\right]^{-1}$$
$$\left(\sqrt{w}x\right)'\left(\sqrt{w}x\right) = (x'Wx)^{-1}(x'Wy)$$

since $\sqrt{w'w} = W$ and $\tilde{x} = \sqrt{w}x$. This is the same as multiplying each row of X and y by the square root of the weight, here $\sqrt{w}$.

49. The Article 140 equation $C_{it}= \alpha+ \beta_1 GNIP_{it} \alpha_i+ b_t+ \mu_t$ is estimated by weighted least squares, with member population sizes as weights, member and annual dummy variables for member and time fixed effects, and heteroscedastic-consistent standard errors clustered on individual members. (The null hypothesis of no first-order serial correlation not rejected by Woolridge (2002) panel data test: $F(1,192)=1.828$, $p>F=0.1780$.) Wald tests always indicate that member and year fixed effects are statistically significant as groups, and these fixed effects are always included. Table A.4.12. reports the estimation results. The statistically insignificant intercept α again supports the EAS assumption and constancy of η over time. Robust regression with cluster-specific standard errors (individual members is the cluster variable) gives HAC standard errors that are robust to any form of serial correlation and heteroscedasticity. Weighted regression gives statistically significant constant

$$\widehat{\eta} = \frac{ln\,(1 - MTR)}{ln\,(1 - ATR)} = \frac{ln\,(1 - 0.0000316)}{ln\,(1 - .0000323)} = 0.978327831$$

for population-weighted regression, and serves as a robustness check to constant $\widehat{\eta}$ = 0.9987862 for unweighted regression. For the population-weighted regression, a Wald test of $H_0{:}\eta{=}0$ gives $X^2_{df}= 1= 36304.67$ (p=0.0000) and $H_0{:}\eta{=}1$ gives $X^2_{df}= 1= 0.12$ (p=0.7258). The linearized standard error by the delta method is 0.005258 with 95% Confidence Interval [0.9915384, 1.012149].

50. The Article 82 equation $C_{it}= \alpha+ \beta_1 GNIP_{it}+ \beta_2 DLOWLAND{*}GNIP_{it}+ a_i+ b_t+ \mu_t$ is estimated by weighted least squares (see below), with cross-sectional fixed effects for UN members and dummy variables for time fixed effects, to account for variations in population across the units of observation, countries i. Robust regression with cluster-specific standard errors (individual members is the cluster variable) gives HAC standard errors that are robust to any form of serial correlation and heteroscedasticity.

51. The results are like the standard regression, and hence are presented here but not further used.

Calculation of social distribution (welfare) weights

52. The social distribution (welfare) weights, $\omega_i = \left[\frac{\overline{Y}}{\widehat{Y}_i}\right]^{\eta}$, can be calculated given the estimate of the elasticity of marginal social utility of income, η, under the assumptions of a utilitarian social welfare function $(\gamma{=}0, W(U){=}\sum_{i=1}^{N} U_i)$, a constant elasticity iso-elastic utility function that is common across countries and a function of real Gross National Income (GNI) = γ, the resulting equality of the social and private marginal utilities of income (see Annex 5), i.e., $\eta{=}\eta{=}\varepsilon{+}\gamma(1{-}\varepsilon){=}\ \varepsilon$, and the principle of equal absolute sacrifice with taxation. The welfare weights depend upon not only real per capita GNI but also upon the extent to which member marginal social utility declines as GNI rises. The

Table A.1.10. Article 140 weighted least squares regression results

Variable	Coefficient	Standard Error	t-Value	p-Value
Member GNI per capita	0.0000316	1.89e-06	16.77	0.0000279
Constant	-0.0150433	0.0106114	-1.42	0.158

Note: Weighted regression with observations weighted by member population and estimated with member and time dummy variables and heteroscedastic-consistent standard errors clustered on members. R^2=0.9727.

lower a member's real per capita GNI level compared to the total per capita GNI level and the greater the extent to which the marginal social utility of income declines, the larger the social welfare weight for a member. The elasticity of marginal social utility of income η captures the rate of decline of marginal social utility with increase in income (here, per capita GNI).

53. For Article 140 members, substituting the estimated marginal tax rate $\hat{\beta}_1$ = 0.0000327 into the formula $\eta_1 = \frac{ln\,(1-MTR)}{ln\,(1-ATR)}$ allows estimating the relative welfare weight $\omega_i = \left[\frac{\overline{Y}}{\hat{Y}_i}\right]^{\eta_1}$ where the average tax rate ATR is computed as the member UN member contribution per capita divided by the member GNI per capita (the same answer is given when total contribution is divided by total GNI). The estimated value η_1= 1.00 gives an inverse relationship between GNI_i and Y_i, which is the specification in the 1971 report on distributing DSM royalties.

54. For Article 82 social welfare weights for low-income landlocked States parties, substituting the estimated marginal tax rate $\hat{\beta}_1 - \hat{\beta}_2$ = 0.0000327 – 0000209 = 0.0000118 into the formula $\eta_2 = \frac{ln\,(1-MTR)}{ln\,(1-ATR)}$ allows estimating the relative welfare weight $\omega_i^2 = \left[\frac{\overline{Y}}{\hat{Y}_i}\right]^{\eta_2}$ where the average tax rate ATR is computed as the member UN contribution per capita divided by the member GNI per capita. The estimated value of $\hat{\eta}_2$ = 1.10 for the low-income landlocked members, which gives a slightly more progressive welfare weight than the Article 140 one. The social welfare weight for the remaining members (i.e., those that are not low-income and landlocked) is calculated as with Article 140 members, using value $\hat{\beta}_1$= 0.0000327 (which is the same for both regressions).

Appendix 2: Principles and associated metrics for conceptualizing and distributing equitable shares

1. Appendix 2 is divided into eight parts:
   - Relationships between the distribution weight ω_i and the State party per capita GNI for Article 140 and Article 82 distributions
   - Article 140 shares, mostly with η=1
   - Article 140 shares allocated by States parties groups η=1

Table A.1.11. Article 82 weighted least squares regression results

Variable	Coefficient	Standard Error	t-Value	p-Value
Member GNI per capita robust regression	0 .0000297	1.69E-06	17.58	0.000
DLOWLANDLOCKED* Member GNI per capita robust regression	-9.44E-06	3.91E-06	-2.42	0.017
Constant robust regression	391.6082	62.53518	6.26	0.000
Within	0.5431			
Between	0.9515			
Overall	0.9288			

Note: Heteroscedastic Autocorrelation Standard Errors. Observations weighted by square root of population.

- Small and large tail ends of the distributions for Article 140 shares η=1
- Article 82 shares, mostly with η=1
- Article 82 shares allocated by States parties groups η=1
- Relationship between Article 140 and Article 82 share distributions, η=1
- Impact upon Article 140 shares from increasing η from η=1 to η=2

Relationships between distribution weight ω_i and State party per capita *GNI* for Article 140 and Article 82 distributions

2. The following figures illustrate the hyperbolic relationship for Article 140 and Article 82 distribution weights ω_i as given by the empirical analysis. Both figures show that the relative distribution weight ω_i rapidly increases when States parties have low per capita GNI. This means that all low-income States parties receive a higher weighting that in turn leads to a higher allocation share for both Article 140 and Article 82 proceeds, and that low-income landlocked countries receive an even higher distribution weight and allocation share for Article 82 proceeds.[101]

3. The following figures illustrate the relationship for Article 140 and Article 82 distribution weights ωi as given by the empirical analysis only for low-income landlocked States parties, Pacific Island Developing States parties,102 and all regional group States parties. These figures illustrate the diversity within each group and that individual groups can potentially contain considerable variation. For example, the category of Pacific Island Developing States parties contains States parties with per capita GNI greater than, about equal to, and less than global per capita GNI. The curve is correspondingly further from the origin (zero, where the vertical and horizontal axes meet) due to a comparatively high per capita GNI (due to the States parties within this group with per capita GNIs exceeding the per capita GNI of all States parties) and displays a more gradual transition from distribution weights of higher and lower incomes (due to the distribution of per capita GNIs from higher than to less than the per capita GNI of all States parties). The distribution for African Group States parties looks much more like those for all States parties together, with the distribution weights rising swiftly at a low per capita GNI. Depending on the definition of the States parties group, intra-group variation can complicate broad or simple generalizations.

4. Almost always, the relationship between the distribution weight and State party per capita GNI is smooth without "outliers" or "zigs and zags" in the line, but not in all cases (notably, Article 82 distribution weights). One reason is that the sorting of States parties' ratio of global per capita NGI to individual State party per capita GNI is not necessarily by even amounts between States parties. Another reason is that the relationship between UN General Assembly members' assessments and per capita GNI is not strictly proportional due to the price ceilings and floors for assessments and allowances for debt repayment. Mostly importantly, this follows because Article 82 distribution weights ω_i give a value of the elasticity of social marginal utility of income η=1.1 for low-income landlocked States parties and η=1 for all other States parties.

[101] The low-income landlocked States parties are (for brevity, full legal names are not used): Armenia, Azerbaijan, Bolivia, Botswana, Burkina Faso, Chad, Eswatini, Laos, Lesotho, Malawi, Mali, Mongolia, Nepal, Niger, Paraguay, Moldova, Northern Macedonia, Uganda, Zambia and Zimbabwe.
[102] The Pacific Small Island Developing States are (for brevity, full legal names are not used): Cook Islands, Fiji, Kiribati, Marshall Islands, Micronesia, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu.

Figure A.2.1. Relationship between distribution weight ω_i and State party per Capita GNI for Article 140 distributions (η=1)

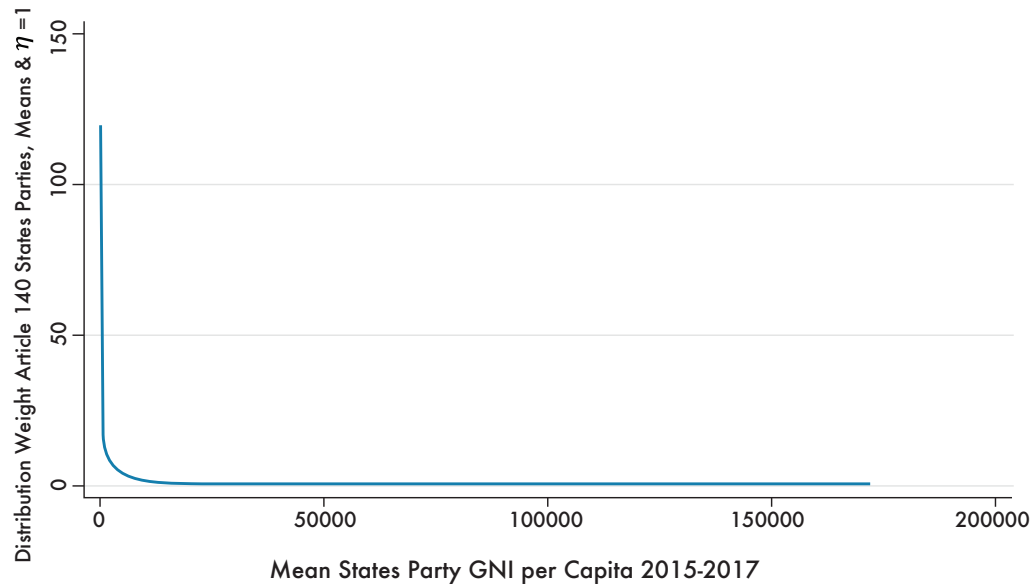


Figure A.2.2. Relationship between distribution weight ω_i and State party per capita *GNI* for Article 82 distributions (η=1.1 for low income, landlocked, η=1 otherwise)

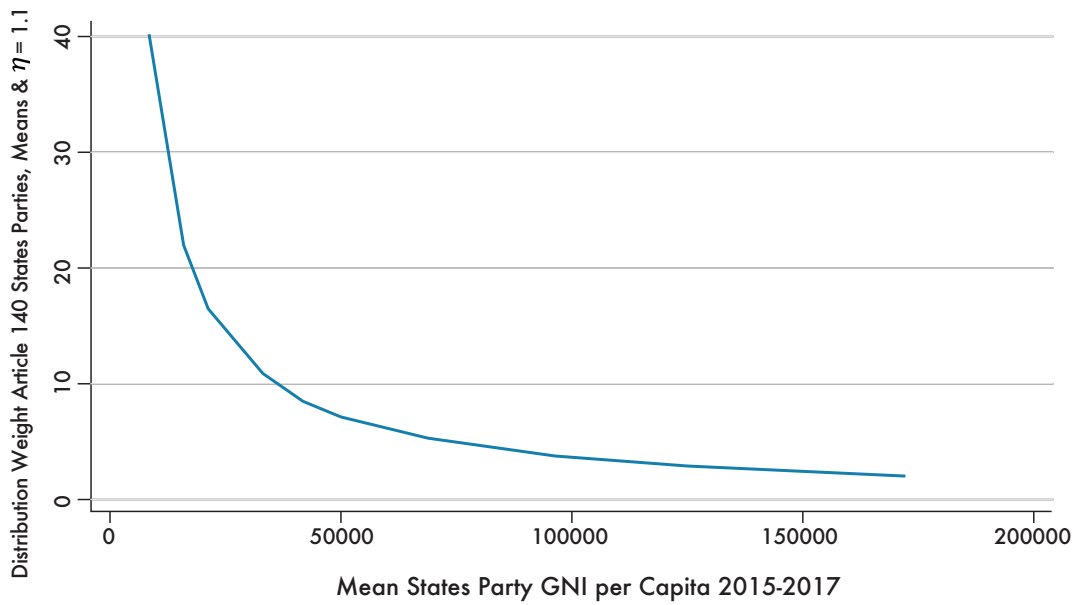


Figure A.2.3. Relationship between distribution weight ω_i and State party per capita GNI for Article 140 distributions (η=1): low-income landlocked States parties

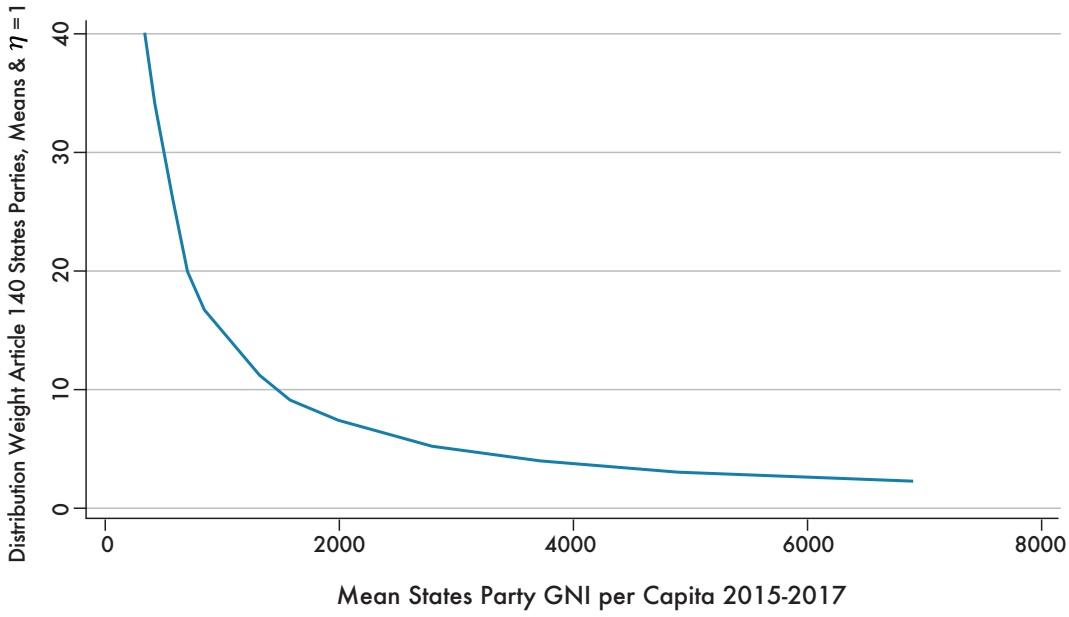


Figure A.2.4. Relationship between distribution weight ω_i and State party per capita GNI for Article 140 distributions (η=1): Pacific island developing States parties

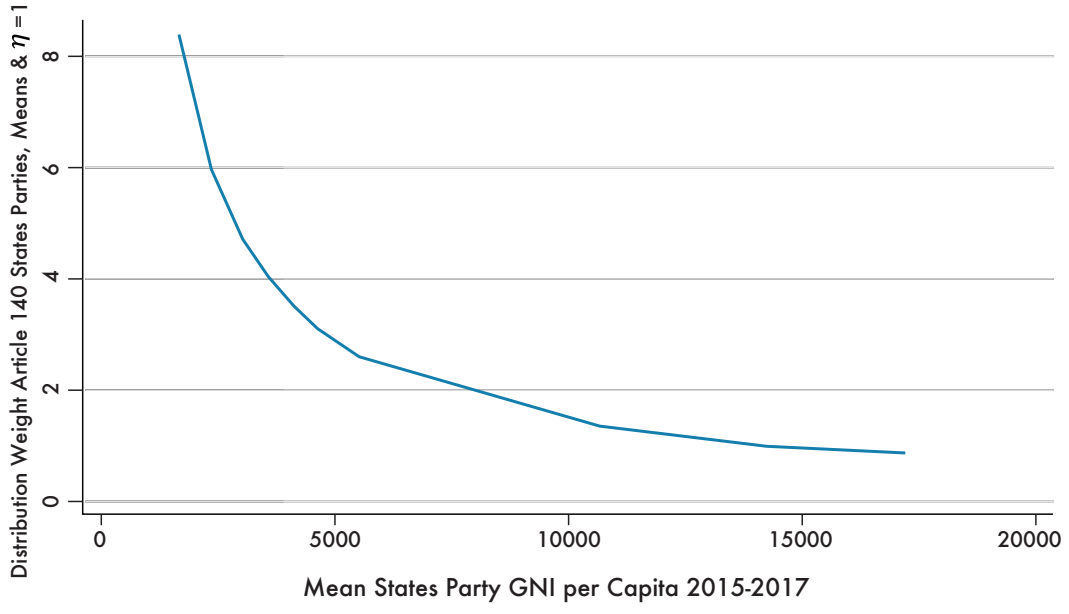


Figure A.2.5. Relationship between distribution weight ω_i and State party per capita GNI for Article 140 distributions (η=1): Pacific island developing States parties

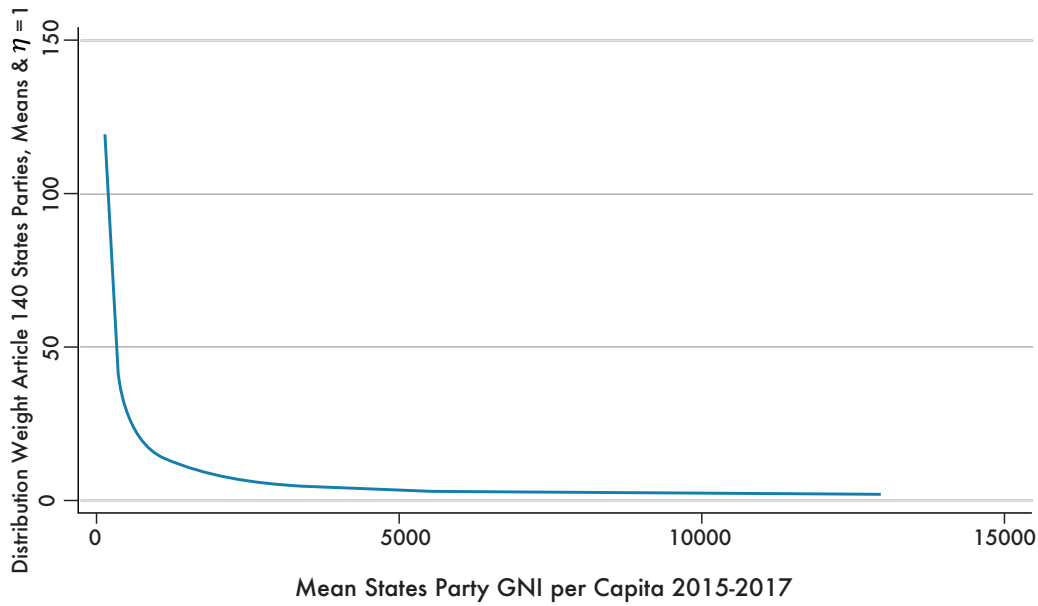


Figure A.2.6. Relationship between distribution weight ω_i and State party per capita GNI for Article 140 distributions (η=1): African Group States parties

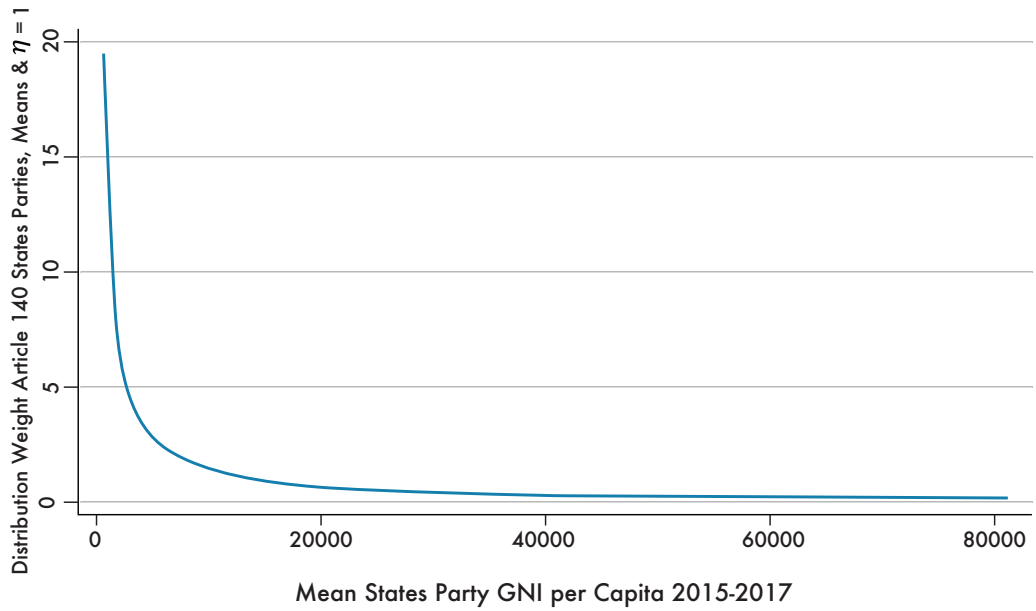


Figure A.2.7. Relationship between distribution weight ω_i and State party per capita GNI for Article 140 distributions (η=1): Latin American and Caribbean Group States parties

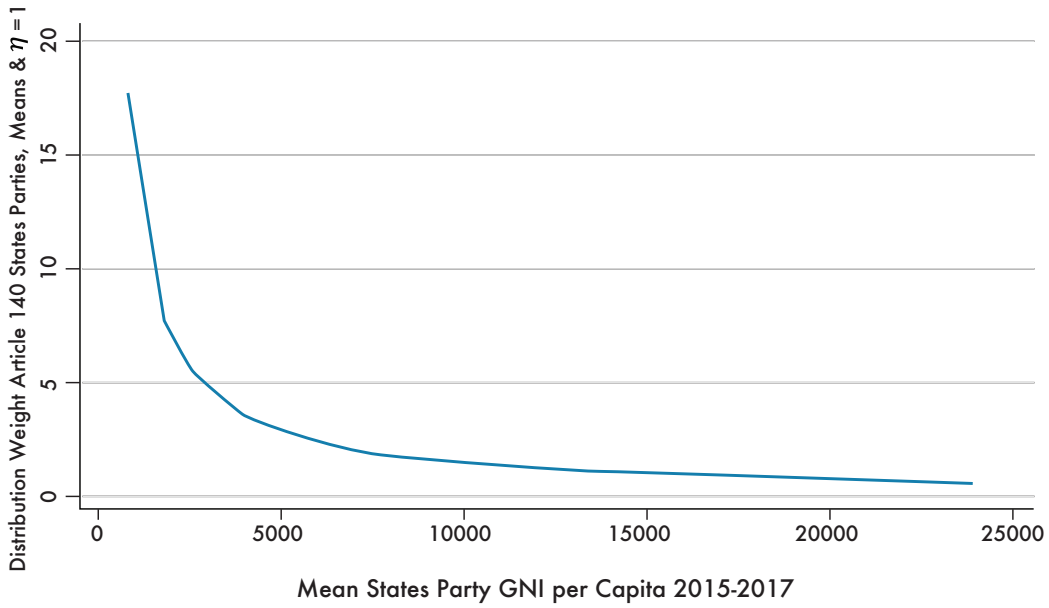


Figure A.2.8. Relationship between distribution weight ω_i and State party per capita GNI for Article 140 distributions (η=1): Eastern European Group States parties

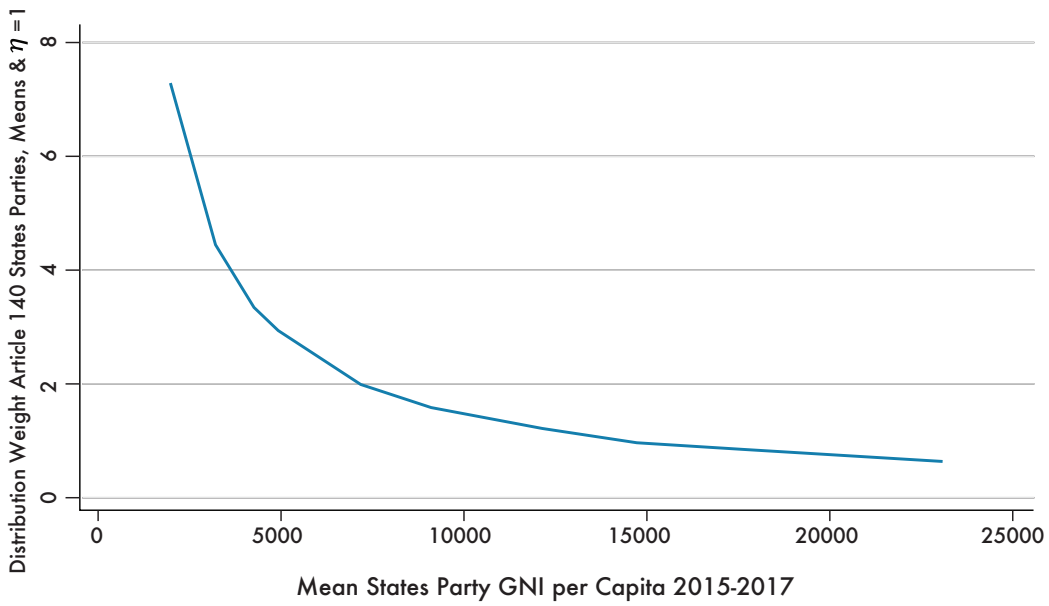
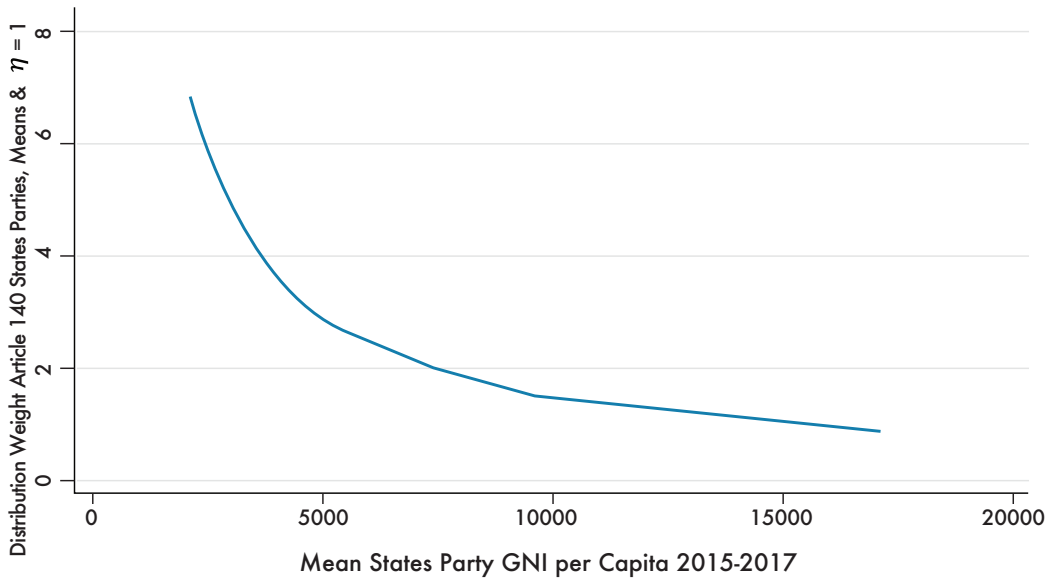


Figure A.2.9. Relationship between distribution weight ω_i and State party per capita GNI for Article 140 distributions (η=1): Western European and Other Group States parties



5. The next set of figures examine the relationship between the distribution weight ω_i and State party per capita GNI for Article 82 distributions for the marginal social utility of income η=1.1 for low-income landlocked States parties and η=1for all other States parties.

Figure A.2.10. Relationship between distribution weight ω_i and State party per capita GNI for Article 82 distributions (η=1.1 for low income, landlocked, η=1 otherwise): low-income landlocked States parties

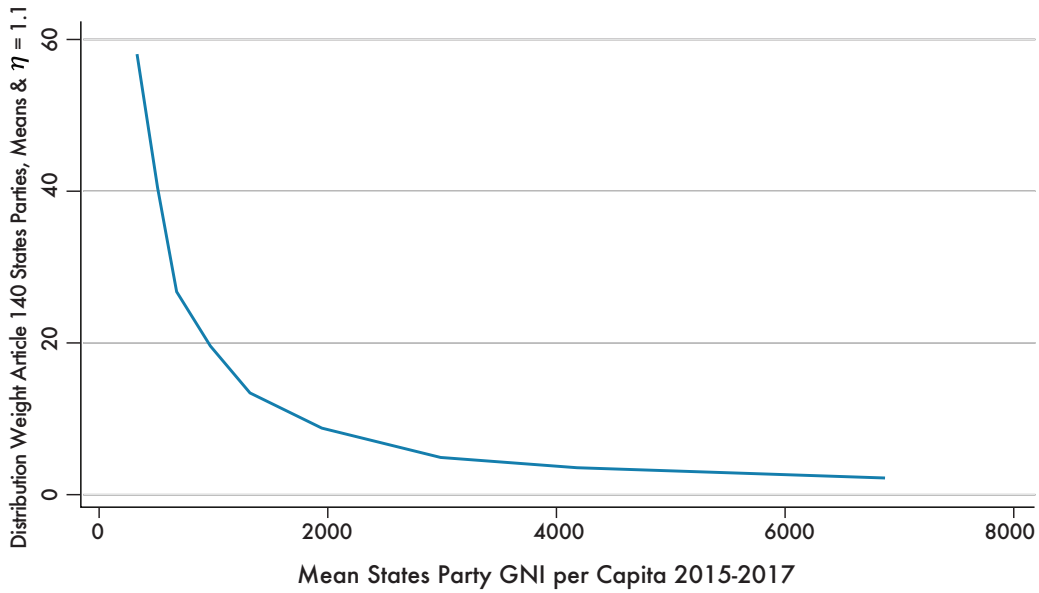


Figure A.2.11. Relationship between distribution weight ω_i and State party per capita GNI for Article 82 distributions (η=1.1 for low income, landlocked, η=1 otherwise): Pacific island developing States parties

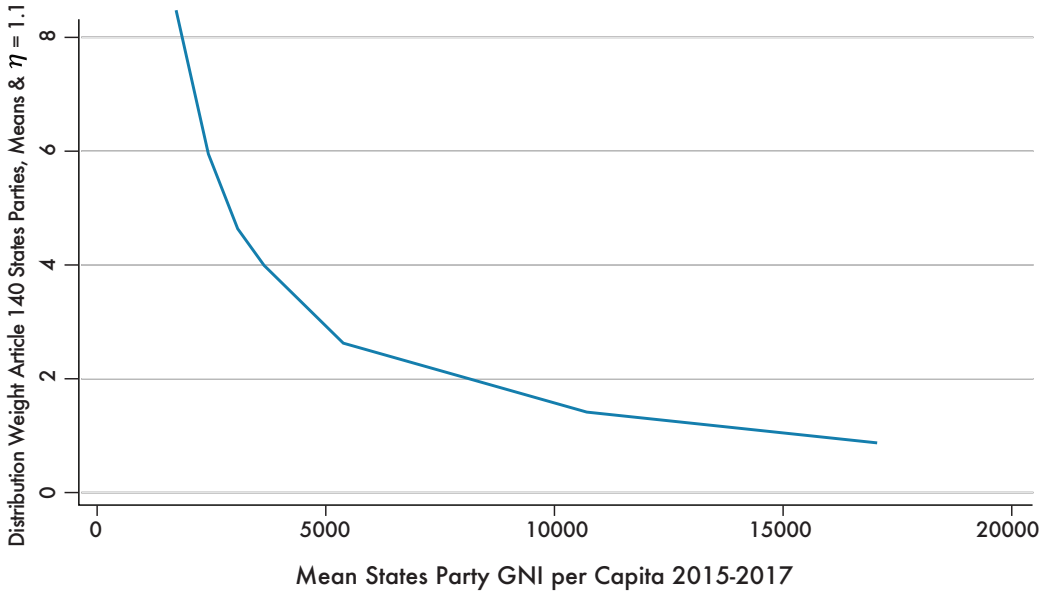


Figure A.2.12. Relationship between distribution weight ω_i and State party per capita GNI for Article 82 distributions (η=1.1 for low income, landlocked, η=1 otherwise): African Group States parties

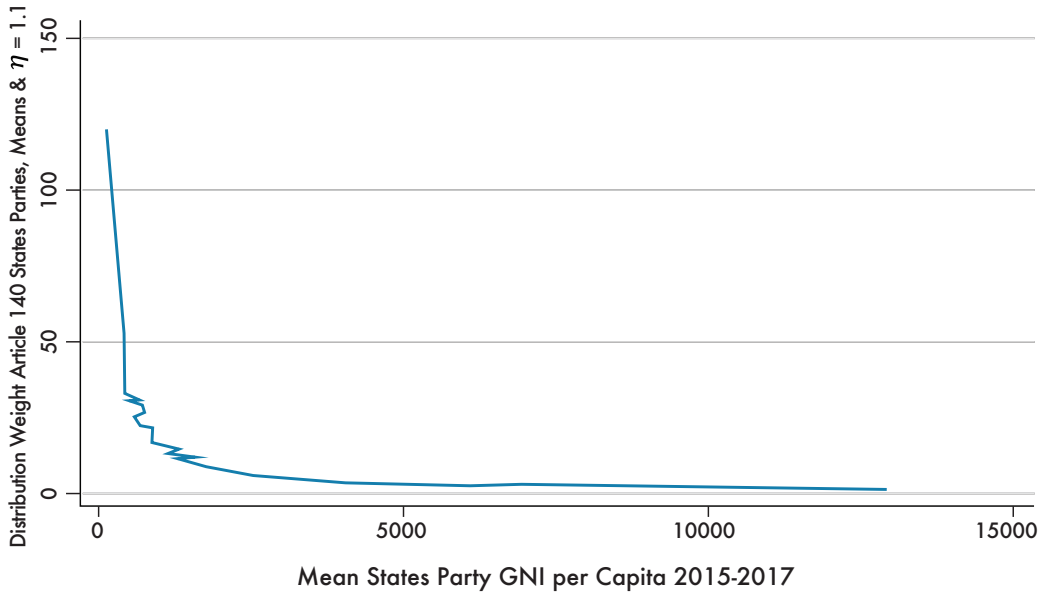


Figure A.2.13. Relationship between distribution weight ω_i and State party per capita GNI for Article 82 distributions (η=1.1 for low income, landlocked, η=1 otherwise): Asia-Pacific Group States parties

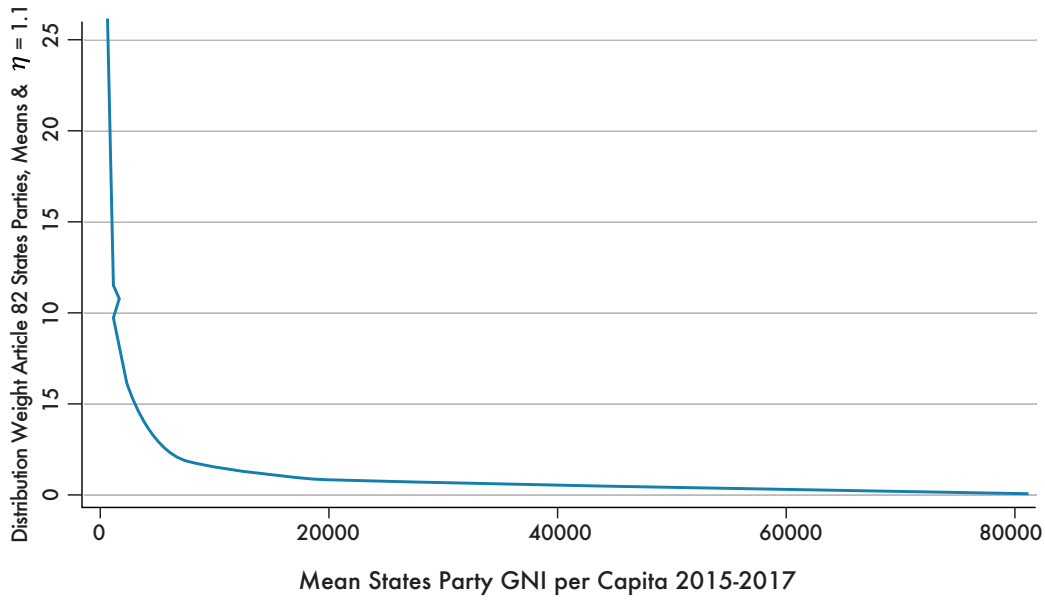


Figure A.2.14. Relationship between distribution weight ω_i and State party per capita GNI for Article 82 distributions (η=1.1 for low income, landlocked, η=1 otherwise): Latin American and Caribbean Group States parties

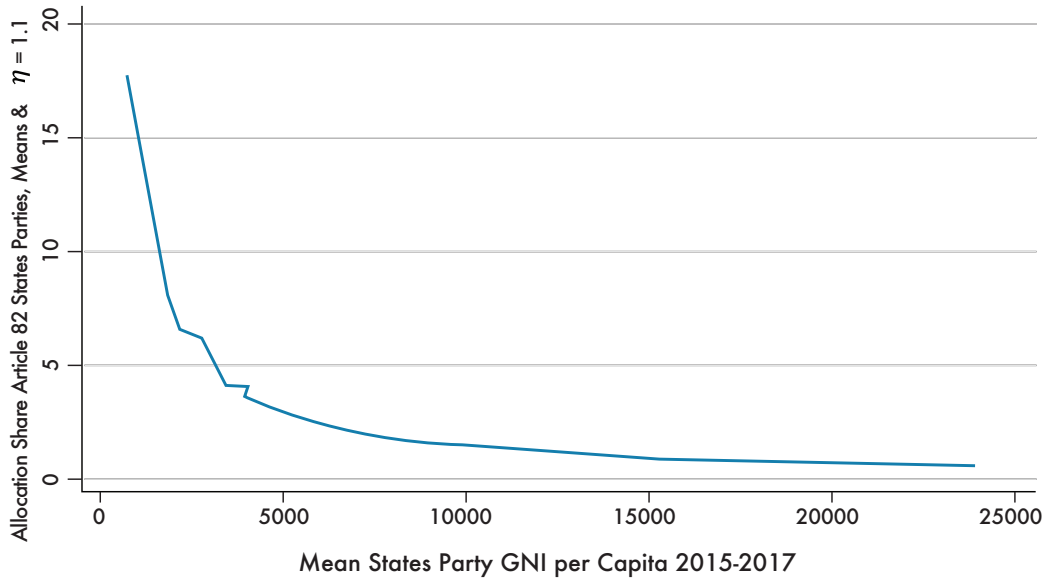


Figure A.2.15. Relationship between distribution weight ω_i and State party per capita GNI for Article 82 distributions (η=1.1 for low income, landlocked, η=1 otherwise): Eastern European Group States parties

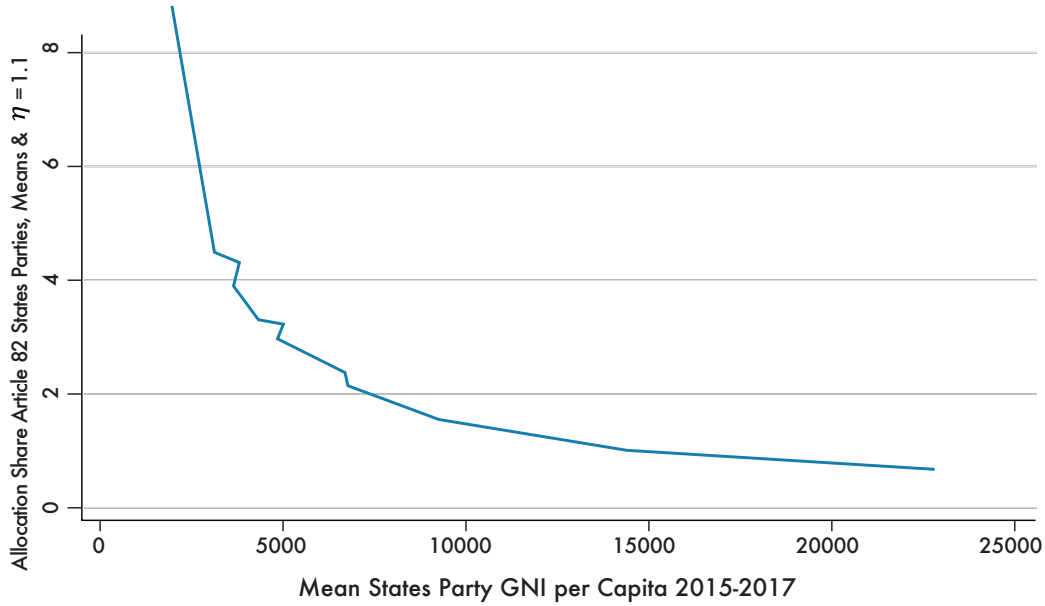
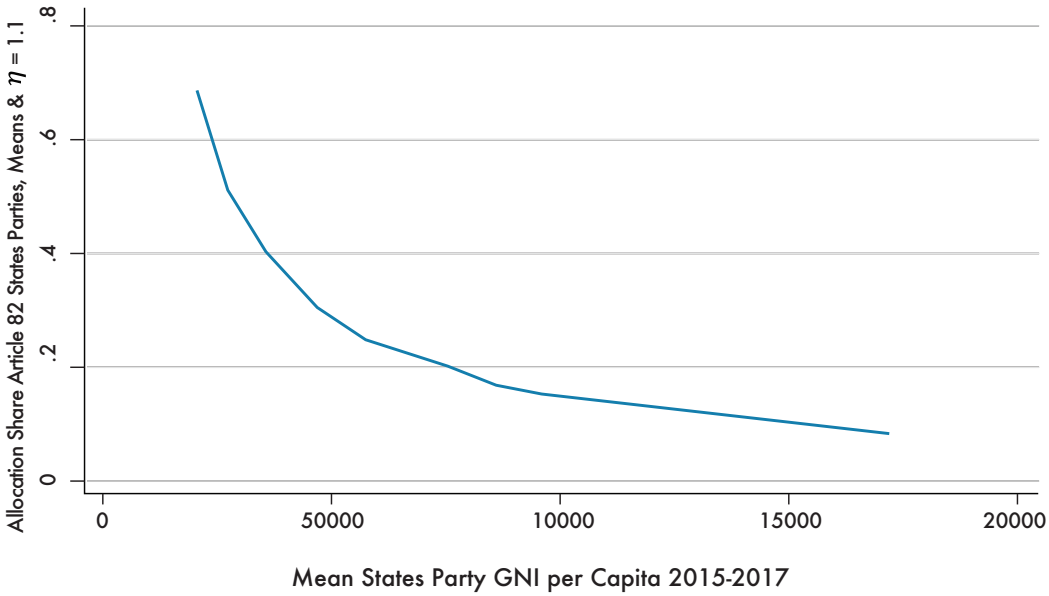


Figure A.2.16. Relationship between distribution weight ω_i and State party per capita GNI for Article 82 distributions (η=1.1 for low income, landlocked, η=1 otherwise): Eastern European Group States parties



6. These values for η are those revealed by the UN General Assembly through its annual member assessment schedule. ISA can then modify these revealed preferences for η to any value that meets its notion of equity. Lower values of η would reduce the degree of progressivity and larger values of η would strengthen the degree of progressivity. Allocation shares S_i are reported below for larger and hence more progressive values of η.

Article 140 shares

7. Table A.2.1., which repeats Table 4 of the main text, provides summary statistics of allocated shares for the original, geometric mean and original with floor and ceiling formulae.

Table A.2.1. Summary statistics of allocated shares for the original, geometric mean, and original with floor and ceiling formulae for Article 140

Type of Allocated Shares S_i	Mean η=1	Skewness η=1	Skewness η=2	Minimum Share η=1	Minimum Share η=2	Maximum Share η=1	Maximum Share η=2	More or Less Compact with Larger η?
Original	0.0060	10.11	7.82	3.77E-08	3.72E-10	0.3078	0.2833	More
Geometric Mean	0.0060	3.92	4.11	2.72E-05	3.44E-06	0.0778	0.0948	More
Original with Floor (0.00001) and Ceiling (0.1631)	0.0060	5.82		0.0000112		0.1631		

Note: A blank cell for the original formula with a floor and ceiling arises since the allocated share S_i was not calculated for η=2. Mean share values (column 2) are arithmetic means.

Figure A.2.17. Histogram and kernel density estimator: original formula η=1

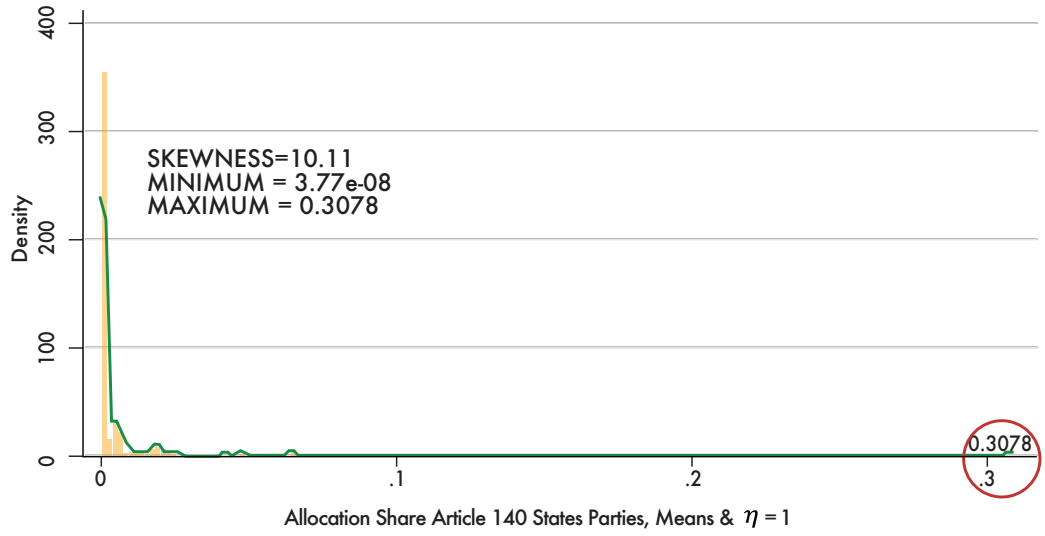


Figure A.2.18. Histogram and kernel density estimator: geometric mean formula η=1

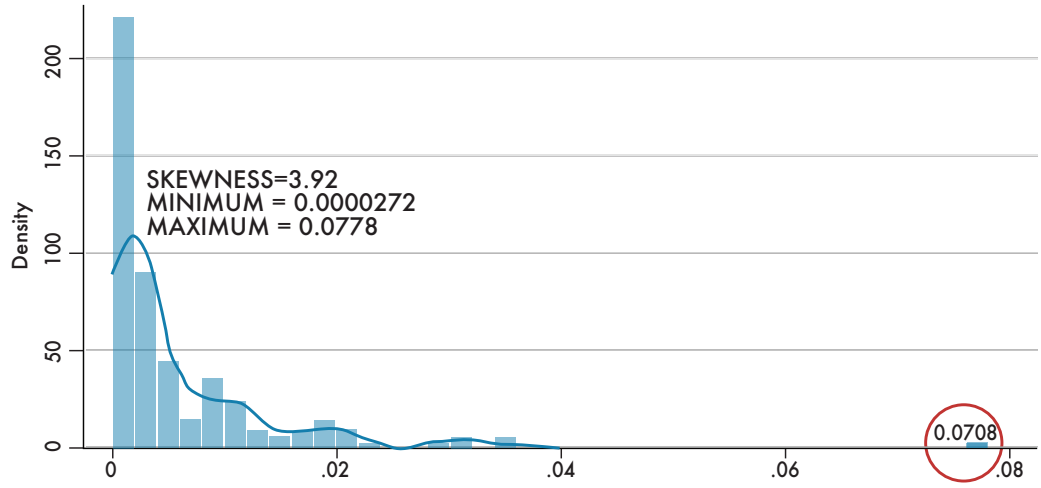
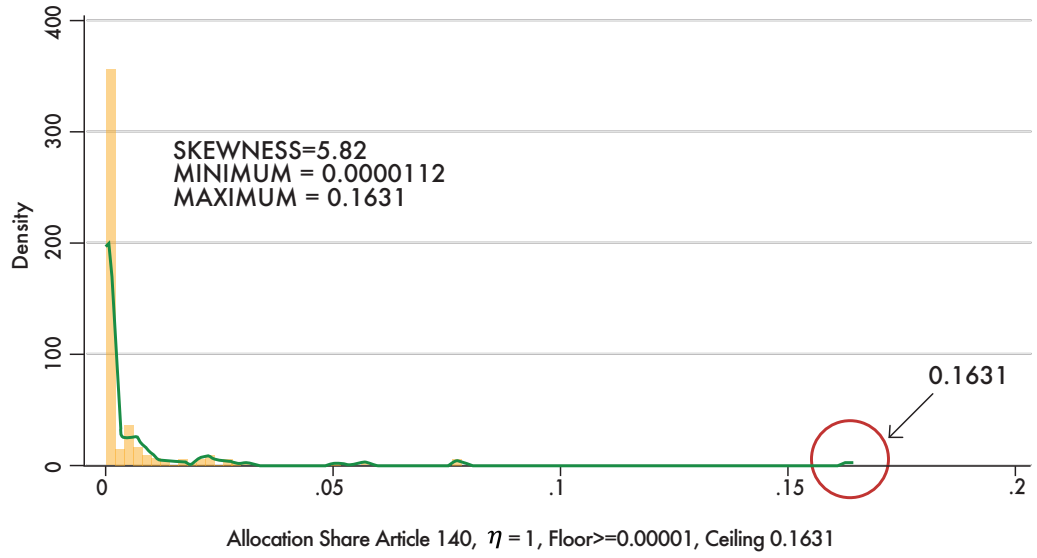


Figure A.2.19. Histogram and kernel density estimator: original with floor and ceiling η=1



Article 140 allocation shares by States parties groups, η=1

8. Figure A.2.20 illustrates the differences in mean allocation shares per State party by States parties group for Article 140 distributions with η=1.

9. Figure A.2.21 and A.2.22 illustrate the differences in mean allocation shares within each regional group and the low-income landlocked States parties group for Article 140 distributions with η=1, respectively.

Figure A.2.20. Allocation shares and States parties' GNI, Article 140 distributions: by States parties group

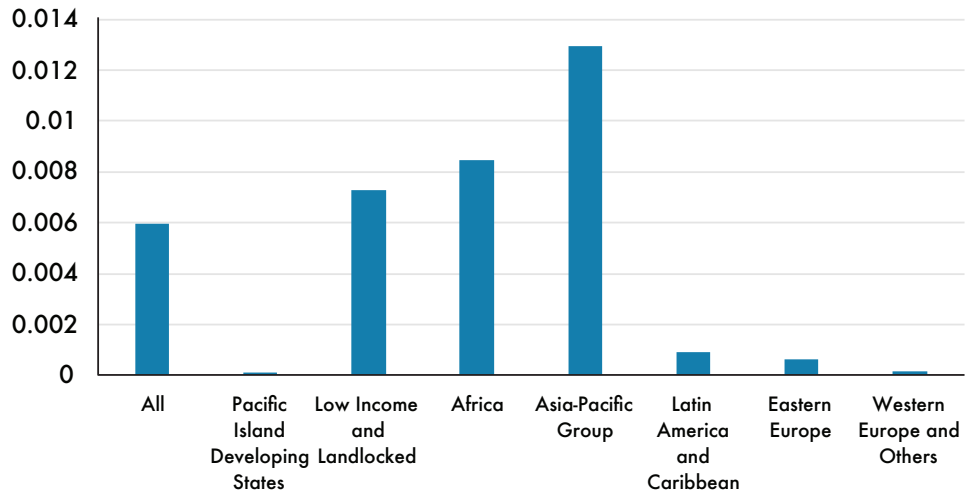


Figure A.2.21. Allocation shares and States parties' GNI, Article 140 distributions: within each States parties group

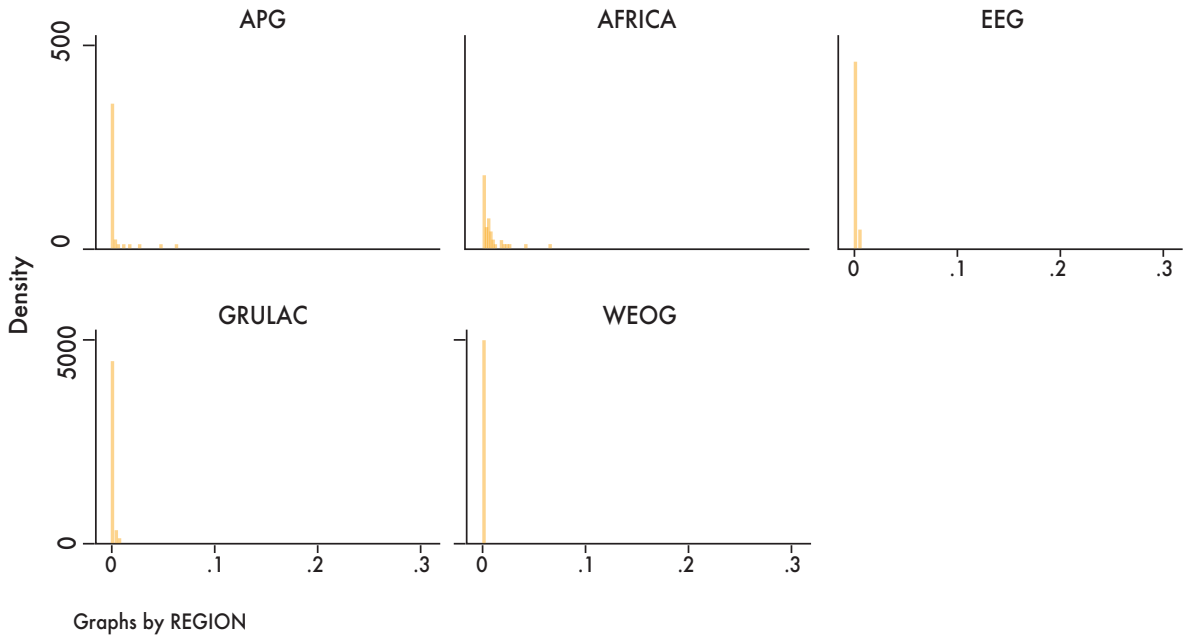
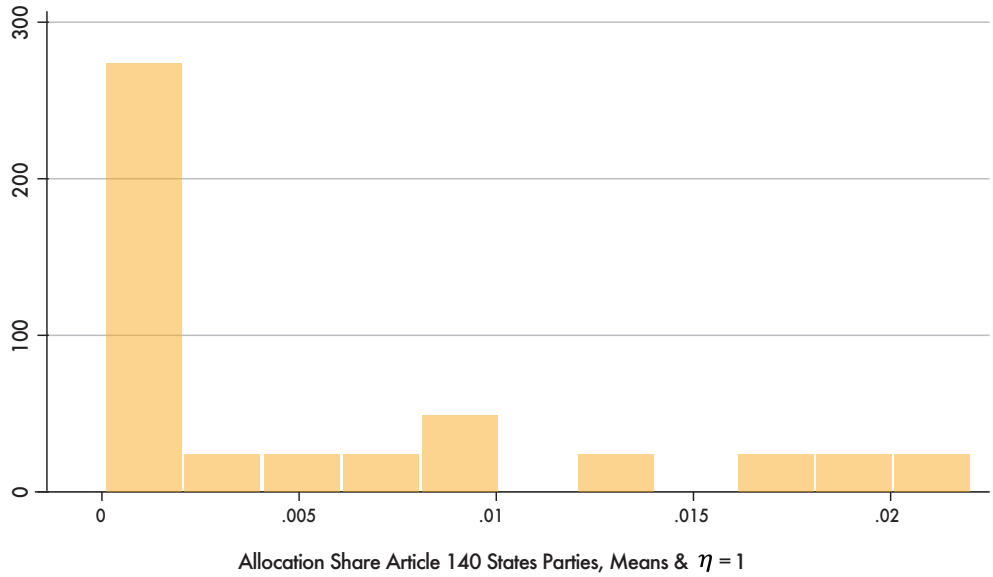


Figure A.2.22. Allocation shares and States parties' GNI, Article 140 distributions: within low-income landlocked group



10. The following figures illustrate the relationship between allocation shares and States parties' GNI for Article 140 distributions and various groups of countries. States parties' allocation shares increase with lower per capita GNIs and higher shares of total population of all States parties. The relationship becomes more irregular than the relationship between the distribution weight per States party and its per capita GNI due to the addition of share of total population of all States parties that interacts with the nonlinear distribution weight (itself determined by the relationship between per capita GNI and the State party's per capita GNI raised to the power of the elasticity of social marginal utility of income, which for Article 140 distributions is η=1).

Figure A.2.23. Allocation shares and States parties' GNI, Article 140 distributions: all States parties

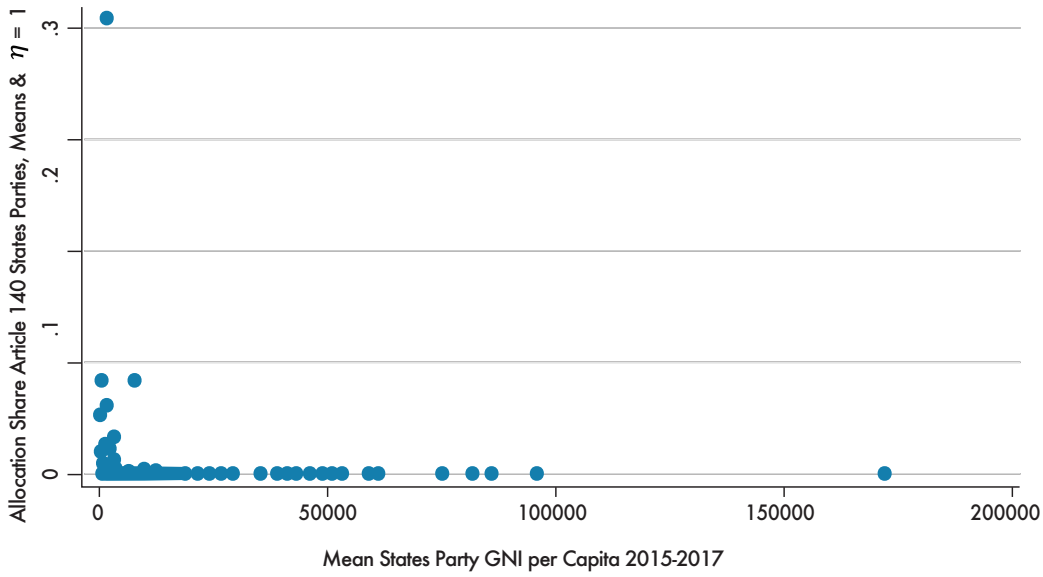


Figure A.2.24. Allocation shares and States parties' GNI, Article 140 distributions: low-income landlocked States parties

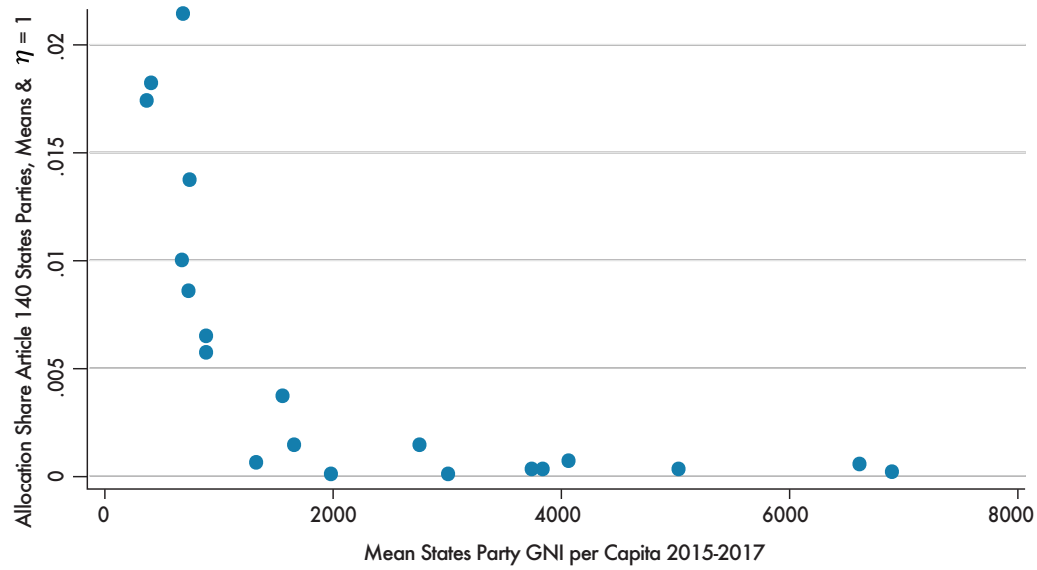


Figure A.2.25. Allocation shares and States parties' GNI, Article 140 distributions: Pacific island developing States parties

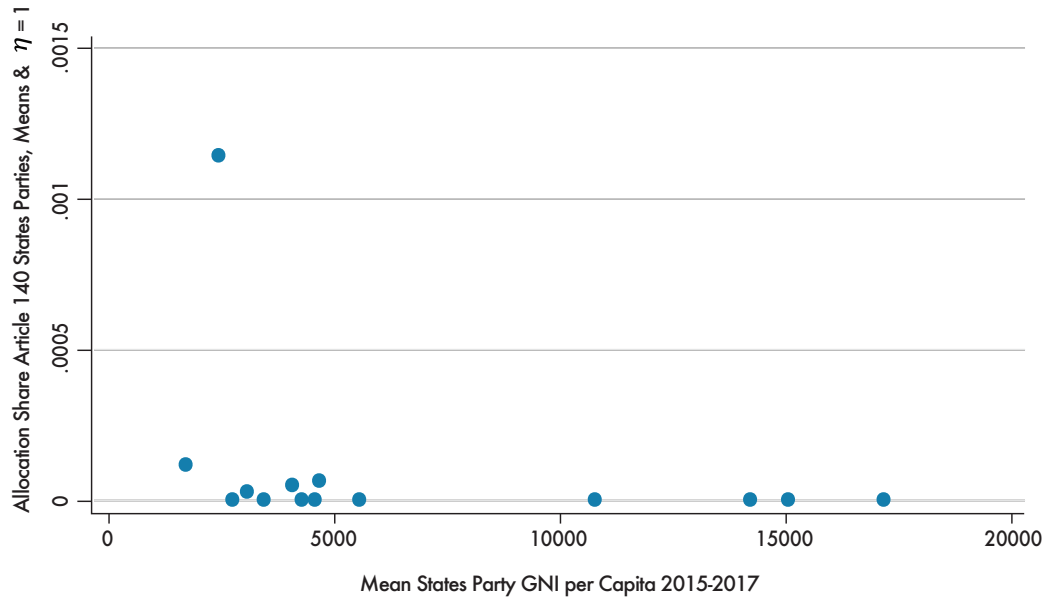


Figure A.2.26. Allocation shares and States parties' GNI, Article 140 distributions: African Group States parties

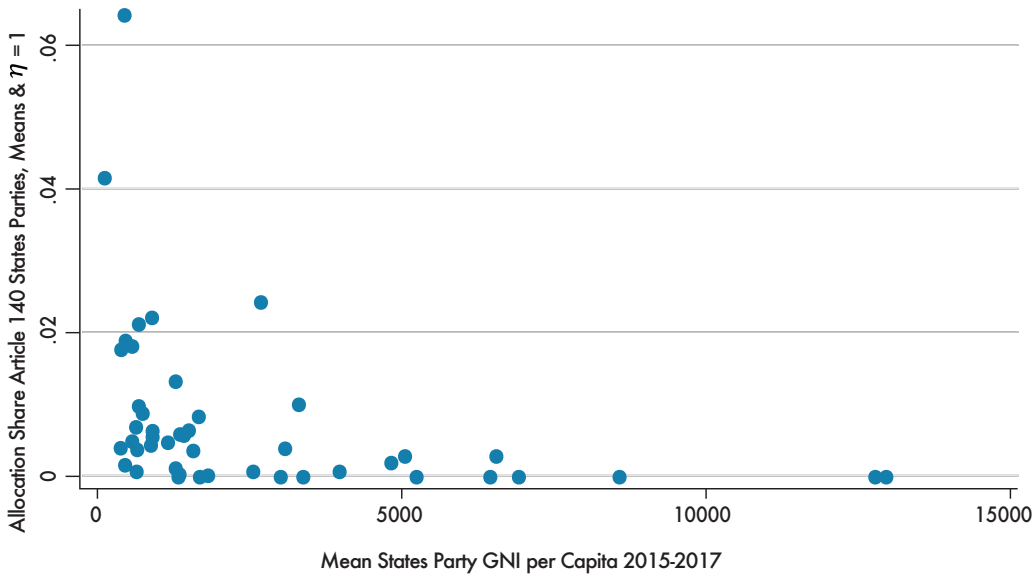


Figure A.2.27. Allocation shares and States parties' GNI, Article 140 distributions: Asia-Pacific Group States parties

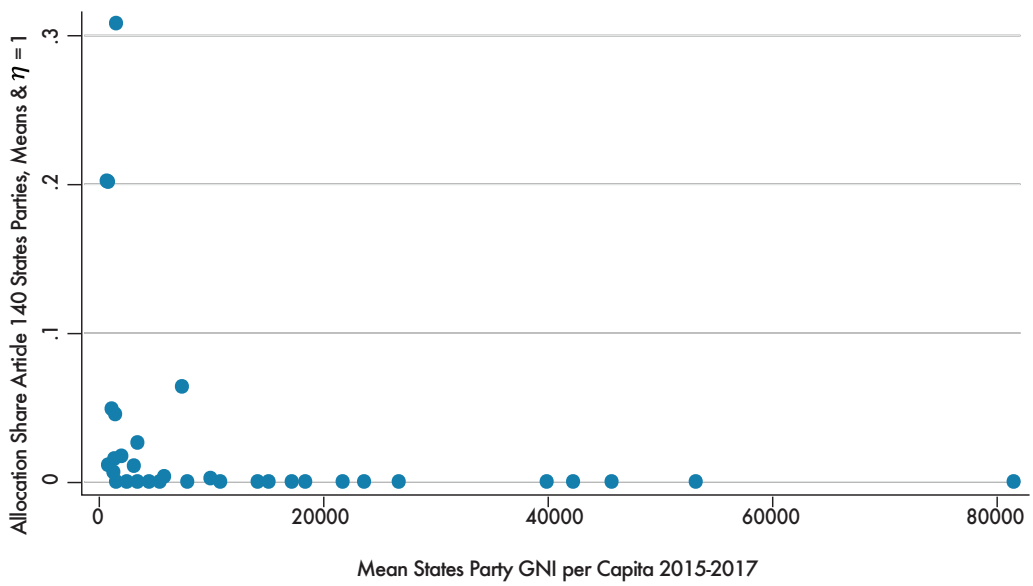


Figure A.2.28. Allocation shares and States parties' GNI, Article 140 distributions: Latin American and Caribbean Group States parties

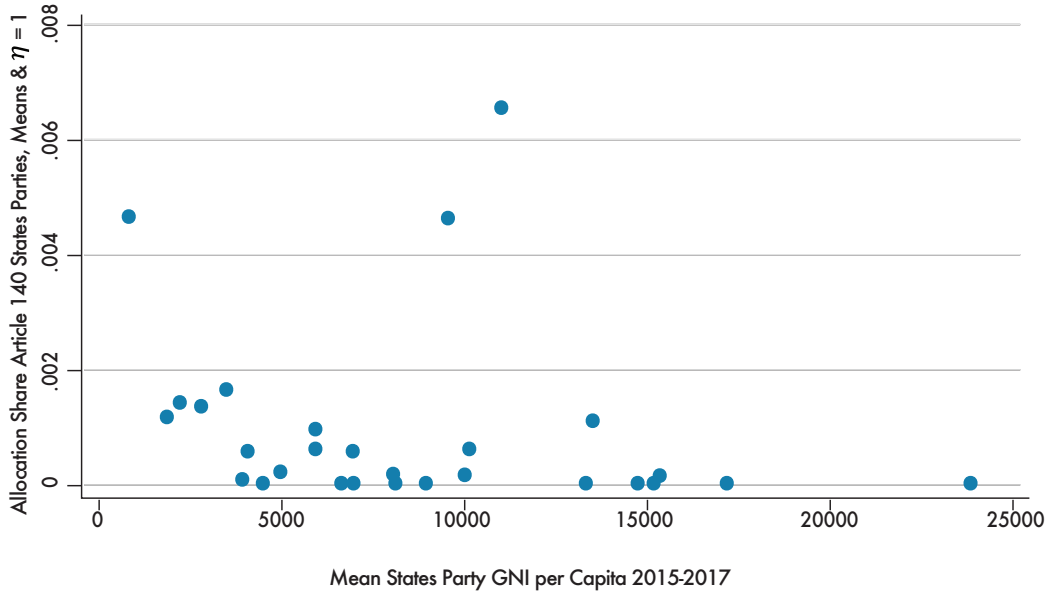


Figure A.2.29. Allocation shares and States parties' GNI, Article 140 distributions: Eastern European Group States parties

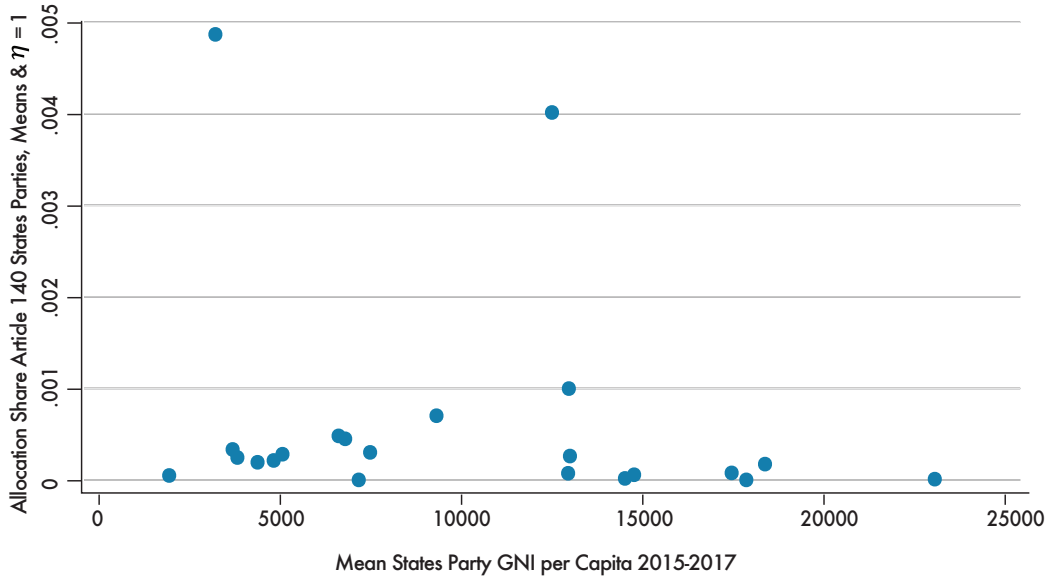
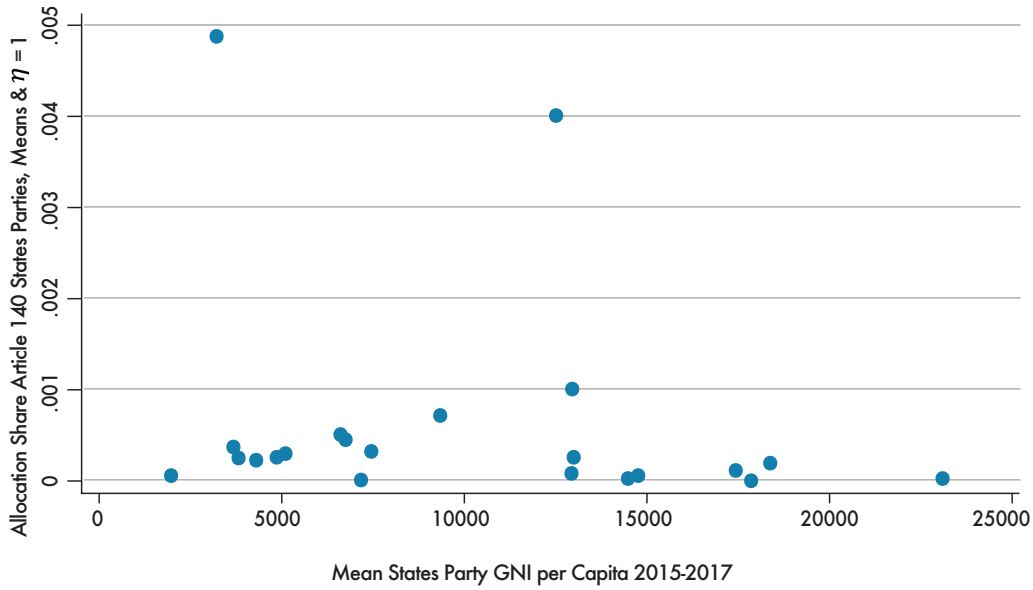


Figure A.2.30. Allocation shares and States parties' GNI, Article 140 distributions: Western European and Other Group States parties



Small and large tail ends of the distribution for Article 140 formulae, η=1

11. The following tables, A.2.2.–A.2.4., examine the original, geometric mean, and original with floor and ceiling formulae for Article 140 shares, all with η=1, in greater detail at the tail ends of the distribution. The tables' order allocates royalty shares from smallest to largest, giving the corresponding arithmetic mean of the share. For each percentage bin, the tables give the smallest value for the shares at below the 50 per cent share size and the largest value for the shares above the 50 per cent share size. The original formula allocates smaller minimum shares (arithmetic mean = 7.82e-08, smallest = 3.77e-08), followed by the original with floor and ceiling (arithmetic mean = 0.0000114, smallest = 0.0000112), with the geometric mean having the largest minimum sized share measured by both the arithmetic mean of the share size (0.0000392) and the largest minimum size of the share (0.0000272). The original formula for larger percentile shares (5–25 per cent) always has the smallest arithmetic mean and minimum sized share of all three formulae. The geometric mean formula, compared to the original formula with floor and ceiling, increases share size for shares below the 50 per cent mark. **Conclusion: The geometric mean formula clearly gives larger mean and minimum sized shares at share sizes below the 50 per cent size level.**

12. We now examine allocated royalty share size at the larger end of the spectrum, from the 75 per cent share size to the 99 per cent share size. Starting with the largest shares at the 99 per cent bin, the shares ranked from largest to smallest for both the arithmetic mean of the 99 per cent bin and the largest share in that bin are: original > original with floor and ceiling > geometric mean. For the 95 per cent bin, the shares ranked from largest to smallest for both the arithmetic mean and largest share are: original with floor and ceiling > original > geometric mean. For the 90 per cent bin, the shares ranked from largest to smallest for both the arithmetic mean and largest share are: original with

floor and ceiling > geometric mean > original. **Conclusion: The geometric mean formula generally gives smaller mean and maximum sized shares at share sizes above the 50 per cent level.**

Table A.2.2. Summary statistics of the original formula η=1

Percentile (%)	Arithmetic Mean	Smallest
1 %	7.82E-08	3.77E-08
5 %	2.58E-06	7.82E-08
10 %	5.78E-06	3.21E-07
25 %	0.000396	3.57E-07
50 %	0.0003333	
		Largest
75 %	0.0040058	0.04823
90 %	0.013775	0.0640389
95 %	0.022318	0.0643023
99 %	0.0643023	0.3078352

Overall statistics: Arithmetic mean 0.005988, standard deviation 0.0256045, skewness 10.11276, kurtosis 117.4916.

Table A.2.3. Summary statistics by percentile of the geometric mean formula η=1

Percentile (%)	Arithmetic Mean	Smallest
1 %	0.0000392	0.0000272
5 %	0.000225	0.0000392
10 %	0.0003369	0.0000794
25 %	0.0008821	0.0000838
50 %	0.0025596	
		Largest
75 %	0.0088729	0.0307878
90 %	0.0164538	0.0354766
95 %	0.0209434	0.03555495
99 %	0.0355495	0.077782

Overall statistics: Arithmetic mean 0.005988, standard deviation 0.0090732, skewness 3.92425, kurtosis 26.44782.

Table A.2.4. Summary statistics by percentile of the original with floor and ceiling formula η=1

Percentile (%)	Arithmetic Mean	Smallest
1 %	0.0000114	0.0000112
5 %	0.0000114	0.0000114
10 %	0.0000114	0.0000114
25 %	0.0000479	0.0000114
50 %	0.000403	
		Largest
75 %	0.0048425	0.0583045
90 %	0.0166524	0.0774157
95 %	0.0269798	0.077734
99 %	0.077734	0.1631

Overall statistics: Arithmetic mean 0.005988, standard deviation 0.0173, skewness 5.75, kurtosis 45.65.

Article 82 Shares

13. The following tables summarize allocation shares to individual States parties for Article 82 distributions for various values of the social marginal utility of income η and by States parties groups and values of η, ranging from η=1 to η=1.5.

Table A.2.5. Allocation shares to individual States parties, Article 82 distributions: all States parties

Variable	Mean Allocation Share	Standard Deviation	Minimum Allocation Share	Maximum Allocation Share
Distribution Weight using Mean Per Capita Income by Value of η				
η = 1	0.005988	0.0256045	3.77E-08	0.3078352
η = 1.1	0.005988	0.0247329	3.63E-08	0.2961013
η = 1.2	0.005988	0.0237156	3.45E-08	0.2813165
η = 1.3	0.005988	0.0226118	3.22E-08	0.2631670
η = 1.4	0.005988	0.0215481	2.96E-08	0.2416014
η = 1.5	0.005988	0.0215469	2.96E-08	0.2145893

14. The following histogram illustrates the compact distribution of Article 82 shares (η=1.1) at very small value. Note that one State party has a share of about 0.31, which appears on the far right-hand side of the figure.

15. The histogram (Figure A.2.32) gives the frequency of each allocated Article 82 share (η=1.1). The vertical axis is the frequency of occurrence. Again, the allocated shares are distributed at very small values. Again, note that one State party has a share of about 0.3 with a (frequency of one), which appears on the far right-hand side of the figure.

16. Figure A.2.33 also depicts the distribution of Article 82 allocated shares (η=1.1). The salient point from the figure is the high concentration of small shares to States parties and then no allocated shares until just past 0.3.

Figure A.2.31. Article 82 allocation shares (η=1.1)

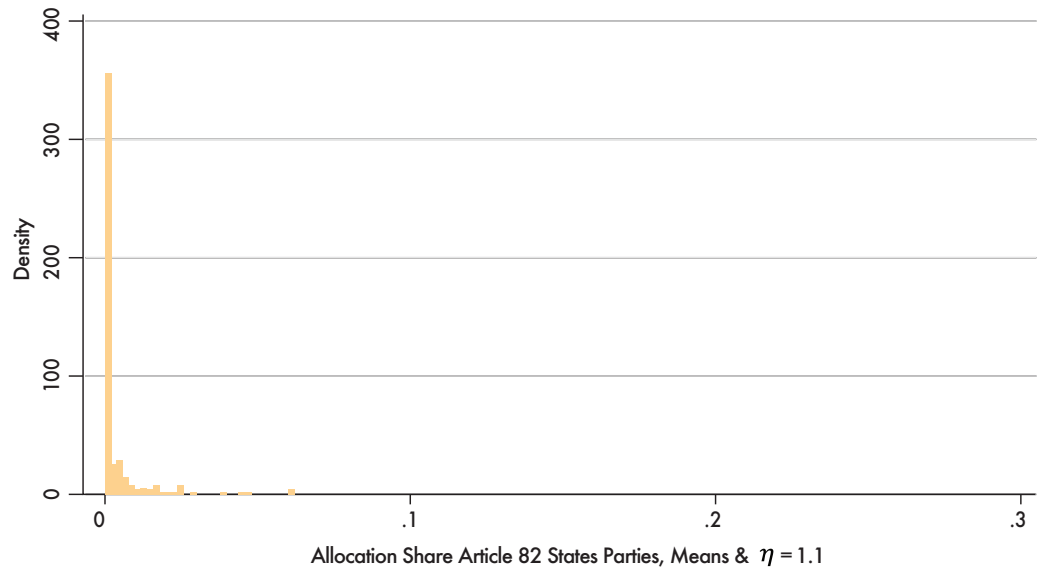


Figure A.2.32. Frequency of Article 82 allocation shares (η=1.1)

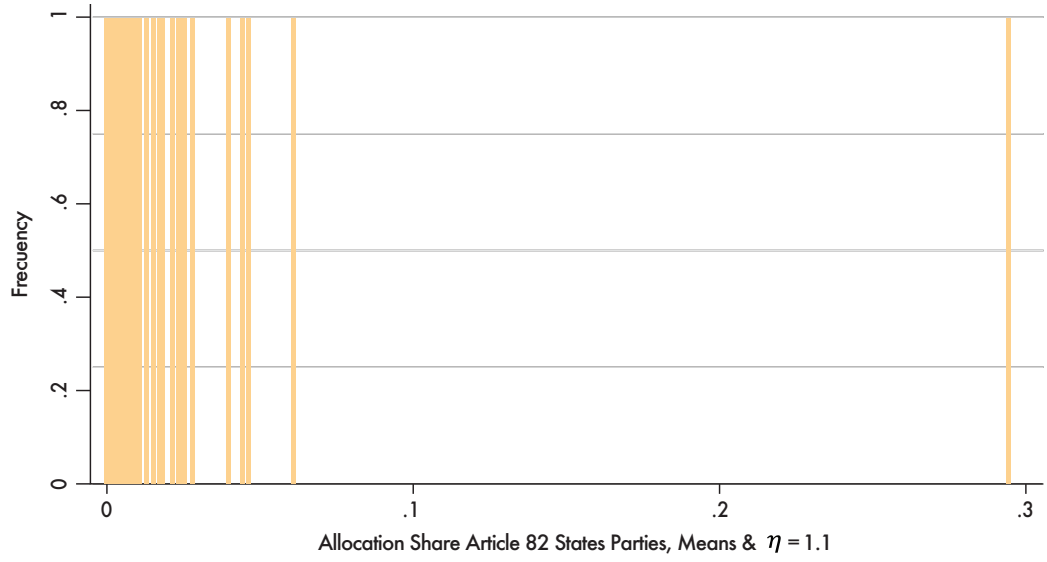
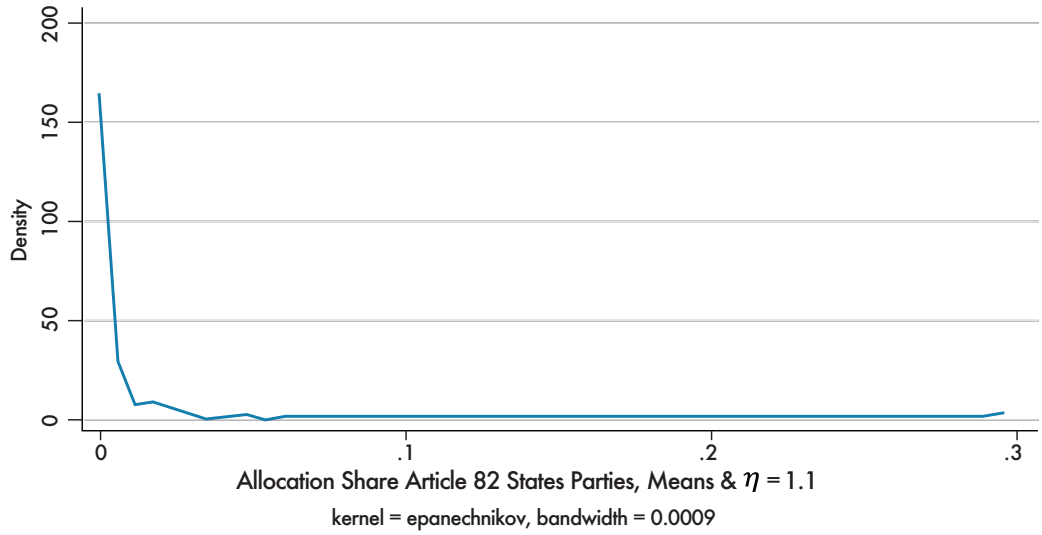


Figure A.2.33. Kernel density function of Article 82 allocation shares (η=1.1)



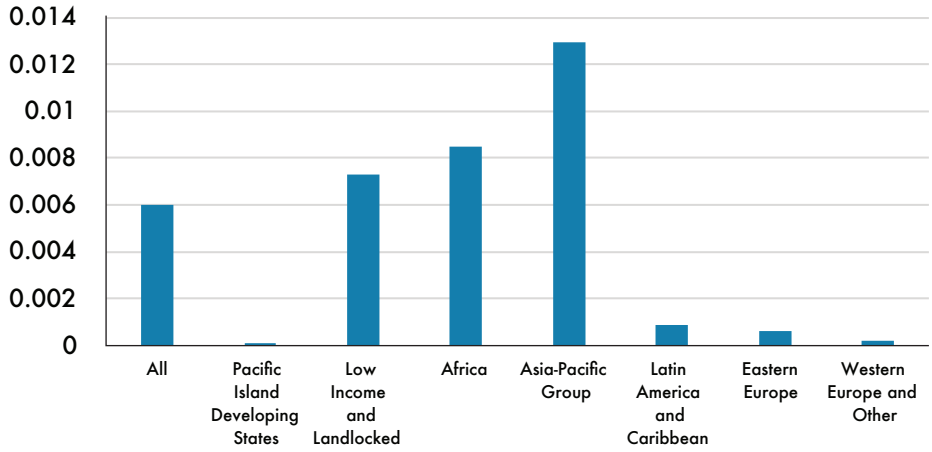
Article 82 allocations of shares by regional groups

17. The following Table A.2.6. gives summary statistics by States parties group for the allocation shares to individual States parties for Article 82 allocations with η=1.1 for low-income landlocked States parties and η=1 for all other States parties. The Asia-Pacific Group receives the largest mean group share, undoubtedly influenced by India and China with their large populations. The Pacific Island Developing States Group receives the smallest mean group share, undoubtedly influenced by their small populations.

Table A.2.6. Allocation shares to individual States parties, Article 82 distributions η=1.1: by States parties group

Group of States	Mean Allocation Share	Standard Deviation	Minimum Allocation Share	Maximum Allocation Share
All	0.005988	0.0247329	3.63E-08	0.2961013
Pacific Island Developing States	0.0001005	0.002913	3.63E-08	0.0011057
Low Income and Landlocked	0.0071158	0.0094419	0.0000882	0.0281649
Africa	0.0084189	0.0121056	2.48E-06	0.0618512
Asia-Pacific Group	0.0130161	0.0463016	3.63E-08	0.2961013
Latin America and Caribbean	0.0008982	0.0015705	1.25E-06	0.0063434
Eastern Europe	0.0006331	0.0012156	0.0000248	0.0047111
Western Europe and Others	0.0001810	0.0002143	7.52E-08	0.0005912

Figure A.2.34. Allocation shares and States parties' GNI, Article 82 distributions: by States parties group



18. The previous figure illustrates the differences in mean allocation shares per State party by States parties group for Article 82 distributions with η=1.1 for low-income landlocked States parties and η=1 for all other States parties. States parties with low per capita GNI relative to the global per capita GNI and/or large shares of the global population had a substantial impact upon the mean allocation shares per State party. The Asia-Pacific Group receives the largest mean group share, undoubtedly influenced by India and China with their large populations. The Pacific Island Developing States Group receives the smallest mean group share, undoubtedly influenced by their small populations.

19. The following two histograms illustrate the differences in mean allocation shares within each regional group and the low-income landlocked States parties group for Article 82 distributions with η=1.1, respectively.

Figure A.2.35. Allocation shares and States parties' GNI, Article 140 distributions: within each States parties group

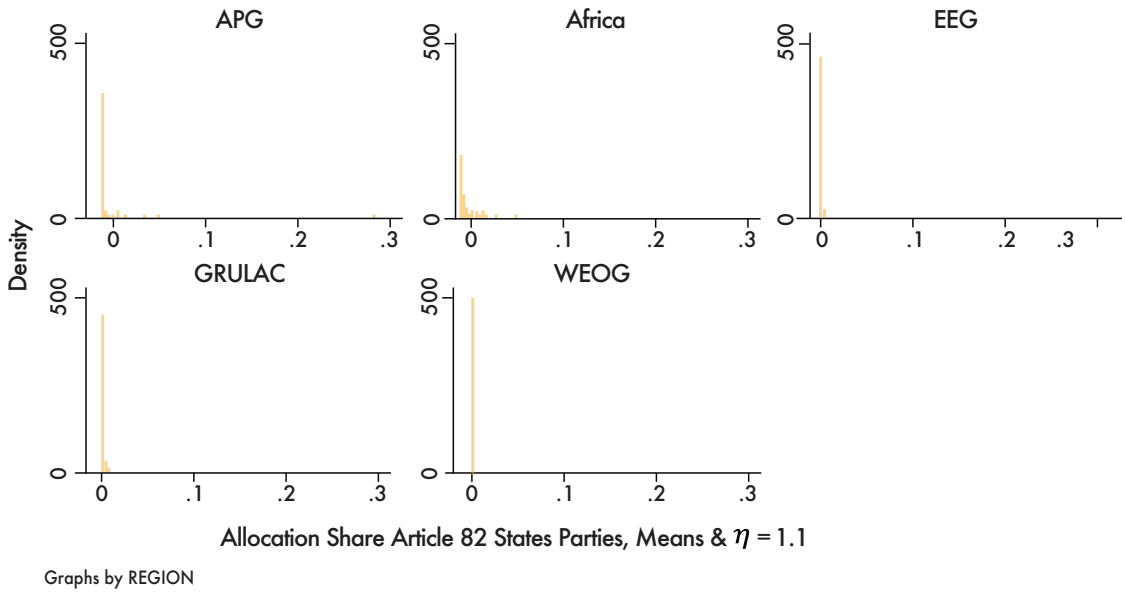
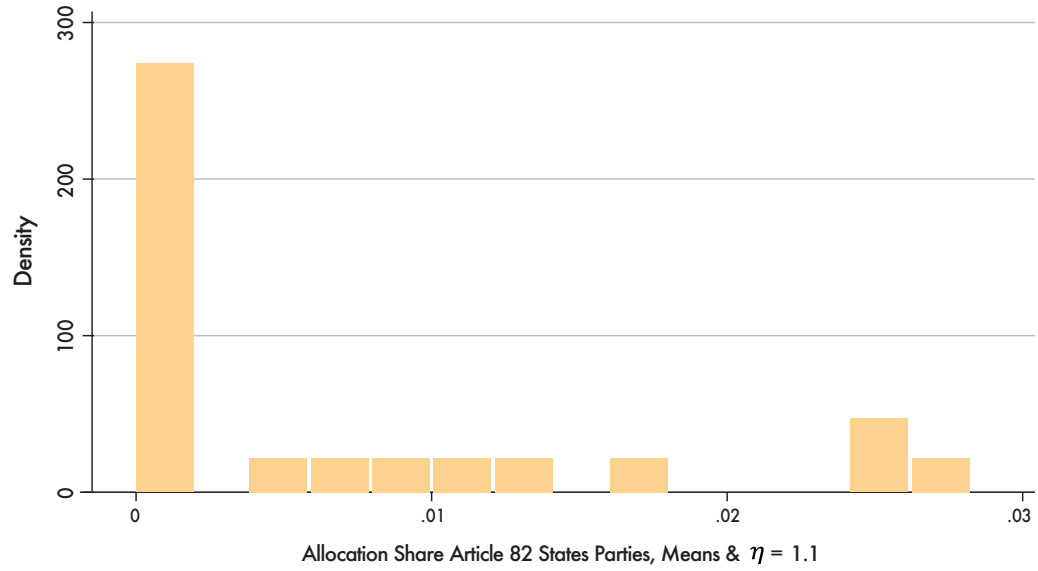


Figure A.2.36. Allocation shares and States parties' GNI, Article 140 distributions: within low-income landlocked group



20. The following figures illustrate the relationships between allocation shares S_i and States parties' per capita GNI for Article 82 distributions and various groups of countries. States parties' allocation shares increase with lower per capita GNIs and higher shares of the total population of all States parties. The relationship becomes more irregular than the relationship between the distribution weight per State party and its per capita GNI due to the addition of share of total population of all States parties that interacts with the nonlinear distribution weight (itself determined by the relationship between total per capita GNI and the State party's per capita GNI raised to the power of the elasticity of social marginal utility of income, which for Article 82 distributions is η=1.1).

Figure A.2.37. Allocation shares and States parties' GNI: Article 82 distributions

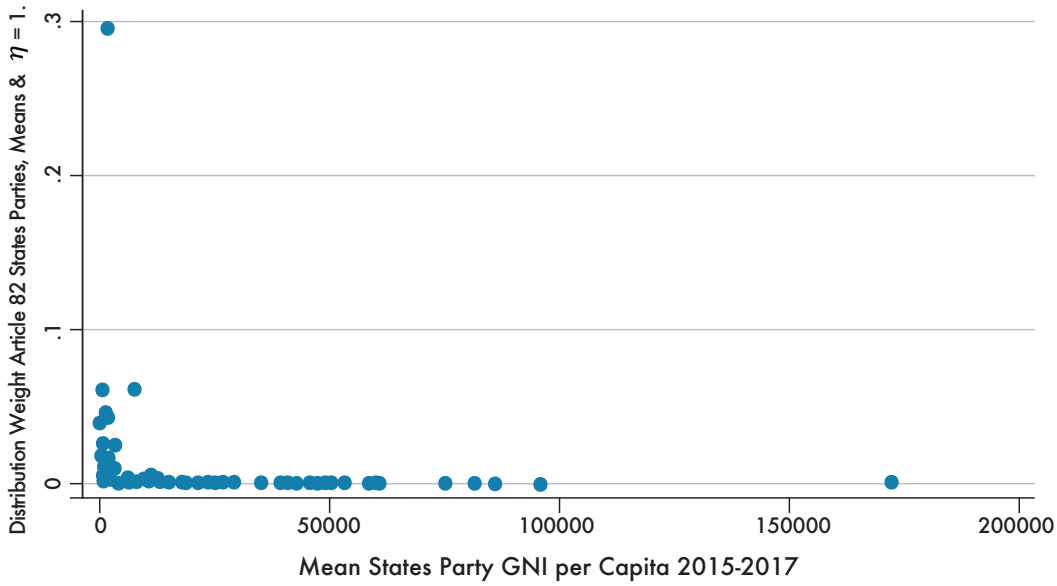


Figure A.2.38. Allocation shares and States parties' GNI, Article 82 distributions: low-income landlocked States parties

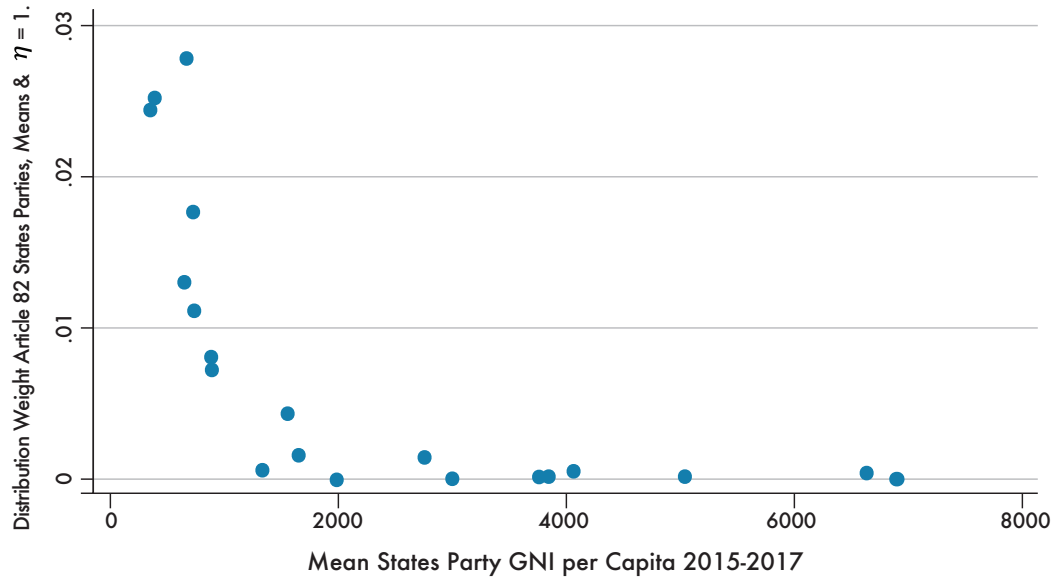


Figure A.2.39. Allocation shares and States parties' GNI, Article 82 distributions: Pacific island developing States parties

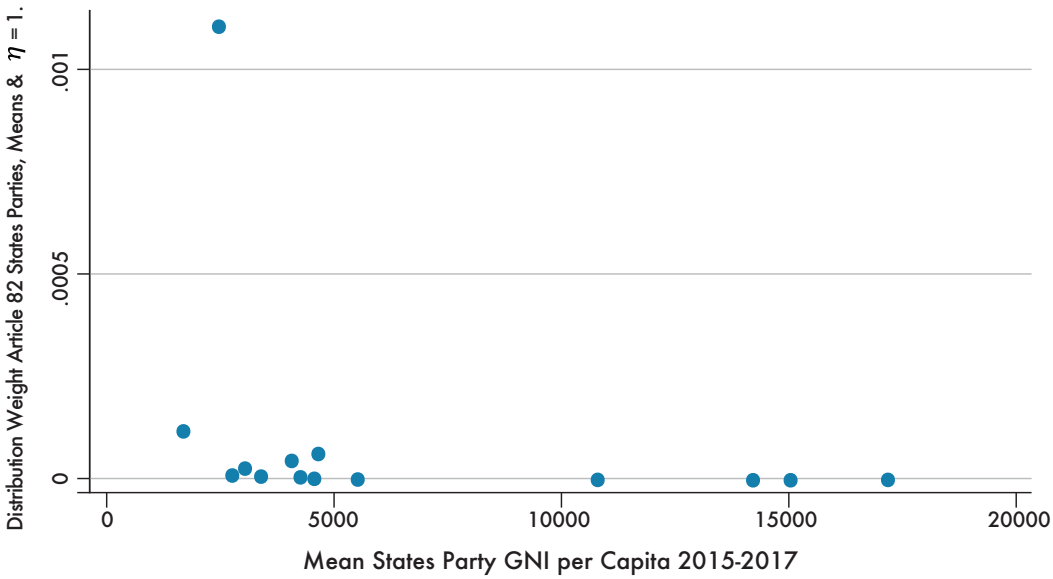


Figure A.2.40. Allocation shares and States parties' GNI, Article 82 distributions: African Group States parties

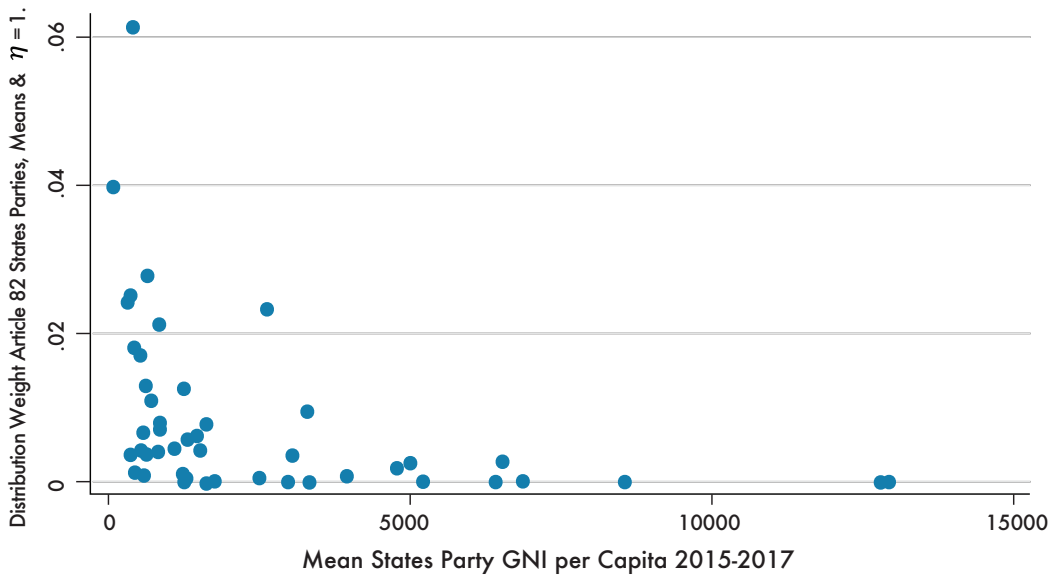


Figure A.2.41. Allocation shares and States parties' GNI, Article 82 distributions: Asia-Pacific Group States parties

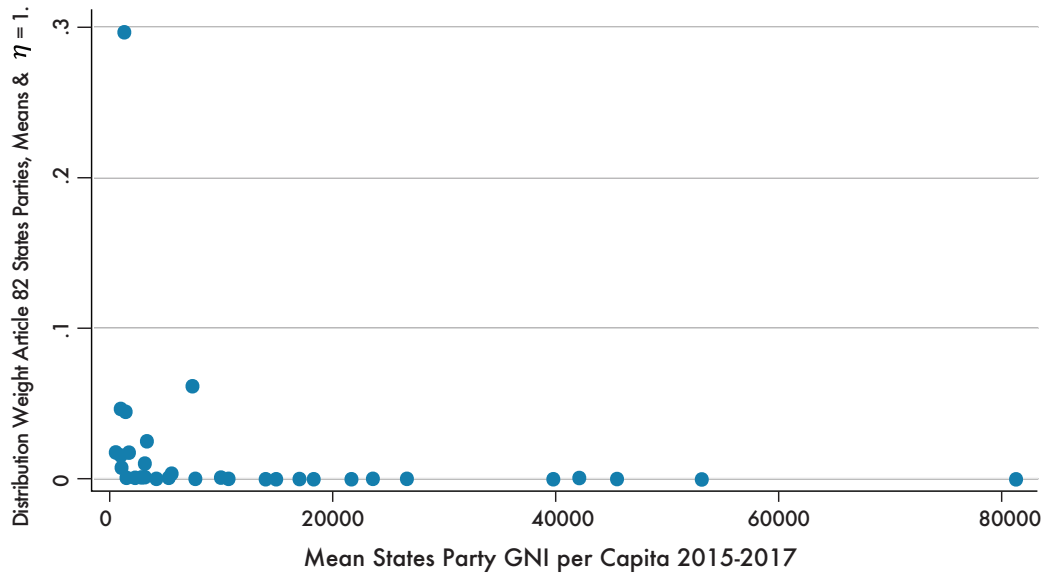


Figure A.2.42. Allocation shares and States parties' GNI, Article 82 distributions: Latin American and Caribbean Group States parties

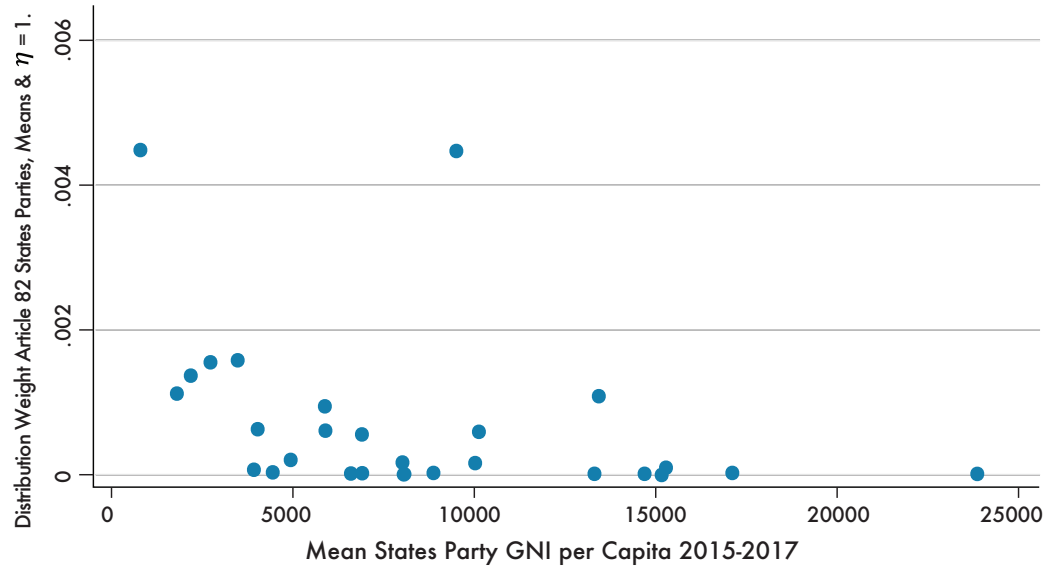


Figure A.2.43. Allocation shares and States parties' GNI, Article 82 distributions: Eastern European Group States parties

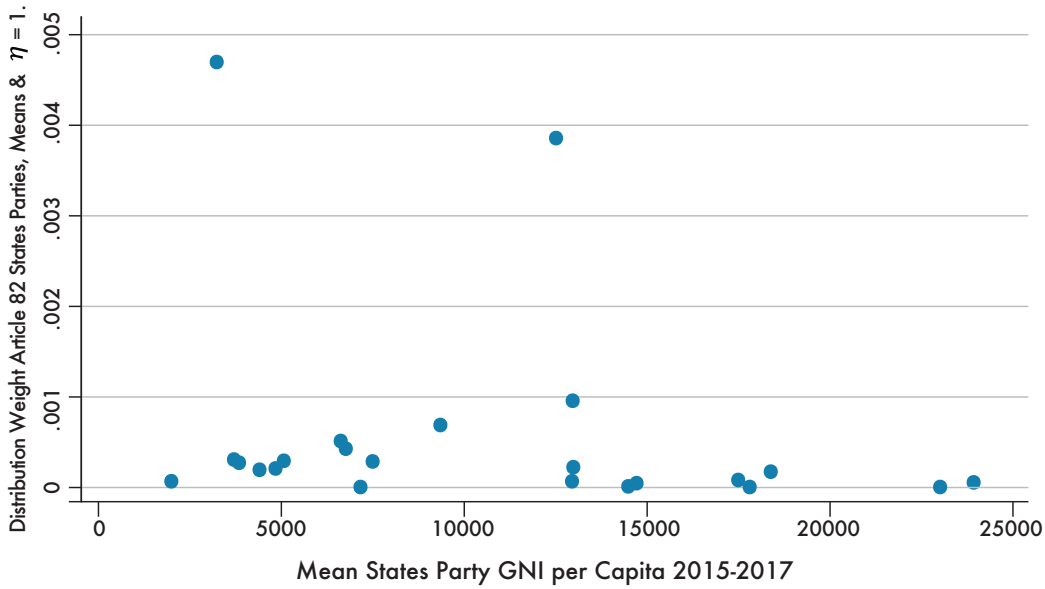
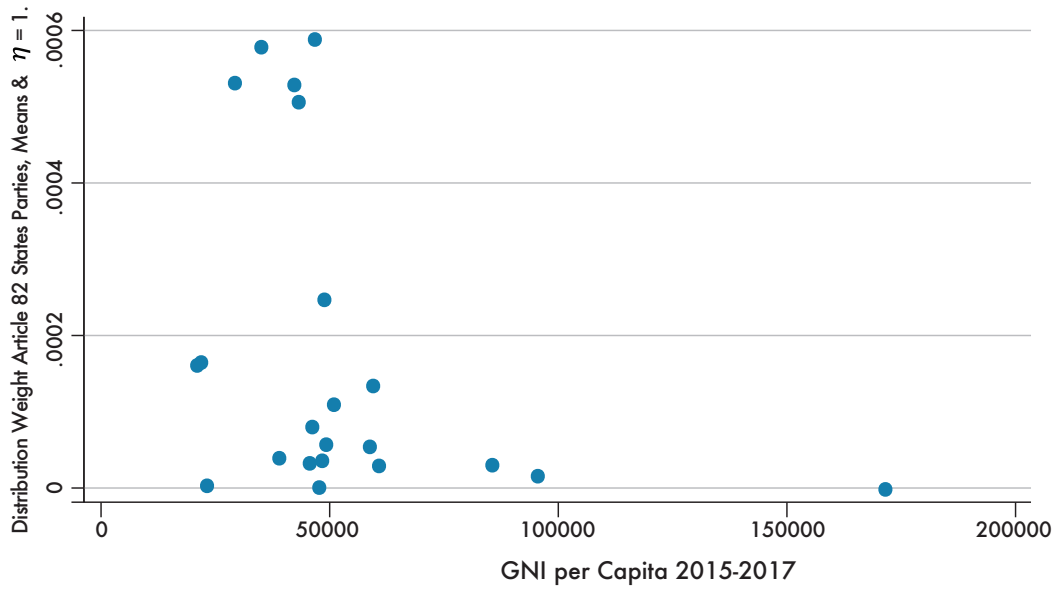


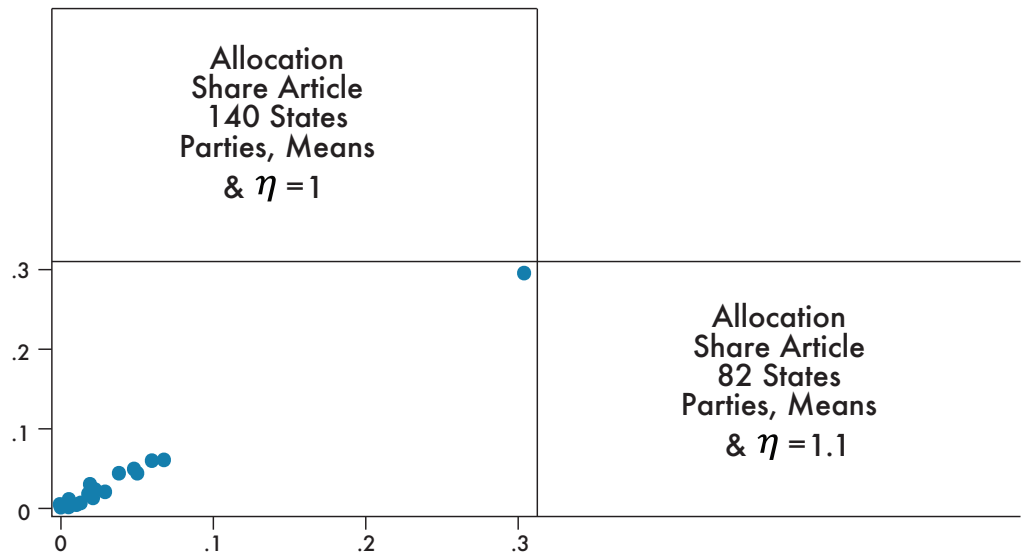
Figure A.2.44. Allocation shares and States parties' GNI, Article 82 distributions: Western European and Other Group States parties



Relationship between Article 140 and Article 82 distributions

21. The following Figure A.2.45. for Article 140 and Article 82 share distributions illustrates the close relationship between the two types of shares. The close relationship follows because the only difference is the calculation of distribution weights $\omega_i = \left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta}$ for low-income landlocked States, η=1 for Article 140 ω_i and η=1.1 for Article 82 ω_i.

Figure A.2.45. Relationship between Article 140 and Article 82 allocated shares



22. The allocated shares for Article 140 and Article 82 distributions are very similar in the aggregate. The correlation coefficient between the two distributions is 0.999 and statistically significant at the highest level of significance. A Wilcoxon signed rank test of the null hypothesis that the medians of the two samples (Article 140 and Article 82 allocated shares) are equal was rejected at conventional levels of significance, indicated that the medians differ (z=7.111, p=0.0000). The following figure illustrates the extremely close relationship between the Article 140 and Article 82 allocated shares.

Impact on Article 140 shares from increasing η from η=1 To η=2

23. Tables A.2.7.–A.2.10. examine the impact upon Article 140 shares from increasing η from η=1 to η=2 for the original formula and the geometric mean formula. Table A.2.7. depicts the impact for the original formula and Table A.2.8. for the geometric mean formula, and A.2.9. and A.2.10. depict the subtracted difference in shares for η=2 less η=1 for the original and geometric mean formulae. The tables depict the two tail ends of the distribution of shares in percentage bins, giving the arithmetic means and smallest value for each bin when 50 per cent or less of the shares have been allocated and the arithmetic mean and largest value for each bin when 75 per cent or more of the shares have been allocated. For both the original and geometric mean formulae, increasing η from η=1 to η=2 decreases the size (geometric mean and smallest value) of the shares for the lowest half of the distribution (< 50 per cent) and from 90 per cent and above increases the size (geometric mean and largest value) of the shares for the largest 10 per cent of the allocated shares (i.e., > 90 per cent).

Table A.2.7. Summary statistics of allocated Article 140 shares by percentile of the original formula η=2

Percentile (%)	Arithmetic Mean	Smallest
1 %	2.05E-09	3.72E-10
5 %	7.59E-08	2.05E-09
10 %	3.26E-07	1.70E-08
25 %	2.01E-06	1.85E-08
50 %		
		Largest
75 %	0.0007662	0.0403341
90 %	0.0085169	0.1228704
95 %	0.0262127	0.1674672
99 %	0.1674672	0.283344

Overall statistics: Arithmetic mean 0.005988, standard deviation 0.0276168, skewness 7.820978, kurtosis 70.72772.

Table A.2.8. Summary statistics of allocated Article 140 shares by percentile of the geometric mean formula η=2

Percentile (%)	Arithmetic Mean	Smallest
1 %	8.07E-06	3.44E-06
5 %	0.000491	
10 %	0.0001017	
25 %	0.0002529	
50 %	0.0011646	
		Largest
75 %	0.0049322	0.0357857
90 %	0.0164442	0.0624592
95 %	0.0288489	0.0729185
99 %	0.0729185	0.0948483

Overall statistics: Arithmetic mean 0.005988, standard deviation 0.0124577, skewness 4.112711, kurtosis 24.25342.

Table A.2.9. Summary statistics by percentile of percentage difference in allocated Article 140 shares for the original formulae η=2 minus allocated Article 140 shares for the original formulae η=1

Percentile (%)	Arithmetic Mean	Smallest
1 %	-99.16	-99.53
5 %	-98.46	-99.16
10 %	-98.21	-99.05
25 %	-94.62	-98.99
50 %	-85.56	
		Largest
75 %	-55.42	103.13
90 %	1.34	107.79
95 %	42.36	128.39
99 %	128.39	500.42

Overall statistics: Arithmetic mean -63.19%, standard deviation 67.89, skewness 5.75, kurtosis 50.40.

Table A.2.10. Summary statistics by percentile of percentage difference in allocated Article 140 shares for the geometric mean formulae η=2 minus allocated Article 140 shares for the geometric mean formulae η=1

Percentile (%)	Arithmetic Mean (%)	Smallest (%)
1 %	-88.25	-91.24
5 %	-84.24	-88.25
10 %	-83.01	-87.59
25 %	-70.53	-87.26
50 %	-51.70	
		Largest (%)
75 %	-15.13	81.15
90 %	27.95	83.22
95 %	51.65	92.06
99 %	92.09	231.55

Overall statistics: Arithmetic mean -38.57, standard deviation 46.76, skewness 1.95, kurtosis 9.10.

Table A.2.11. Atkinson and generalized entropy (Theil) inequality measures and Gini coefficient original and geometric mean formulae η=1 and η=2 for Article 140 shares

Formula/ Measure	Atkinson's Inequality Index *A(γ=0)*	Atkinson's Inequality Index *A(γ=1)*	Atkinson's Inequality Index *A(γ=2)*	Theil's Second (L) Generalized Entropy Inequality Index *GE(0)*	Theil's First (T) Generalized Entropy Inequality Index *GE(1)*	Gini Coefficient	P90/P10
Original η=1	0.69532	0.94910	0.99948	2.97793	1.97984	0.86938	2385.228
	(3)	(3)	(4)	(3)	(3)	(3)	(3)
Original η=2	0.81140	0.9999	0.99279	4.93166	2.41495	0.92215	26149.12
	(4)	(4)	(3)	(4)	(4)	(4)	(4)
Geometric Mean η=1	0.33077	0.59128	0.87892	0.89472	0.71947	0.62635	48.839
	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Geometric Mean η=2	0.50366	0.80442	0.97190	1.63176	1.15597	0.75735	161.707
	(2)	(2)	(2)	(2)	(2)	(2)	(2)

Notes: Each column includes inequality measure and inequality rank for that column. Atkinson: Lower values more equal, 0≤ A(γ) ≤1. Higher γ is higher inequality aversion. Generalized Entropy: Theil T = GE (1) & Theil L = GE(0): 0 ≤ GE(0), GE(1) ≤ ∞, lower values are more equal. GE (1) more sensitive to higher income than GE(0). With positive and large α, the index G*E* will be more sensitive to what happens in the upper tail of the income distribution. With positive and small α, the index G*E* will be more sensitive to what happens at the bottom tail of the income distribution. Gini coefficient: Lower values are more equal, 0 ≤ G ≤ 1. Standard error given in parentheses. All values equivalent for allocated share 0 ≤ Si ≤ 1 and allocated share of US$500 million.

24. In Table A.2.11. (above) for Article 140 shares, the Atkinson and Generalized Entropy (Theil) inequality measures, Gini Coefficient, and ratio of the top 10th percentile to the lower 10th percentile allocated shares S_i when η=2 (almost always) show the following rankings from the distribution that is most equitable with highest social welfare: geometric mean η=1 > geometric mean η=2 > original η=1 > original η=2.

25. The scatterplot in Figure A.2.46. between the original (vertical axis) and geometric mean (horizontal axis) formulae Article 140 shares S_i with η=2 is somewhat nonlinear that increases at an increasing rate. The scatterplot also shows that the largest three States parties' shares dominate the relationship that increases at an increasing rate.

26. The scatterplot in Figure A.2.47. (below) between the original Article 140 shares S_i with η=1 (vertical axis) and original Article 140 shares S_i with η=2 (horizontal axis) shows that shares are positively related and concentrated with low share values. However, the large shares of three States parties again are much larger than for other States parties with one share showing an increase at a decreasing rate and one share showing an increase at a decreasing rate.

27. The scatterplot in Figure A.2.47. between the original Article 140 shares S_i with η=1 (vertical axis) and original Article 140 shares S_i with η=2 (horizontal axis) shows that shares are positively related and concentrated with low share values. However, the large shares of three States parties again are much larger than for other States parties with one share showing an increase at a decreasing rate and one share showing an increase at a decreasing rate.

28. The scatterplot in Figure A.2.48. (below) between the geometric mean Article 140 shares S_i with η=1 (vertical axis) and original Article 140 shares S_i with η=2 (horizontal axis) shows the same overall positively correlated pattern as the original formula in Figure A.2.47. However, the geometric mean shares are less concentrated and have a wider dispersion.

Figure A.2.46. Scatterplot between original and geometric mean Article 140 shares η=2

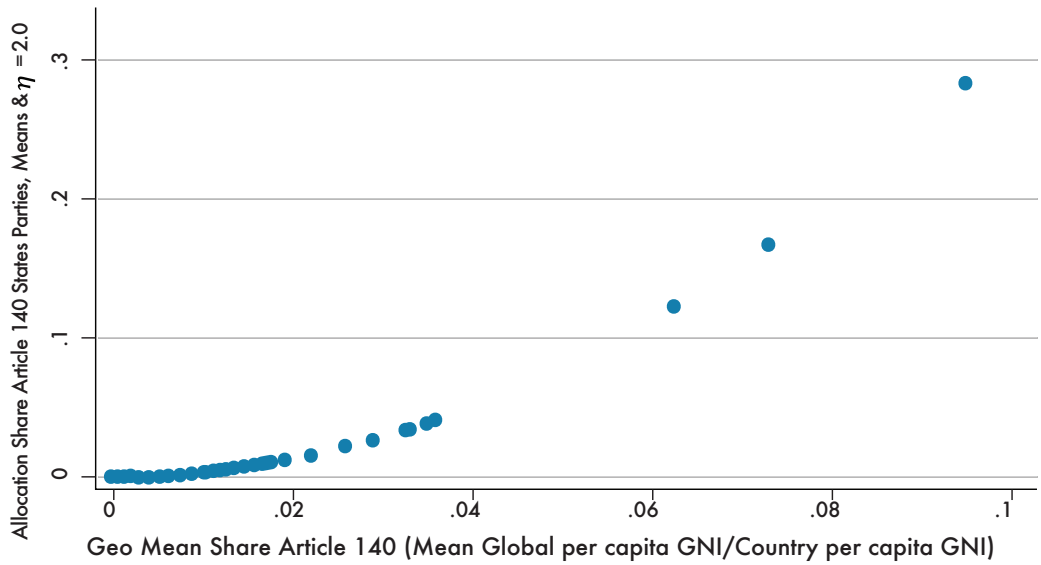


Figure A.2.47. Scatterplot between original formula shares Article 140 η=1 and η=2

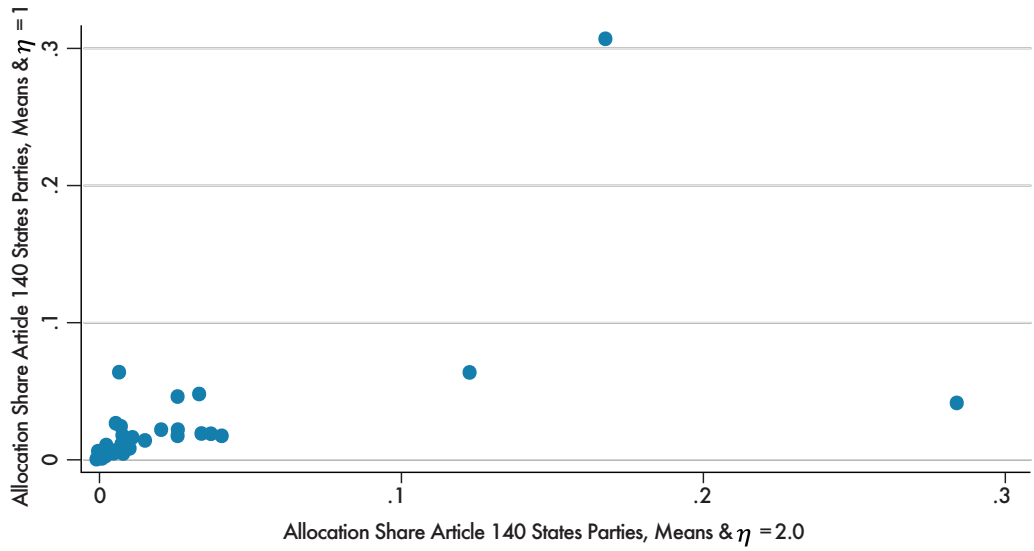
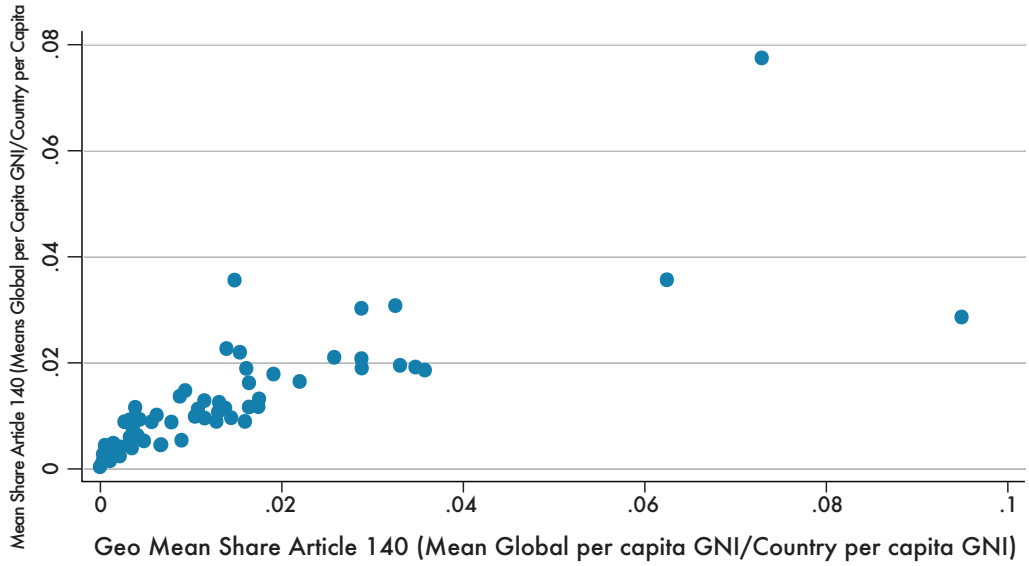


Figure A.2.48. Scatterplot between geometric mean formula shares Article 140 η=1 and η=2



29. The histogram in Figure A.2.49 depicts the percentage difference in social distribution weights ω_i for the original formula formed by subtracting the weights formed using η=1 from the weights formed using η=2. The long tail for negative percent differences, i.e., when ω_i formed using η=2 are smaller than ω_i formed using η=1, has a wider range of values for ω_i compared to the compact distribution of values of ω_i formed using η=2 are larger than $\omega_i$formed using η=1. There are also fewer negative valued ω_i than positive ω_i.

Figure A.2.49. Histogram for percentage difference in social distribution weights for the original formula (η=2)-(η=1) for Article 140 shares

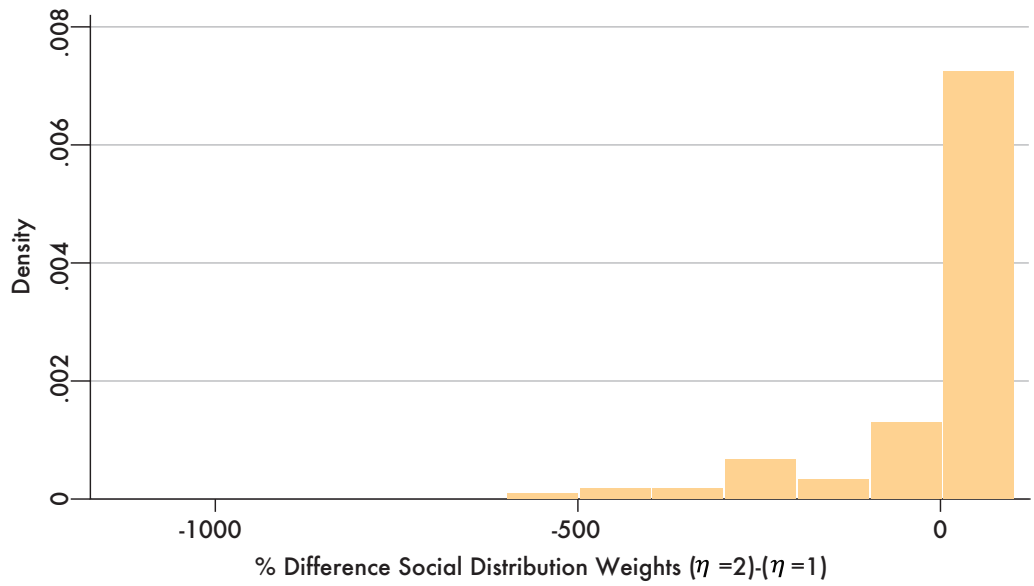
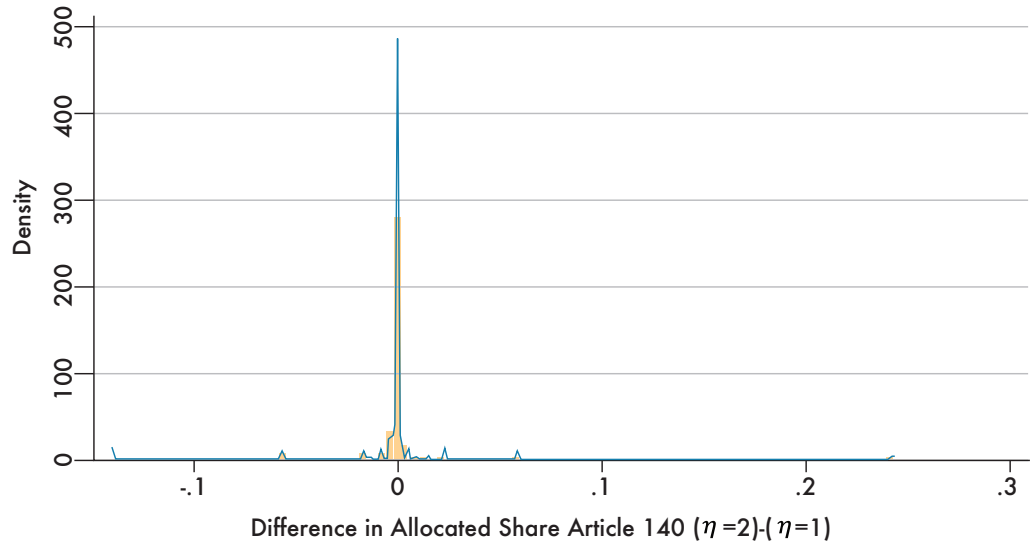


Figure A.2.50. Histogram and kernel density estimator of (difference in) social distribution weights for the original formulae η=2 minus social distribution weights for the original formulae η=1 for Article 140 shares



30. The histogram in Figure A.2.51. depicts the allocated shares S_i for the original formula calculated using η=1 (blue) and η=2 (red). As expected, increasing η from η=1 to η=2 increases the largest values of S_i as indicated on the right-hand tail of the distribution. The figure indicates that at very small values of S_i, the left-hand side of the distribution, there are slightly more shares calculated with η=2 compared to η=1. The figure also shows that there are more shares of a larger but still smaller value (S_i<0.1) when calculated with η=2.

31. The histogram of percentage difference in allocated shares for the original formula for η=2 less η=1 in Figure A.2.53. clearly shows that more States parties lose on a percentage basis with the original formula when increasing η from η=1 to η=2 and that a limited number of States parties enjoy a percentage gain of almost 600 per cent.

Figure A.2.51. Histogram of allocated shares for the original formulae η=1 and η=2

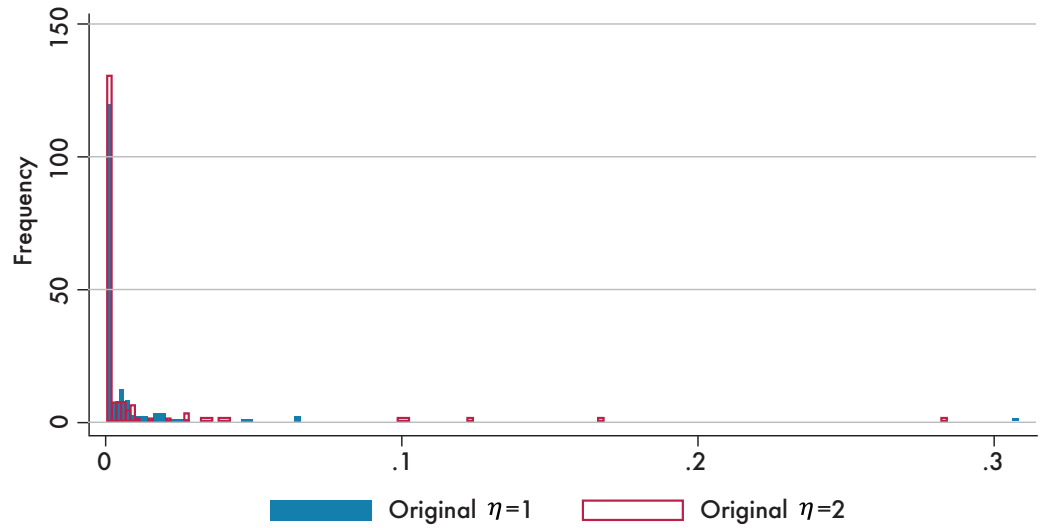


Figure A.2.52. Kernel density estimator of allocated shares for the original formulae η=1 and η=2

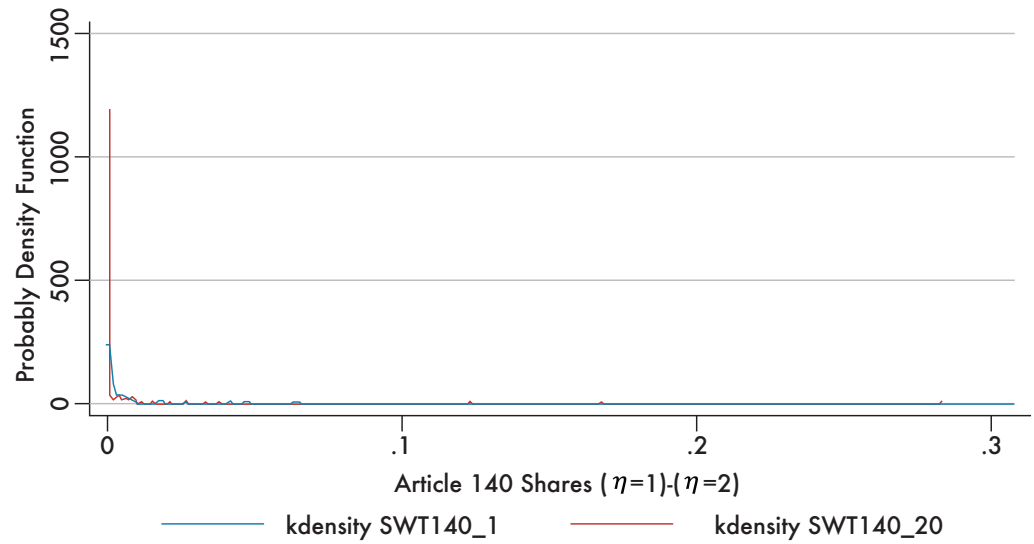
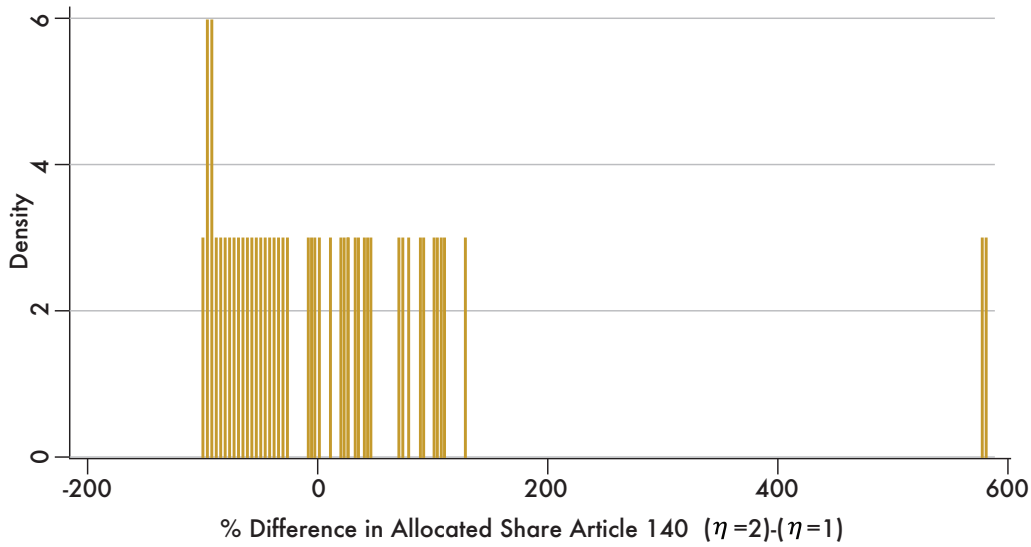


Figure A.2.53. Histogram of percentage difference in allocated shares for the original formulae η=2 minus allocated shares for the original formulae η=1



The distribution is skewed with a long tail in favour of gainers and a concentration of losers.

32. Figure A.2.54., the histogram of allocated shares for the geometric mean formula for η=1 (blue) and η=2 (red), shows that shares with η=2 generally have smaller values for almost all share sizes.

33. The histogram and kernel density estimator in Figure A.2.55. (above) for the difference between η=2 and η=1 with the geometric mean formula shows that in terms of numbers (frequency) of States parties, more States parties lose than gain. This result confirms the results from Figure A.2.54.

Figure A.2.54. Histogram of allocated shares for the geometric mean formula η=1 and η=2

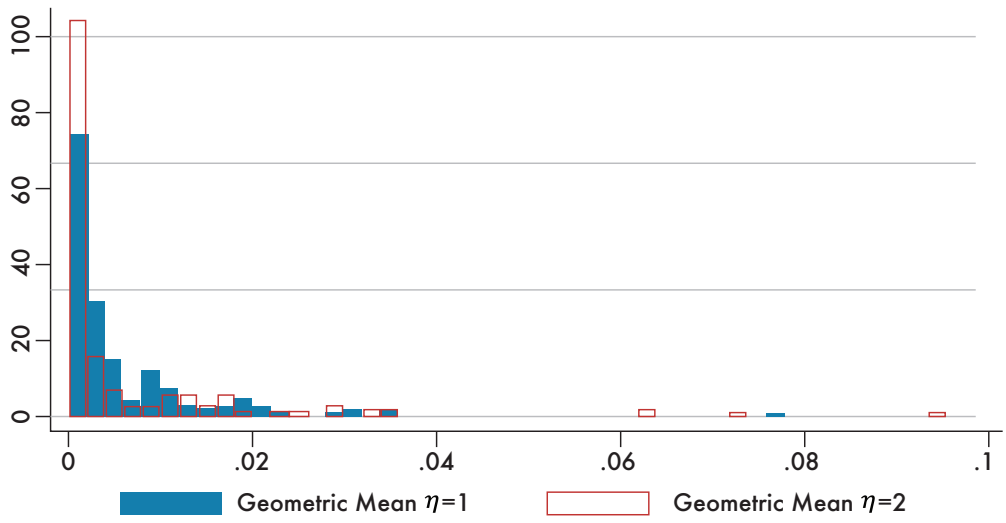


Figure A.2.55. Histogram and kernel density estimator of difference in allocated shares for the geometric mean formulae η=1 and η=2

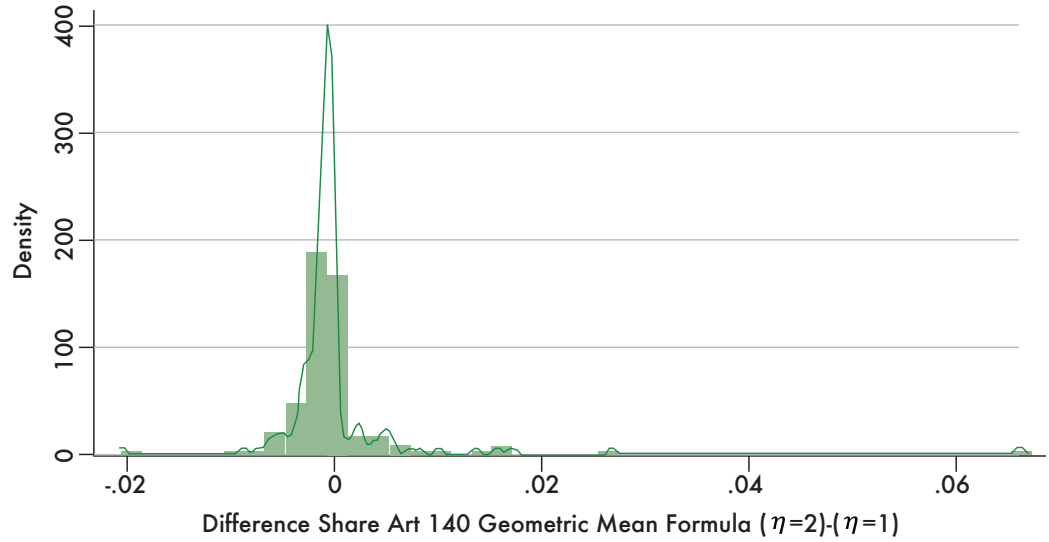
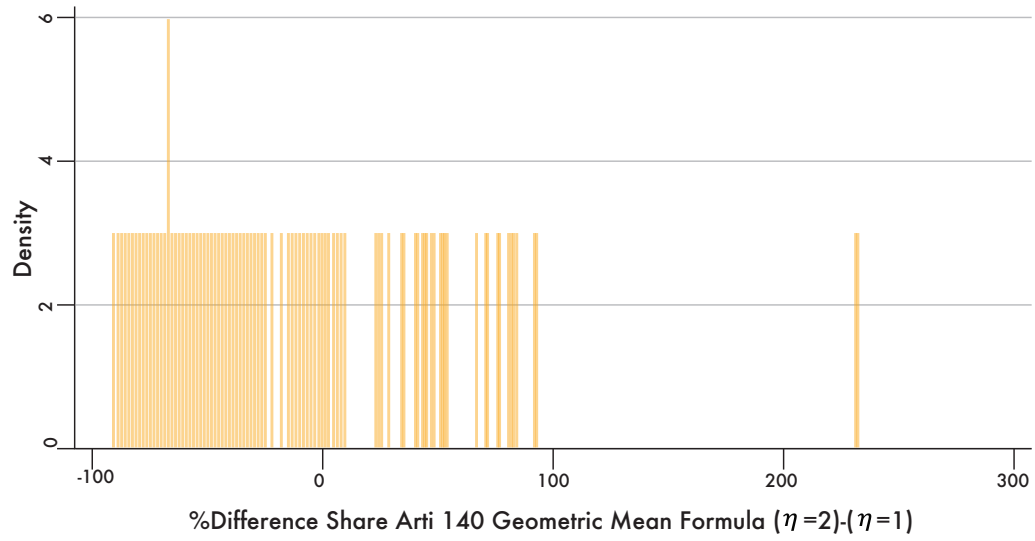
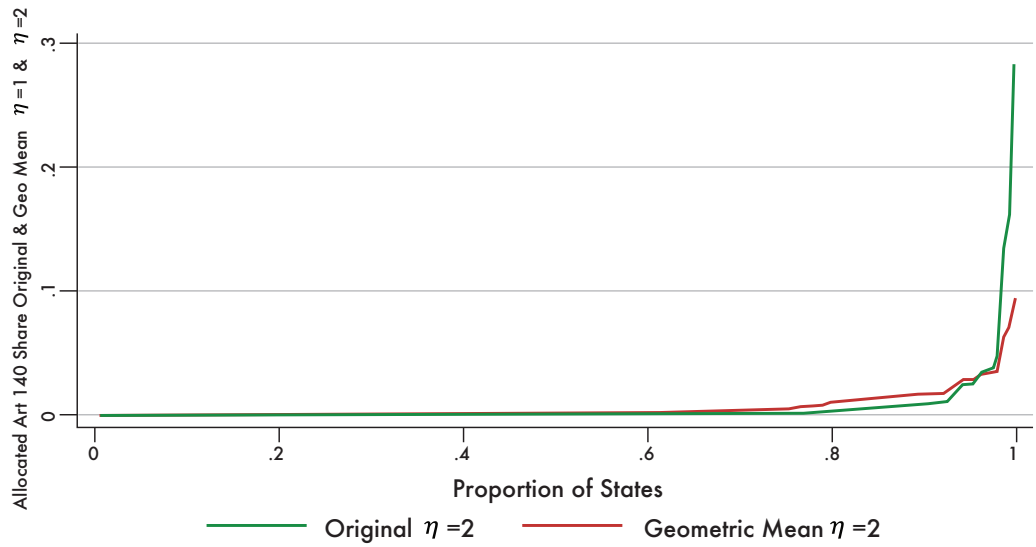


Figure A.2.56. Histogram of percentage difference in allocated shares for the geometric mean formulae η=2 minus allocated shares for the geometric mean formulae η=1



34. The histogram of percentage difference in allocated shares for the geometric mean formula for η=2 less η=1 in Figure A.2.56. (above) clearly shows that more States parties lose on a percentage basis with the geometric mean formula when increasing η from η=1 to η=2 and that a limited number of States parties enjoy a percentage gain of over 200 per cent. The distribution is skewed with a long tail in favour of gainers and a concentration of losers. Compared to the original formula, there is a shorter tail of gainers (right-hand side of the figure) and a longer tail of losers (left-hand side of the figure).

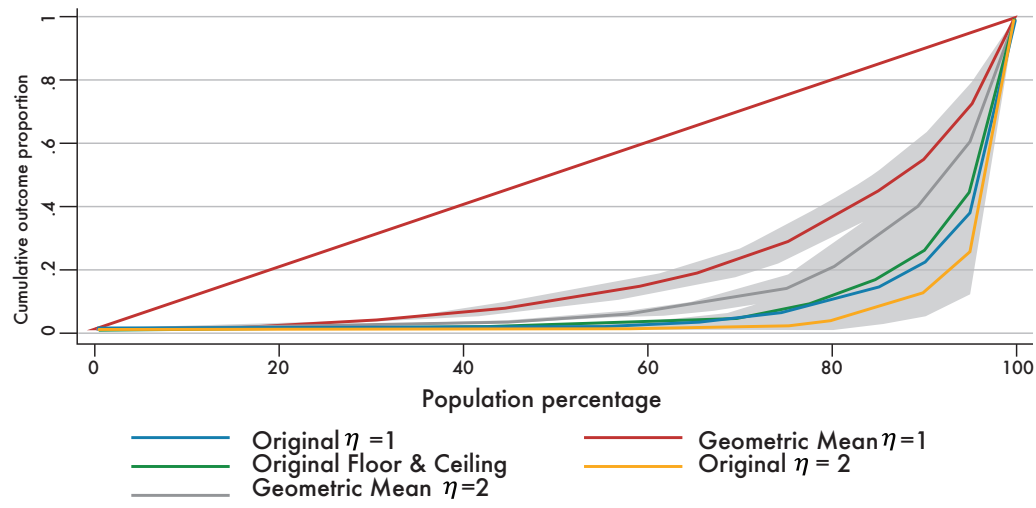
Figure A.2.57. Pen's parade for allocated shares for the original and geometric mean formulae η=1 and η=2



35. Pen's Parade in Figure A.2.57. (above) depicts the difference in rate of allocation for the original and geometric mean formulae with η=2. The two formulae allocate shares at about the same rate until about 60 per cent of the shares have been allocated, after which they diverge. From about 60 per cent to about 90–95 per cent the geometric mean formulae allocate shares more rapidly after which the original formulae overtake the geometric formula. The difference in maximum share size is also depicted, with the geometric mean formulae clearly demonstrating its smaller maximum share size.

36. The Lorenz Curve results in Table A.2.58. (above) reinforce the conclusions of the histograms and kernel density estimators that raising η from η=1 to η=2 creates more losers than gainers when reallocating proportions or shares of a fixed amount based on η.

Figure A.2.58. Lorenz curve for allocated shares for the original, geometric mean, and original with floor and ceiling for η=1 and η=2



37. The ranking of the original and geometric mean formulae for values of η=1 and η=2 in terms of most equitable and highest social welfare from highest to lowest is geometric mean η=1 > geometric mean η=2 > original with floor and ceiling η=1 > original η=1 > original η=2.

Appendix 3: Social welfare functions

1. A Social Welfare Function (SWF) constitutes a systematic framework for structuring ethical/moral preferences to give a framework to specifying these preferences.[103] An SWF establishes criteria under which efficiency and equity outcomes are transformed into a single metric, making them directly comparable. An SWF is a function that associates a single aggregate number with every distribution of State party utility (measuring the well-being of everyone within some population) or national income in global societies – an SWF is a "collective utility function". An SWF is ultimately based upon individuals' well-being captured by the notion of utility. The SWF framework has two key elements: (1) an interpersonally comparable utility function, which transforms any given outcome (a possible consequence of policy choice) into a list or "vector" of utility numbers, one for each person in the population; and (2) some rule for ranking these vectors. Under some formulations, well-being can incorporate risk and preferences for "fairness" and issues of income distribution.

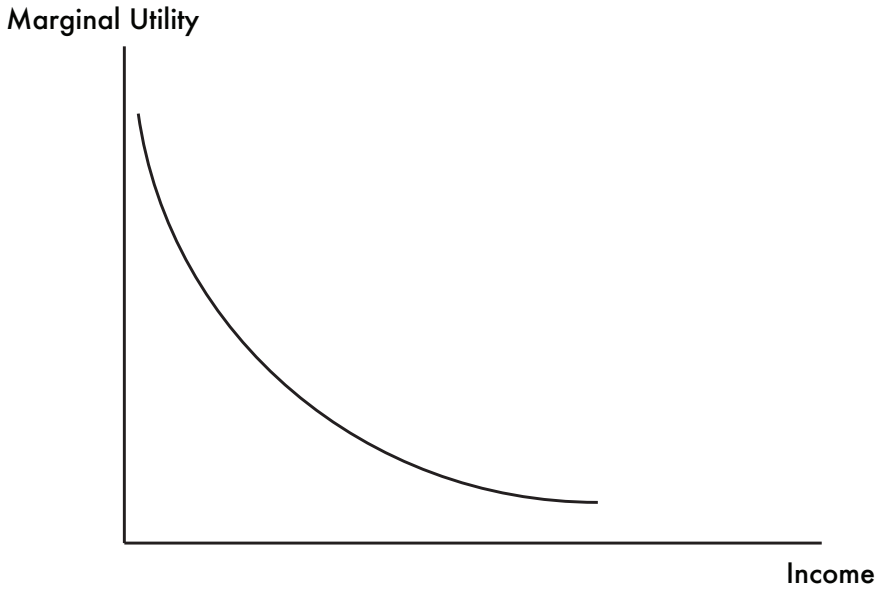
2. Let the global aggregate SWF be defined as $W(U) = f(U_1,U_2,...,U_N)$, where U_i denotes the utility or well-being of country i and is individualistic (U_i is independent of $U_j, i \neq j$, and ultimately depends upon individuals' preferences).[104] $W(U)$ is typically assumed continuous, differentiable, symmetric (each country's utility counts equally, which satisfies some concerns of fairness and reciprocity), and monotonicity holds (higher U_i leads to non-declining W holding all other countries constant or remaining equal, i.e. $\frac{\partial w(U)}{\partial U_i} \geq 0$, which satisfies the Pareto principle), subject to non-increasing marginal welfare $\frac{\partial^2 w(U)}{\partial U_i^2} \geq 0$ when the SWF is quasi-concave, or strictly declining marginal welfare $\frac{\partial^2 w(U)}{\partial U_i^2} \geq 0$ when the SWF is strictly concave. To achieve a stable ranking of outcomes, all ethically/morally plausible SWFs require some degree of interpersonal comparability of well-being. The global SWF determines the whole benefit for global society by summing up the single benefit for individual countries in the global society.

3. Utility functions are typically specified as a function of income (but could include non-income attributes A_i). In general, an individual's income does not have to equal consumption. However, in a one-period SWF (rather than an inter-temporal SWF) without bequests, income and consumption are identical. Utility in the SWF can thus

[103] Specifically, this is a Bergson-Samuelson SWF. This SWF assigns a welfare number to each alternative and then uses these numbers to determine a social preference ordering of them. In its individualistic form, a Bergson-Samuelson SWF is constructed in two stages: the individual utilities obtained with an alternative are first determined and then these utilities are aggregated into the value of social welfare. The function that aggregates the utilities provides a social welfare ordering of vectors of individual utilities. Consequentialist approaches to social evaluation compare and evaluate alternatives exclusively in terms of the outcomes associated with each alternative. Welfarism is a form of consequentialism in which only welfare consequences matter. Individualistic Bergson-Samuelson social welfare functions are welfarist.

[104] We take global society's preferences, as represented by the UN General Assembly, as given and do not analyze how they could arise through the political process. We take the standard welfarist approach where the government maximizes a SWF that depends solely on individual country utilities. We keep individual preferences standard and individuals' utility maximization intact. From Saez (2016) It is possible to modify individual preferences to directly incorporate justice and fairness criteria (see Alesina and Angeletos, 2005; Fehr and Schmidt, 1999) or certain forms of sympathy or envy. The question of how to aggregate individual preferences remains open. For a comprehensive general treatment, see Adler (2019).

Figure A.3.1. Declining marginal utility of income



depend upon consumption C_i and non-consumption attributes A_i (which can be multiple, in which case A_i is a vector of non-consumption attributes): U_i (C_i, A_i). Adler (2016) states that distributional weights of the consumption-only form of the SWF can be theoretically supported in only two special cases: (1) those affected by the policy are heterogeneous with respect to status quo consumption but relatively homogeneous with respect to status quo non-consumption attributes; or (2) the utility function not only satisfies the invariance requirement but takes a special additively separable form.

4. When a country i's utility is a function solely of its Gross National Income (GNI), also denoted by Y_i, utility is written as U_i (Y_i). The SWF can be written as $W(U(Y)) = f(U_1(Y_1), U_2(Y_2), \ldots, U_N(Y_N))$ where $U_1(Y_i)$ is typically assumed to be non-decreasing in Y_i (i.e. $\frac{\partial U_i}{\partial Y_i} \geq 0$), $\frac{\partial U_i}{\partial Y_i} \geq 0$ represents a welfare improvement, and U_i subject to declining marginal utility of income (i.e. $\frac{\partial^2 U_i}{\partial Y_i^2} \geq 0$). Figure 1 depicts declining marginal utility with increasing income. The welfare of an individual country i is measured independently of the GNI of other individual countries (i.e., country welfare is individualistic). If, when comparing any two GNI levels common to all countries, Y_a and Y_b, $W_a = f(U_1(Y_a), U_2(Y_a), \ldots, U_N(Y_a)) > W_b = f(U_1(Y_b), U_2(Y_b), \ldots, U_N(Y_b))$, then Y_a is socially preferred to Y_b. Often the SWF is directly written in reduced form as a function of income: $W = f(Y_1, Y_2, \ldots, Y_N)$ which allows directly determining the marginal social welfare contribution of income Y_i.

5. The SWF does not have to be restricted solely to utility, but can also be defined in terms of the signals summarizing all the relevant variables that affect the behaviour of private agents (firms, consumers), such as prices, taxes, quantity constraints etc., called the environment and denoted by S in general and by S_i for an individual country i.[105] Given the environment S_i, behavior of consumers and producers and levels of utility or profit are known. The SWF then indicates the social planner's (e.g., the government's) preferences between different environments. The

[105] See Drèze and Stern (1986).

public sector can conduct a (feasible) policy, a function, denoted by $\phi(Z)$, , which associates with each public production plan or public activities Z an environment S. The SWF could extend S to include the public sector and its production plan or activities and even positive or negative externalities Z. The SWF can then be written as $W= f(\phi_1(Z_1),\phi_2(Z_2),...,\phi\_N(Z_N))$, where $\phi_1(Z_i)$ is typically assumed to be non-decreasing in Z_i (i.e. $\frac{\partial \phi_i}{\partial Z_i} \geq 0$), $\frac{\partial \phi_i}{\partial Z_i} \geq 0$ is a welfare improvement, and $\phi_i(Z_i)$ is subject to diminishing returns (i.e., $\frac{\partial^2 \phi_i}{\partial Z_i^2} \geq 0$). With this understanding of the generality of the SWF, we restrict our discussion to the more typically encountered $W = f(U_1(Y_1),U_2(Y_2),...,U_N(Y_N))$.

6. SWFs (and inequality measurement) can (and typically do) satisfy several properties. One property is the Pareto principle: if at least one country's utility increases, and no other country's utility decreases, the value of the SWF increases. Another SWF property is monotonicity, in that higher levels of utility lead to higher levels of social welfare. Another property a SWF may satisfy is an axiom of anonymity/impartiality/symmetry, meaning indifference between any given utility vector and all rearrangements of its component utility numbers. Anonymous/impartial SWFs focus only on the pattern of well-being, and not on the identities of the countries which end up at particular well-being levels—i.e., social welfare depends on the *levels* of individual welfare in a society, not on *who* enjoys a particular level of welfare. Anonymity is sometimes treated as a notion of equity, in that all countries are treated equally.[106]

7. There are additional properties of SWFs and inequality measurement. One of these additional SWF properties is separability, meaning that the ranking of outcomes is not influenced by the utility levels of unaffected countries.[107] Separability is a big practical advantage in policy analysis, enabling the analyst to focus efforts on determining the utilities of those whose well-being would be changed by a policy, and not also to worry about how the policy would alter their position relative to the potentially vast number of unaffected. When the SWF is additively separable, any two countries' utilities can be aggregated independently of all others. As noted, under the property of individualism, the welfare of an individual country i is measured independently of the welfare of other individual countries. The principle of transfers is another property that is often considered desirable and a principle of fairness: a transfer from a poorer country to a richer country, without any other country's income changing, must increase inequality, or conversely, a transfer from a richer to a poorer country, without any other country's income changing, must decrease inequality so that the social welfare ordering increases (or at least does not decrease).[108] The principle or property of scale invariance states that the relation between two countries' utilities is unchanged if both of them are multiplied by the same scalar, e.g., the relationship does not depend on the unit of measurement.

8. Different functional forms have been posited for W, where different functional forms convey different implications for inequality aversion. The utilitarian SWF associated with Bentham can be written as the simple sum of utilities: $W= \sum_{i=1}^{N} U_i$ (which is also additive and separable). Utilitarianism is a polar case of the SWF. The utilitarian SWF says that a policy P is socially

[106] All permutations among countries of a given utility distribution must be ranked equivalently.
[107] The marginal rate of social substitution between any two countries' utility functions is independent of the level of utility of another. Arrow's independence of irrelevant alternatives: social preference between any two alternatives is required to depend only on individual preferences restricted to this pair.
[108] This is also called the Pigou-Dalton principle, which leads to prioritarian social welfare functions.

better than a policy P* if the sum of the increase in individual well-being is greater with P, i.e., the increase in the utility of the gainers more than offsets the decrease of those who lose. Only total welfare matters. Although utilitarianism is sensitive to the distribution of income (due to declining marginal utility of income), utilitarianism does not take account of the distribution of utility itself. The utilitarian SWF requires interpersonal comparability of well-being differences. The corresponding tax system would be close to a linear tax system, with a constant marginal tax rate. The Bentham or utilitarian SWF is equivalent to zero inequality aversion (indifference to inequalities because only the total matters). This SWF satisfies the Pareto principle: if at least one country's utility increases, and no other country's utility decreases, the value of the SWF increases. This SWF also satisfies an axiom of anonymity/impartiality, meaning indifference between any given utility vector and all rearrangements of its component utility numbers. Anonymous/impartial SWFs focus only on the pattern of well-being, and not the identities of the countries which end up at particular well-being levels. This SWF is separable, meaning that the ranking of outcomes is not influenced by the utility levels of unaffected countries.

9. The SWF associated with Rawls (1972) explicitly cares about which country benefits. The Rawlsians choose that alternative which offers the greatest benefit to the least advantaged, even if the alternative provides greater benefit to the less deprived. This SWF is sensitive to the distribution of utility. It is willing to incur arbitrarily large utility or income losses for better-off countries in order to realize a utility or income gain (however small) for a country which is worse off and would remain so after the gain. The Rawls SWF is: $W\ (U) = min\ (U_1,U_2,...,U_N)$ or $W\ (Y) = min\ (Y_1,Y_2,...,Y_N)$ if welfare is a direct function of income. This SWF is sometimes called maximin because the objective is to maximize the welfare of the worst-off country. Social welfare cannot increase unless the social welfare of the poorest individual is increased. When social welfare is a function of income, income increases associated with any other country do not increase social welfare. The Rawlsian SWF is equivalent to an infinite inequality aversion (since it gives absolute priority to the worst off).

Iso-elastic social welfare functions

10. The iso-elastic SWF brackets the polar opposite utilitarian or Rawlsian SWFs, so that the iso-elastic SWF is written: $W\ (U) = \left[\frac{1}{1-\gamma}\ \Sigma_{i=1}^{N}\left[(U_i)^{1-\gamma}\right]\right]$. When the SWF is a direct function of income Y_i, the SWF is written: $W\ (U) = \left[\frac{1}{1-\gamma}\ \Sigma_{i=1}^{N}\left[(U_i)^{1-\gamma}\right]\right]$

For both SWFs, the relative inequality aversion parameter γ is a constant and $0 \leq \gamma \leq \infty$ with quasi-concavity of the SWF (strict concavity gives < instead of $\leq$). The term $\frac{1}{1-\gamma}$ ensures that U_i rises with income, no matter whether γ is above or below unity. The coefficient of relative inequality aversion is: $\gamma = -\ U_i\ \frac{\frac{\partial^2 w\ (U)}{\partial U_i^2}}{\frac{\partial w\ (U)}{\partial U_i}}$.

Summing individual evaluation indicators or their first differences makes sense only if their units of measurement can be meaningfully compared across persons. The isoelastic SWF is more demanding in terms of interpersonal comparability than the utilitarian SWF. While the utilitarian SWF requires interpersonal comparability of differences, the isoelastic SWF requires interpersonal comparability of levels, differences, and ratios. Iso-elastic moral preferences give priority to well-being changes affecting worse-off individuals, where the degree of such priority is embodied in the inequality aversion parameter $\gamma > 0$.

11. The iso-elastic SWFs (including utilitarian when $\gamma = 0$) are symmetrical among economic agents, satisfy the Pareto principle (if at least one individual's utility increases and no individual's utility decreases then the value of the SWF increases), satisfies the axiom of anonymity/impartiality (indifference between an utility vector and all permutations (rearrangements) of its component utility numbers so that the SWF focuses only upon the pattern of well-being and not on the identities of the individuals who end up at some utility level), are separable (rankings of outcomes are unaffected by the utility levels of unaffected individuals), and require inter-individual comparisons of well-being differences. The isoelastic SWF requires interpersonal comparability of differences but the isoelastic SWF requires interpersonal comparability of levels, differences, and ratios. The isoelastic SWF requires positive utility numbers whereas the utilitarian does not.

Different values of relative inequality aversion parameter *y*

12. Different values of the relative inequality aversion parameter γ give different SWFs. When $\gamma = 0$, $W = \sum_{i=1}^{N} U_i$ or $= \sum_{i=1}^{N} Y_i$, i.e., the utilitarian SWF. When $\gamma \to \infty$ $W = min\ (U_1, U_2, ..., U_N)$ or $W = min\ (Y_1, Y_2, ..., Y_N)$ i.e., the Rawlsian SWF. When $\gamma \to 1$, $W = \prod^{N}_{i=1} U_i$ or $W = \prod^{N}_{i=1} Y_i$, i.e., the Bernoulli-Nash (Cobb-Douglas) SWF for total utility (or $\left[\prod^{N}_{i=1} U_i\right]^{\frac{1}{N}}$ or $\left[\prod^{N}_{i=1} U_i\right]^{\frac{1}{N}}$ the geometric mean for average utility or income). When $\gamma = 1$, $W = \sum_{i=1}^{N} lnU_i$ or $W = \sum_{i=1}^{N} lnY_i$, the SWF treats equal proportional increases in utility, income or consumption equally across countries/individuals. That is, the SWF $W = \sum_{i=1}^{N} lnU_i$ treats an X% increase for the poorer country the same as for a better-off country. When $\gamma > 1$, the SWF treats an x% increase for the poorer country as more welfare increasing than x% for the better-off country. As γ increases toward infinity (the Rawls SWF), small increases in income or utility for the worst-off get weighted much more than large increases in income or utility. In the limit, the Rawlsian case, increases in income or utility for the better-off do not impact welfare.

13. The parameter γ can be interpreted as the coefficient of aversion to inequality (which is analogous to the coefficient of relative risk aversion in the theory of choice under uncertainty).[109] The parameter y, called the elasticity of marginal social utility, is as noted above, $\gamma = -U \frac{\partial^2 w\,(U)\ /\partial U^2}{[\partial w\,(U)\ /\partial U]}$ where $\partial^2 w\ (U)\ /\partial U^2$ reflects the rate at which the marginal social utility declines with higher levels of utility and $\partial w\ (U)\ /\partial U$ is marginal social utility or the change in social welfare with a change in utility. The parameter y indicates the amount by which welfare declines with an increase in income, i.e., the relative inequality aversion. The higher y is, the higher the relative aversion to inequality in utilities. The higher y is, the faster the rate of proportional decline in welfare to a proportional increase in income (or utility). y captures the extent to which the social planner wants to place higher values on monetary gains accruing to various countries, i.e., the inequality-aversion coefficient captures the moral/ethical principles of a social planner who prefers to give some priority to utility changes affecting worse-off countries rather than simply aggregating utilities in a utilitarian manner.

14. To illustrate the interpretation of γ, consider a global economy with two countries in which the higher-income country consumes twice as much as the lower-income country. Consider a marginal redistributive policy to increase consumption in the lower income country by $1. What is the maximum sacrifice justified for the higher-income country to

[109] The parameter y also measures aversion to consumption fluctuations over time in the standard consumption-savings problem or the inverse of the intertemporal elasticity of substitution.

provide this benefit to the lower-income country? A $1 transfer is inequality neutral, a transfer of more than $1 reveals some degree of inequality aversion. A degree of inequality aversion of 2 means that the higher-income country should be ready to transfer as much as $k = 2^{\gamma}$ or $4 of consumption or income to the lower-income country.

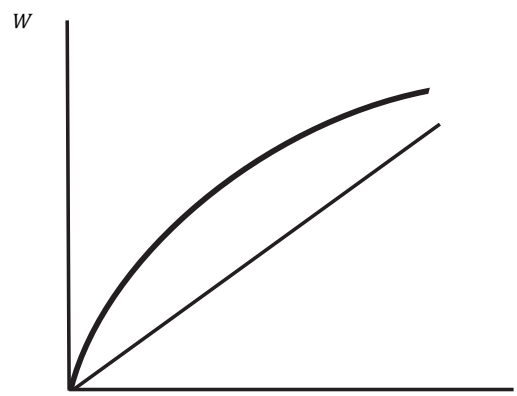
15. This standard model is parsimonious in simultaneously representing three different concepts (risk, inequality and allocation over time) by one parameter γ. This standard model may not be rich enough to separate the key ethical dimensions relevant to exploitation of an exhaustible resource (deep-seabed minerals) with adverse long-term impacts upon the environment. γ in our case implicitly assumes attitudes toward risk of constant relative risk aversion. In an inter-temporal SWF (see below) γ, besides capturing intra-temporal distribution of income (or consumption), incorporates the inter-temporal distribution and relative inequality aversion.

16. In sum, SWFs are related to inequality aversion (plus risk and inter-generational allocation or equity). Inequality aversion means that social welfare is more sensitive to a shift in the GNI of a poorer country than to the same shift affecting a richer country (concave line in Figure 1 below). Inequality aversion is thus a response to an increase in perceived inequality among countries in the global economy that does not affect any other features of global country utility distribution.

17. Inequality aversion requires an ethical/moral valuation. Mathematically, inequality aversion is expressed by a negative second derivative of W with respect to GNI $\frac{\partial w}{\partial U_i}\frac{\partial U_i}{\partial Y_i} < 0$ or $Y_i \frac{\partial w}{\partial Y_i} < 0$. Inequality neutrality means that social welfare is affected equally whenever a shift of GNI occurs irrespective to the position of individuals affected (straight line in Figure 1 below). Mathematically, inequality neutrality is expressed by $\frac{\partial w}{\partial U_i}\frac{\partial U_i}{\partial Y_i} = 0$ or $\frac{\partial w}{\partial Y_i} = 0$ if welfare is a direct function of income).

18. Relative inequality aversion with social welfare and GNI (or consumption) can be depicted by Figure A.3.2.

Figure A.3.2. Social welfare function and inequality aversion



19. Figure A.3.2 relates social welfare W to individual country GNI (Y). The concavity of the SWF $W(U)$ involves a value judgment that indicates society's aversion to inequality in the distribution of utilities.[110] A given amount of GNI gives an increase in W, i.e., $\frac{\partial w}{\partial GNI} > 0$. A given increase in income gives the same increase in social welfare on the straight line. The 45° linear SWF indicates that a dollar of GNI is a dollar of GNI regardless of which country receives it and corresponds to the utilitarian SWF in which $\gamma = 0$. A given increase in income at

[110] Figure A.3.2 could also be drawn in terms of individual country utility, U_i, where the degree of concavity of U(Y) is an empirical question. Moreover, we also assume away issues such as altruism, by which one country's welfare might be affected by another country's welfare, envy, or the absence of a well-defined preference ordering, bias etc. Moreover, because society can dislike inequality based off of risk aversion, inequality aversion or both, we abstract from the relationship between inequality aversion and risk aversion.

lower GNI levels gives more welfare than the same increase at higher GNI levels on the concave line, which corresponds to the iso-elastic SWF with $\gamma > 0$. The more concave the SWF, the lower the value attached to additional GNI accruing to richer countries, i.e., the lower the increase in social welfare. The concavity of the SWF indicates the rate at which the country's marginal utility of income falls as income rises, where a greater rate of decline favours more inequality aversion and hence redistribution, all other factors held constant. The SWF's degree of concavity thus indicates the inequality aversion in Figure 1, with greater concavity indicating greater relative inequality aversion. A convex relationship would be regressive and indicate a preference for inequality.

Social welfare (distribution) weights

20. Social welfare (social distribution) weights or different weights associated with different countries can be postulated. Social welfare weights indicate the marginal social value of an extra unit of income to individual country i. Consider the composite SWF $W(Y(Y)) = f(U_1(Y_1), U_2(Y_2), \ldots, U_N(Y_N))$ so that

$$dW(U(Y)) = \sum_{i=1}^{N} \frac{\partial w}{\partial U_i}\frac{\partial U_i}{\partial Y_i}\, dY_i = \sum_{i=1}^{N} \omega_i\, dY_i$$

where the $\omega_i = \frac{\partial w}{\partial U_i}\frac{\partial U_i}{\partial Y_i}$ are the social welfare weights, also called distribution weights. They represent the value that society puts on providing an additional dollar of income or consumption to any given individual (person, country). These weights directly reflect society's concerns for fairness. It is typically assumed that social welfare weights are positive and monotonically declining in utility or income due to positive but diminishing marginal utility of income or strict concavity in the social welfare function. This means that the weight attached to each country i when it receives an extra unit of income is positive and that the more income a country receives the smaller the relative social weight becomes. A necessary condition for Paretian preferences is that weights are positive at all income levels: $\omega_i > 0$. Non-Paretian preferences place negative social weights on some levels: $\omega_i < 0$ The definition of utility relies on subjective satisfaction or happiness. The utilitarian approach specifies $\omega_i = 1$ (which necessarily entails inter-country comparisons of utility or well-being and reflect the marginal utility of consumption/income). Welfare weights with an iso-elastic SWF also reflect the marginal utility of consumption/income but requiring a further moral judgment regarding the appropriate degree of inequality aversion and the specification of a "zero point" (subsistence level) so that utility will be measurable on a ratio scale.

21. The welfare/distribution weights $\omega_i = \frac{\partial w}{\partial U_i}\frac{\partial U_i}{\partial Y_i}$ are comprised of two sets of weights, $\frac{\partial w}{\partial U_i}$ and $\frac{\partial U_i}{\partial Y_i}$. The first weight, $\frac{\partial w}{\partial U_i}$, represents the weight given to each country $i's$ utility in the welfare (distribution) weight. The second weight, $\frac{\partial U_i}{\partial Y_i}$, represents shows how individual country utility varies with the level of GNI Y_i.

22. Generalized welfare weights (Saez, 2016) in principle incorporate alternative notions of fairness and justice that are not captured by the standard welfarist approach (based upon utility). Generalized welfare weights can be derived from social justice principles.

23. What is the value of a transfer of one unit of income from wealthier country j to poorer country i? What is the marginal social value of income redistribution, the extent to which a unit of currency is considered worth more to a poorer country than to a richer one? With an iso-elastic SWF $W(U) = \left[\frac{1}{1-\gamma}\sum_{i=1}^{N}[(U_i)^{1-\gamma}]\right]$ and the strong assumption that all countries have the same utility function,

the social marginal utility of transferring one unit of income to country i is $\frac{\partial w(U)}{\partial U_i} = \left[U_i\right]^{-\gamma}$ and the social marginal utility of transferring one unit of income from wealthier country j to poorer country i is the ratio of the marginal utility of country i to the marginal utility of country j, $h_{ij} = \frac{\frac{\partial W(U)}{\partial U_i}}{\frac{\partial W(U)}{\partial U_j}} = \frac{[U_i]^{-\gamma}}{[U_j]^{-\gamma}} = \left[\frac{U_j}{U_i}\right]^{\gamma}$, which is the ratio of utility levels for countries i and j. The expression $h_{ij} = \frac{[U_j]^{\gamma}}{[U_i]}$ forms the relative weights for the SWF $W(U)$. The elasticity of marginal social welfare of individual utility is: $-U_i \frac{\frac{\partial^2 W(U)}{\partial U_i^2}}{\frac{\partial W(U)}{\partial U_j}} = -U_i \frac{-\gamma U_i^{-\gamma-1}}{U_i^{-\gamma}} = \gamma.$

The derivatives of $W(U)$ are with respect to U (and not with respect to Y) because the issue is the concavity of the SWF $W(U)$ in terms of U. The constant elasticity parameter y measures the concavity of W as a function of U, $W(U)$. $\gamma = -U_i \frac{\frac{\partial^2 W(U)}{\partial U_i^2}}{\frac{\partial W(U)}{\partial U_j}} > 1$ implies a progressive income distribution, $\gamma=1$ implies proportional income distribution, $\gamma<1$ implies a regressive income distribution, and $\gamma=0$ is a utilitarian income distribution and $W(U)$ is not strictly concave and is instead linear.

24. For operational purposes, an individual country's utility U_i is typically related to its income Y_i (or consumption) through a function with a constant elasticity of the private marginal utility of income (or consumption): $U_i = \frac{1}{1-\alpha_i} Y_i^{1-\varepsilon_i}$, where ε_i is this elasticity and is restricted $0 \leq \varepsilon_i \leq 1$ to assure $U_i > 0$ (Ray, 1984; Kaplow, 2003). The term $\frac{1}{1-\varepsilon}$ ensures that U_i rises with income, no matter whether ε is above or below unity. With this definition, the marginal utility of income is $\frac{\partial U_i}{\partial Y_i} = Y_i^{-\varepsilon_i} > 0$ The concavity of $U_i(Y_i)$, measured by $-Y_i \frac{\frac{\partial^2 U_i(Y_i)}{\partial Y_i^2}}{\frac{\partial U_i(Y_i)}{\partial Y_i}}$ indicates the rate at which an individual country's marginal utility of income $\frac{\partial U_i}{\partial Y_i}$ falls as income rises; a greater rate of diminution favours more redistribution, *ceteris paribus*. The degree of concavity of $U_i(Y_i)$ is an empirical question because it is reflected, for example, in behavior under uncertainty; it is often measured by the coefficient of relative risk aversion. The relative weights for the utility function are given by: $_{ij} = \frac{\partial U_i / \partial Y_i}{\partial U_j / \partial Y_j} = \frac{Y_i^{-\varepsilon_i}}{Y_j^{-\varepsilon_j}}$.

Since common practice sets $\varepsilon_i=\varepsilon_j=\varepsilon$ (a constant elasticity of the private marginal utility of income across all individuals), relative weights for the utility function become $g_{ij} = \left[\frac{Y_j}{Y_i}\right]^{\varepsilon}$. y With an iso-elastic composite SWF,

$W\big(U(Y)\big) = f\big(U_1(Y_1), U_2(Y_2), \ldots, U_N(Y_N)\big)$

$= \left[\frac{1}{1-\gamma} \sum_{i=1}^{N} [(U_i)^{1-\gamma}]\right]$

$dW = \sum_{i=1}^{N} \frac{\partial W}{\partial U_i} \frac{\partial U_i}{\partial Y_i} dY_i = \sum_{i=1}^{N} \omega_i dY_i$ the ω_i are social welfare weights. The relative social welfare weights, which combine the relative welfare weights of the SWF $W(U)$ and the individual utility functions $U(Y)$, can be defined as $\omega_{i=} \frac{\frac{\partial^2 W}{\partial U_i \partial Y_i}}{\frac{\partial^2 W}{\partial U_j \partial Y_j}} = \left[\frac{U_j}{U_i}\right]^{\gamma} \left[\frac{Y_j}{Y_i}\right]^{\varepsilon} = h_{ij} g_{ij}$ (Ray 1984). Substituting the level of utility for country i, $U_i = \frac{1}{1-\varepsilon} Y_i^{1-\varepsilon}$ (letting $\varepsilon_i=\varepsilon_j=\varepsilon$, into $\omega_i = h_{ij} g_{ij} = \left[\frac{U_j}{U_i}\right]^{\gamma} \left[\frac{Y_j}{Y_i}\right]^{\varepsilon}$ gives

$\omega_i = \left[\frac{\frac{1}{1-\epsilon} Y_j^{1-\varepsilon}}{\frac{1}{1-\varepsilon} Y_i^{1-\varepsilon}}\right]^{\gamma} \left[\frac{Y_j}{Y_i}\right]^{\varepsilon} = \left[\frac{Y_j}{Y_i}\right]^{(1-\varepsilon)\gamma} \left[\frac{Y_j}{Y_i}\right]^{\varepsilon}$

$= \left[\frac{Y_j}{Y_i}\right]^{(1-\varepsilon)\gamma+\varepsilon}$. The relative social welfare weights ω_i depend upon two elasticity parameters, γ and ε. When the SWF is utilitarian SWF, so that $\gamma = 1 \Rightarrow 1-\gamma = 0$ ω_i depends solely upon the constant

elasticity of private marginal utility of income ε:$\omega_i = h_{ij}g_{ij} = \left[\frac{Y_j}{Y_i}\right]^{\varepsilon}$. When the unit of analysis is not the individual but households or countries, an additional term is given to the relative welfare weight, the country or household weight or number of individuals in the household or country (Cowell, 1999), ψ_i, giving $\omega_i = \psi_i h_{ij} g_{ij}$.

Social marginal utility of income η

25. Social welfare weights are usually related to another elasticity parameter, the social marginal welfare of individual income, denoted by η. The elasticity for the social marginal welfare of income, which is assumed to be the same for every country's income, is defined as: $\eta = -Y_i \frac{\frac{\partial^2 W(Y)}{\partial Y_i^2}}{\frac{\partial W(Y)}{\partial Y_i}}$.[111] The elasticity for the social marginal welfare of income η indicates the concavity of the composite function $W(Y)$ with respect to its argument, income Y and the overall social preference for income redistribution. η contains both the relative risk aversion parameter ε and relative inequality aversion parameter (both intra- and inter-generationally) y, and is thus a mixture of risk aversion and ethical values. However, usually only one parameter is used, intra-generational distribution, so that relative risk aversion and inter-generational income distribution are implicitly held constant.

26. The elasticity for the social marginal welfare of income η can be derived for the composite SWF, $W(U(Y)) = f\left(U_1(Y_1), U_2(Y_2), \ldots, U_N(Y_N)\right)$ or from the reduced form SWF as a direct function of income, $W(Y) = f(Y_1, Y_2, \ldots, Y_N)$ (Ray, 1984; Kaplow, 2003). The first and second derivatives of the composite SWF with respect to Y (and dropping the index of individual countries i) are $\frac{\partial W(U(Y))}{\partial Y} = \frac{\partial W(U)}{\partial U}\frac{\partial U(Y)}{\partial Y}$ and $\frac{\partial^2 W(U(Y))}{\partial Y^2} = \frac{\partial\left[\frac{\partial W(U))}{\partial Y}\right]}{\partial Y} = \frac{\partial\left[\frac{\partial W(U)\partial U(Y)}{\partial U \quad \partial Y}\right]}{\partial Y} = \frac{\partial W(U)}{\partial U}\frac{\partial^2 U(Y)}{\partial Y^2} + \left[\frac{\partial^2 W(U)}{\partial U^2}\frac{\partial U(Y)}{\partial Y}\right]\frac{\partial U(Y)}{\partial Y} = \frac{\partial W(U)}{\partial U}\frac{\partial^2 U(Y)}{\partial Y^2} + \frac{\partial^2 W(U)}{\partial U^2}\left[\frac{\partial U(Y)}{\partial Y}\right]^2$.

Substituting these derivatives into $\eta = -Y_i \frac{\frac{\partial^2 W(Y)}{\partial Y_i^2}}{\frac{\partial W(Y)}{\partial Y_i}}$ gives

$$\eta = -Y \frac{\frac{\partial W(U)\partial^2 U(Y)}{\partial U \quad \partial Y^2} + \frac{\partial^2 W(U)\partial U(Y)}{\partial U^2 \quad \partial Y}}{\frac{\partial W(U)\partial U(Y)}{\partial U \quad \partial Y}}$$

$$= -Y \frac{\frac{\partial^2 U(Y)}{\partial Y^2}}{\frac{\partial U(Y)}{\partial Y}} - Y \frac{\frac{\partial U(Y)\partial^2 W(U)}{\partial Y \quad \partial U^2}}{\frac{\partial W(U)}{\partial U}}.$$ Values for the components of η can be found by differentiating iso-elastic specifications of the utility and social welfare functions. For the iso-elastic utility function as a function of income (and again dropping individual country indices), $U(Y) = \frac{Y^{1-\varepsilon}}{1-\varepsilon}$ $\frac{\partial U(Y)}{\partial Y} = \frac{\partial\left(\frac{Y^{1-\varepsilon}}{1-\varepsilon}\right)}{\partial Y} = \frac{1-\varepsilon}{1-\varepsilon}Y^{1-\varepsilon-1} = Y^{-\varepsilon}$, and

For the iso-elastic SWF as a function of utility, $W(U) = \frac{U^{1-\gamma}}{1-\gamma}$ $\frac{\partial W(U)}{\partial U} = \frac{\partial\left(\frac{U^{1-\gamma}}{1-\gamma}\right)}{\partial U} = \frac{1-\gamma}{1-\gamma}U^{1-\gamma-1} = U^{-\gamma}$and $\frac{\partial^2 W(U)}{\partial U^2} = \frac{\partial U^{-\gamma}}{\partial U} = -\gamma U^{-\gamma-1}$. Substituting these values into $\eta = -Y \frac{\frac{\partial^2 U(Y)}{\partial Y^2}}{\frac{\partial U(Y)}{\partial Y}} - Y \frac{\frac{\partial U(Y)\partial^2 W(U)}{\partial Y \quad \partial U^2}}{\frac{\partial W(U)}{\partial U}}$

gives $\eta = -Y\frac{(-\varepsilon)Y^{-\varepsilon-1}}{Y^{-\varepsilon}} - Y\frac{Y^{-\epsilon}\left(-\gamma U^{-\gamma-1}\right)}{U^{-\gamma}}$

$= -(-\varepsilon)Y^1Y^{-\varepsilon-1}Y^{-(-\epsilon)} -$
$(-\gamma U^{-\gamma-1})U^{-(-\gamma)}Y^1Y^{-\varepsilon}$
$= \varepsilon Y^{1-\epsilon-1+\varepsilon} + \gamma U^{-\gamma-1+\gamma}Y^{1-\varepsilon} =$
$\varepsilon + \gamma\left(\frac{Y^{1-\varepsilon}}{1-\varepsilon}\right)^{-1}Y^{1-\varepsilon}$ (after substituting $U(Y) = \frac{Y^{1-\varepsilon}}{1-\varepsilon}$ into the second term). Further simplifying gives

[111] In contrast to $-U_i \frac{\frac{\partial^2 w(U)}{\partial U_i^2}}{\frac{\partial w(U)}{\partial U_j}} = \gamma$ for the SWF written solely in terms of utility, $W(U)$, the derivatives are written in terms of Y_i for the reduced form composite SWF written in terms of income, $W(U(Y) = W(Y))$.

$\eta = \varepsilon + \gamma\left(\frac{1}{1-\epsilon}\right)^{-1} Y^{(1-\varepsilon)(-1)} Y^{(1-\varepsilon)}$
$= \varepsilon + \gamma(1-\varepsilon) Y^{(-1+\varepsilon)} Y^{(1-\varepsilon)}$
$= \varepsilon + \gamma(1-\varepsilon) Y^{(-1+\varepsilon+1-\varepsilon)}$, so that $\eta = \varepsilon + \gamma(1-\varepsilon)$. This expression for the elasticity of the social marginal welfare of income $\eta = \varepsilon + \gamma(1-\varepsilon)$ is the same expression obtained above in $\omega_i = \left[\frac{Y_j}{Y_i}\right]^{(1-\epsilon)\gamma+\varepsilon}$, so that $\omega_i = \left[\frac{Y_j}{Y_i}\right]^{\eta} = \left[\frac{Y_j}{Y_i}\right]^{(1-\epsilon)\gamma+\varepsilon}$.

27. The elasticity for the social marginal welfare of income $\eta = \varepsilon + \gamma(1-\varepsilon)$ is a function of two parameters, the coefficient of relative inequality aversion y and elasticity of the private marginal utility of income (or consumption) ε. This elasticity η is a feature of individuals' utility functions $U(Y)$ that can in principle be observed and the SWF $W(U)$ that reflects a social value judgement, so that η, derived from the composite SWF $W(U(Y))$, which is a combination of the two. If the utilitarian SWF is chosen, then $\gamma = 1 \Longrightarrow 1 - \gamma = 0$, ω_i depends solely upon ε, the elasticity of the private marginal utility of income. The marginal social utility of income with the utilitarian SWF is then: $\frac{\partial W(Y)}{\partial Y_i} = Y_i^{-\eta} = Y_i^{-\varepsilon}$.

Social marginal utility of income for iso-elastic social welfare functions

28. In sum and to reiterate, with iso-elastic social welfare and utility functions, the social welfare (distribution) weights using the elasticity for the social marginal welfare of income $\eta = \varepsilon + \gamma(1-\varepsilon)$ are written $\omega_i = h_{ij} g_{ij} = \left[\frac{Y_j}{Y_i}\right]^{\eta} = \left[\frac{Y_j}{Y_i}\right]^{\varepsilon+\gamma(1-\varepsilon)}$.

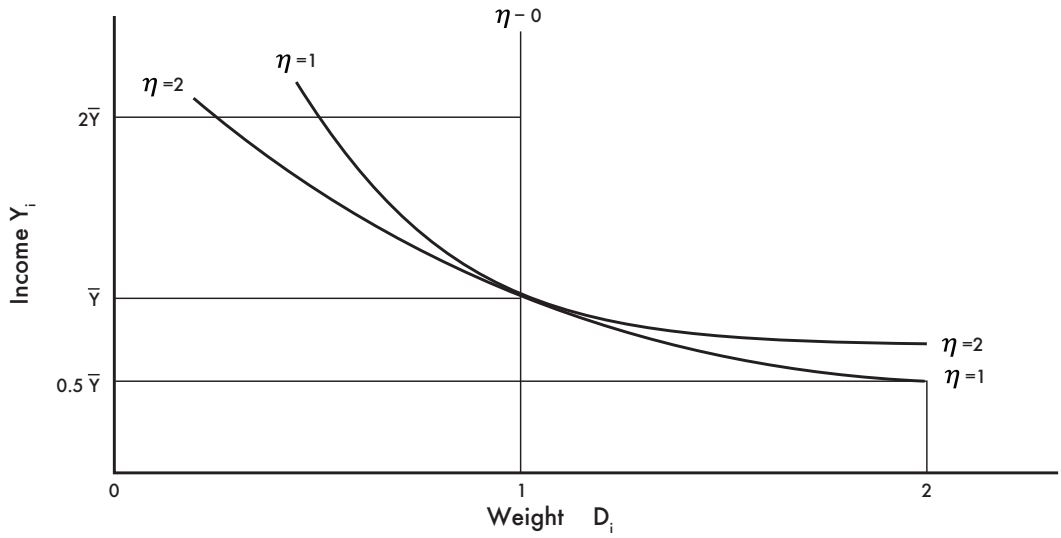
As before, when the unit of analysis is not the individual but households or countries, an additional term can be given to the relative welfare weight, the country or household weight or number of individuals in the household or country (Cowell, 1999), ψ_i, giving $\omega_i = \psi_i h_{ij} g_{ij} = \psi_i \left[\frac{Y_j}{Y_i}\right]^{\eta} = \psi_i \left[\frac{Y_j}{Y_i}\right]^{\varepsilon+\gamma(1-\varepsilon)}$.

A reference level of income is chosen for Y_j, typically the mean per capita income (here GNI) or median per capita income. The weight ω_i is a hyperbolic function of the country income level Y_i, with a value of one at the per capita mean or mean income. The following figure (Figure 1 from Ray, 1984) illustrates this relationship, where $d_i = \omega_i$.

29. The figure illustrates the relationship between income and welfare (distribution/social) weights for the special case of the iso-elastic SWF and iso-elastic utility function, which gives $\eta = \varepsilon + \gamma(1-\varepsilon)$ (adapted from, and partially based upon, Ray, 1984). An important feature of the constant-elasticity iso-elastic SWF is that it gives increasing priority to utility changes the lower the income. With this iso-elastic form, the welfare weights tend to become very large as income disparities increase.

- When the parameter for relative inequality aversion equals zero, i.e., $y = 0$ the social and private elasticities are equal, i.e., $\eta = \varepsilon$, and the SWF function is the classic utilitarian SWF, $W(U) = \sum_{i=1}^{N} U_i$. It is not egalitarian in utility levels, even though the marginal social valuation of income still implies diminishing relative social weights as income rises (i.e., due to diminishing marginal utility of income, $\frac{\partial^2 U(Y)}{\partial Y^2} < 0$). Thus $\omega_i = \left[\frac{Y_j}{Y_i}\right]^{\eta} = \left[\frac{Y_j}{Y_i}\right]^{\varepsilon}$ and $\eta = \varepsilon$ can be large or small.
- With the iso-elastic welfare function and $y = 0$, so that $\eta = \varepsilon + \gamma(1-\varepsilon) = \varepsilon$ and $W(Y) = \sum_{i=1}^{N} Y_i$, the following cases hold for different values of $\eta = \varepsilon$,. Moreover, all social weights are equal, i.e., $\omega_i = \omega_j = 1, \forall i, j \epsilon N, i \neq j$.
  - When $\eta = \varepsilon = 0$, all social weights are unity, i.e., $\omega_i = \left[\frac{\bar{Y}}{Y_i}\right]^{\eta=\varepsilon=0} = 1$, which corresponds to the vertical line at $d_i = 1\ (\omega_i = 1)$ in the above figure. One US$ is one US$ in welfare

Figure A.3.3. Social welfare (distribution) weights



terms, whoever the winner or loser is, as in the Harberger tradition and standard practice in cost-benefit analysis.

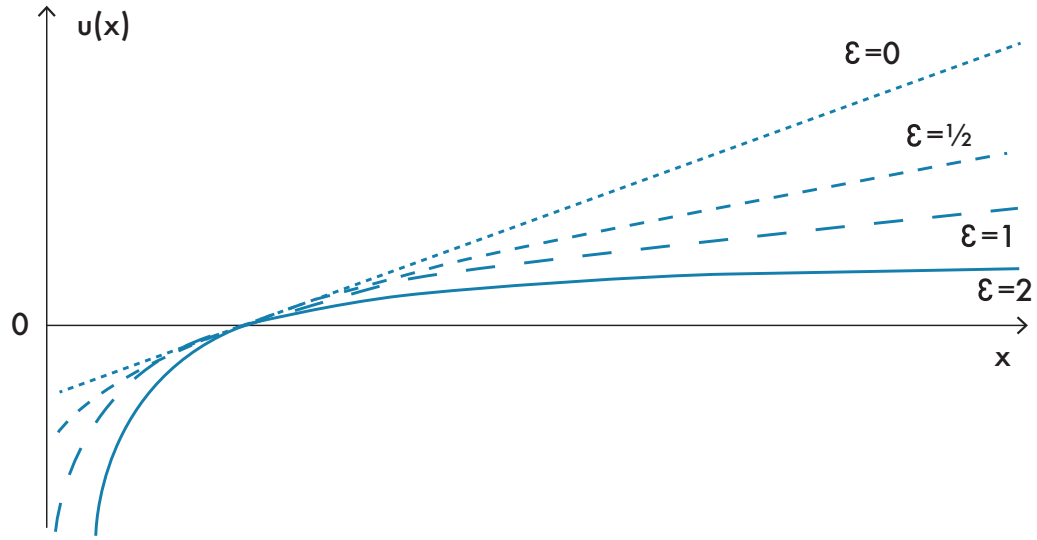
- When $\eta = \varepsilon = 1$, the social welfare weight is simply the inverse of the income (or consumption) of the individual (or group, member, beneficiary in general): $\omega_i = \left[\frac{\bar{Y}}{Y_i}\right]^{\eta=\varepsilon=1}$.
- When $\eta = \varepsilon > 1$, individuals whose income level is above (below) average will be given a weight less (greater) than unity: $\omega_i = \left[\frac{\bar{Y}}{Y_i}\right]^{\varepsilon>1}$.
- A range $0 < \eta = \varepsilon < 1$ implies a moderate inequality aversion and $\omega_i = \left[\frac{\bar{Y}}{Y_i}\right]^{0<\varepsilon<1}$.
- $\eta = \varepsilon = \infty$ gives Rawls' maximin rule, so that $SWF = Min\{U_i\}$, and $\omega_i = \left[\frac{\bar{Y}}{Y_i}\right]^{\varepsilon=\infty}$.
- $0 < \eta = \varepsilon < \infty$ gives an iso-elastic SWF.

- When $\gamma \to \infty$, the Rawlsian maximin case is obtained, so that $W = min\{U_i\}$. The objective is to maximize the utility of the worst-off individual country.
- When $\gamma = 1$, $\eta = \varepsilon + \gamma(1-\varepsilon) = 1$, and $\omega_i = \left[\frac{\bar{Y}}{Y_i}\right]^{\eta=1}$. Again, the social welfare weight is the inverse of the income of the individual.
- Many empirical studies of high income and upper middle-income countries, using iso-elastic social welfare and utility functions, find values of $\eta = \varepsilon$ around 1.4-2.0. The 1971 UN study that previously gave a formula to distribute royalties implicitly specified a value of $\eta = \varepsilon = 1$.

30. The following figure illustrates the relationship between utility and income (x) for different values of ε. Note the increasing concavity of the utility (or SWF) function with increasing values of ε.

31. Relative social distributional/welfare weights $\omega_i = h_{ij}g_{ij} = \left[\frac{Y_j}{Y_i}\right]^{\eta} = \left[\frac{Y_j}{Y_i}\right]^{\varepsilon+\gamma(1-\varepsilon)}$ with this constant elasticity form tend to become very large as income disparities between countries increase. If the differences in income between countries is very unequal, the weights applicable to the lowest income countries become extremely high. The size of η determines the extent to which marginal social utility

Figure A.3.4. Relationship between utility and income (x) for different values of ε



declines as income (or consumption) rises, and knowledge of its value permits a comparison of relative marginal utilities for countries with contrasting (per capita) incomes (or consumption).

32. The utility function defined over consumption and with identical utility functions across countries for the utilitarian SWF, in which $\gamma = 0$ so that $\eta=\varepsilon$, is written: $W = \sum_{i=1}^{N} U(C_i)$, with $\frac{\partial U(C_i)}{\partial c_i} > 0$ (monotonicity, Pareto principle) and with diminishing marginal utility in consumption $\frac{\partial^2 U(C_i)}{\partial C^2} < 0$ and with an iso-elastic utility function $U(C_i) = \frac{C_i^{1-\varepsilon}}{1-\varepsilon}, \eta = \varepsilon \neq 1$ and $U(C_i) = lnC_i, \eta = \varepsilon = 1$.

33. The following table (adapted from Squire and van der Tak, 1975, p. 64) for the utilitarian SWF, in which $\gamma = 0$ so that $\eta = \varepsilon$, and identical utility functions that are iso-elastic. Then, $U(Y_i) = \frac{Y_i^{1-\varepsilon}}{1-\varepsilon}, \eta = \varepsilon \neq 1$ and $U(Y_i) = lnY_i, \eta = \varepsilon = 1$, illustrates different social welfare weights where the reference level of consumption is per capita consumption: $\omega_i = \left[\frac{\bar{Y}}{Y_i}\right]^{\eta=\varepsilon}$.

34. When utility functions can be specified as functions of attributes A_i as well as income (as noted above), one option for welfare weights can be specified as: $\omega_i = \left[\theta_Y \frac{Y_j}{Y_i} + \theta_A \frac{Aj}{Ai}\right]^{\eta}$ and $0 \leq \theta_Y, \theta_A \leq 1, \theta_Y + \theta_A = 1$, and as before 4 $\eta = \alpha + \gamma(1-\alpha)$. Again, a reference level of income is chosen for Y_j, typically the mean per capita income (here GNI) or median per capita income.

35. Another option is to specify separate values for η for Y and for A. Specifically for A representing landlocked low-income countries for Article 82, welfare weights for States that are not landlocked and low-income can be specified as and welfare weights for landlocked low-income States can be specified as $\omega_i^L = \theta_Y \left[\frac{Y_j}{Y_i}\right]^{\eta_1} + \theta_A \left[\frac{Y_k}{l}\right]^{\eta_2}, 0 \leq \theta_Y, \theta_A \leq 1, \theta_Y + \theta_A = 1,$ where $k,l,k\neq l,$ denotes landlocked low-income States.

Caveats

36. Several caveats are in order. First, there are really two levels of value judgment involved: individual country

Table A.3.1. Social welfare (distribution) values for marginal changes

Relative income level $\left(\frac{\bar{Y}}{Y}\right)$	0	0.5	1.0	1.5	2.0
10.00	1.00	3.16	10.00	31.62	100.00
4.00	1.00	2.00	4.00	8.00	16.00
2.00	1.00	1.41	2.00	2.83	4.00
1.33	1.00	1.15	1.33	1.53	1.77
1.00	1.00	1.00	1.00	1.00	1.00
0.66	1.00	0.81	0.66	0.54	0.44
0.33	1.00	0.57	0.33	0.19	0.11
0.17	1.00	0.41	0.17	0.07	0.03
0.10	1.00	0.32	0.10	0.03	0.01

utility functions $U_i\,(Y_i)$ and the SWF $W(U)$ to apply to the individual country utilities. Whereas the same SWF $W(U)$ may be used to convert individual country utility into social utility, converting real country income to individual country utility may require individual country-specific utility functions (rather than the assumption of the same utility functions across countries). Different countries may have different abilities to convert real income to utility if they differ in needs or circumstances or if their preferences differ.

37. Second, utility and social welfare in the above discussion have largely been related to income. The literature is largely focused upon individuals or households and not regions or countries, and thereby sometimes includes leisure. This is not an issue here, although other attributes, notably whether a country is landlocked or not, are. Because leisure is not germane, disincentives upon labour supply or any other behavioural responses created by the UN budget system do not apply. The UN budget system, although principally a function of GNI with modifications to provide elements of progressivity (adjustments for debt burden and a tax ceiling and a tax floor), is not an income tax with implications for labour supply (including choices of leisure versus consumption) or other country behavioural responses such as rates of UN participation. Although some countries may delay in paying their assessed contributions, they eventually fulfil their obligation. The UN assessment or tax system is instead a "lump sum" system, meaning taxation has (close to) zero administrative cost and no adverse incentive effects (e.g., with respect to individual labour supply). ISA royalty system upon DSM, in contrast, is not a lump sum tax system without disincentive impacts upon contractor behaviour, including the amount of exploration and mining (at both the extensive and intensive margins). To the extent that some contractors', potentially State contractors', behaviour is motivated by strategic as well as strictly economic (profits) behaviour, the royalty system may not have disincentive effects upon contractor behaviour.

Inverse optimum

38. Saez (2001, p. 221) first suggested to invert the optimal income tax approach to address the following question: given the primitives, for which welfare function is the observed tax system optimal? If the resulting welfare function implies social marginal welfare weights that are negative, the tax system is not second-best Pareto efficient. These "revealed social preferences" necessarily rely on auxiliary assumptions about labour supply behaviour and the distribution of individual abilities. With the direct or standard approach to optimal taxation, the optimal tax schedule is known to be very sensitive to these assumptions. The same is true of the social preferences revealed by a given marginal tax schedule. If revealed preferences are not well-behaved, this may be because some common assumptions on labour supply behaviour or on the distribution of abilities are inconsistent, which should be equally useful information. Using the inverse optimum approach to infer the implicit welfare weights of the government assumes that the government (i) chooses the tax schedule which maximizes a social welfare function and (ii) uses the correct estimates for the labour supply elasticities. Francois Bourguignon and Amedeo Spadaro (2012), use analytical results from optimal tax theory and assumptions on economic parameters to infer the marginal social welfare weights (MSWWs) currently prevailing in several developed economies. Bargain et al. (2014) showed that it is possible to derive optimal tax schedules under different assumptions about inequality aversion, and to identify the level for which optimal and actual tax rates coincide. inverting the optimal tax model on actual distributions of gross and net incomes to recover the social welfare function which makes the observed system optimal.

Inter-temporal social welfare functions: comparing the welfare of different generations

39. The social welfare function that explicitly compares the welfare of different generations can be specified as follows (Harrison, 2014). Here we present the social welfare function in terms of consumption, but as typically specified, consumption and income are used interchangeably. This social welfare function is based upon growth theory models of a representative, infinitely lived household. This social welfare function is specified as:

$$W\big(U(C)\big) = U(C_0) + \frac{(1+P)^{(1-\rho)}}{(1+\theta)^1}U(C_1) +$$

$$\frac{(1+P)^{(1-\rho)}}{(1+\theta)^2}U(C_2) + \cdots = \sum_{n=0}^{\infty}\frac{(1+P)^{n(1-\rho)}}{(1+\theta)^n}U(C_n)$$

where each term represents a different generation and C_i is the per-person value of lifetime consumption of a typical member of generation i. This specification assumes that each generation can be represented by one utility function and that all generations have the same utility function.

40. The population grows at exogenous rate P. θ denotes the pure social rate of time preference, which is used to discount the utility of future generations (representing the rate used utility and part of the consumption social discount rate such as from the Ramsey Rule). $\theta = 0$ means that all generations count equally, so that $W(U(C)) = \sum_{n=0}^{\infty}(1+P)^{n(1-\rho)}U(C_n).\ \theta > 0$ means less weight is placed on the utility of future generations in $W\,(U\,(C))$.

41. The term $(1-\rho)$ weights the social welfare function for the number of people in each generation. When $\rho = 1, (1-\rho) = 0$ and $W\big(U(C)\big) = \sum_{n=0}^{\infty}\frac{U(C_n)}{(1+\theta)^n}$, social welfare depends only on the average consumption of a generation, and the number of

descendants P does not affect social welfare. A constant population $P = 0$ gives the same result, i.e., $W\big(U(C)\big) = \sum_{n=0}^{\infty} \frac{U(C_n)}{(1+\theta)^n}$, and models each generation of a constant population of identical individuals with the same utility function.

42. When $\rho = 0$, then $W(U(C)) = \sum_{n=0}^{\infty} \frac{(1+P)^n}{(1+\theta)^n} U(C_n)$. This inter-generational utilitarian specification of the social welfare function maximizes the present value of the total utility of all current and future people (Harrison, 2014). Because social welfare depends on both the average utility and number of descendants, when the population grows the future is more valuable than when only average utility matters, i.e., an increase in future consumption per capita has a larger impact upon social welfare, and social welfare falls.

43. When $\theta = 0$ (utility of current and future generations is the same) and $P = 0$ (constant population), the SWF has the additive form in which social welfare is the sum of the individual utilities: $W\big(U(C)\big) = U(C_1) + U(C_2) + \cdots + U(C_N) = \sum_{n=1}^{N} U(C_n)$. This utilitarian SWF represents Bentham's philosophy that the greatest happiness of the greatest number counts.

44. When $\theta > 0$ (utility of current generations counts more than future generations), $P = 0$ (constant population), and allowing for constant relative inequality aversion y, the social welfare function is written $W\big(U(C)\big) = \sum_{n=0}^{\infty} \frac{C_n^{1-\gamma}}{(1+\theta)^n(1-\gamma)}$ (Harrison, 2014). If consumption in each generation is chosen to maximize this social welfare function, in steady-state equilibrium the consumption discount rate given by the Ramsey Rule is r = $\theta + \gamma g$ where g $g$denotes the rate of economic growth.

Appendix 4: Alternative approaches and formulae not adopted

1. During its 2019 discussions on the initial report, the Finance Committee suggested several further options for consideration in relation to the allocation formula (essentially for the numerator). Each of the alternative approaches was reviewed, but it was considered that for the reasons set out below these approaches would make no meaningful difference to the allocation formula.

Equal weights for population share p_i for each State party

2. In this case. $P_i = P_j,\ i \neq j,\ \forall\, i,j \in N$. This formula reduces to the same formula as the State as the basic unit to represent the Common Heritage of Mankind rather than heterogenous States parties' population shares, because multiplying each State party's social distribution weight ω_i by the same constant number (scalar) cancels out in both the numerator and denominator of the formula for S_i. Thus:

$$S_i = \frac{P\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1}}{\sum_{i=1}^{N} P\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1}} = \frac{\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1}}{\sum_{i=1}^{N}\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1}}$$

Population density for each State party

3. An additional variable could be added to the allocated shares formula, the population density of each State party's population, denoted D_i. The variables $P_i\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1}$ are thus multiplied by D_i to give

for the original formula:

$$S_i = \frac{\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta} * P * D_i}{\sum_{i=1}^{N}\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta} * P_i * D_i}$$

4. The impact upon the size and distribution of S_i is expected to be closely aligned to the results without D_i due to the strength of the population share of all ISA States parties, P_i. Another factor that could closely align the results with and without D_i is the expected close correlation between P_i and D_i.

State party as the unit for the common heritage of mankind rather than the individual person

5. The individual State party can be the unit for the common heritage of mankind and for the allocated share S_i rather than the individual person. Aristotle's equity principle still applies, where each State party has an equal claim (since they have equal exogenous rights under international law and parity within the ISA). In this case, each State party's population share P_i is replaced by the integer 1. The original allocation formula becomes:

$$S_i = \frac{\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta}}{\sum_{i=1}^{N}\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta}}$$

6. There is no geometric mean formula for the State party as the basis for the Common Heritage of Mankind, since there is only a single variable, $\omega_i = \left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1}$.

$$S_i = \frac{\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta}}{\sum_{i=1}^{N}\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta}}$$

Additional criteria

7. Any number of additional criteria could be summed to form an aggregate index of the individual criteria C_{ij} for State party i,:

$C_i = \prod_{j=1}^{M} C_{ij}^{\beta_j}$

$i = 1, 2, \ldots, N$, where N denotes the number of States parties, $j = 1, 2, \ldots, M$ individual criteria, M denotes the number of criteria, β_j denotes the weight given to individual criteria C_{ij}, and $\sum_{j=1}^{M}\beta_j = 1$. Individual allocation criteria can be ordinal or cardinal. Index numbers are theoretically consistent formulae that, given β_j, establish the aggregate index C_i. Different index number formula can be considered, where the above is the geometric mean if $\beta_j = \beta_k = \frac{1}{M}, j \neq k, \forall j, j, k \varepsilon M, 0 < \beta_j < 1, \sum_{j=1}^{M}\beta_j = 1$, i.e., β_j becomes the j^{th} root. The index C_i can be directly constructed in the allocation formula in a single step. The index C_i can also be constructed in two or more stages. Multi-stage versus single-stage construction raises the issue of consistency in aggregation, which is discussed in Appendix 6.

8. Cardinal weights do not present a measurement problem in principle. Individual ordinal criteria that are binary (yes/no) may not pose a special measurement problem, since they are readily converted to a cardinal measure of 1/0, Individual ordinal criteria, however, can present measurement issues if each individual criterion is itself comprised of ordinal rankings.

9. The formula for States parties' allocated shares S_i can be written:

$$S_i = \frac{\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta} * C_i}{\sum_{i=1}^{N}\left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta} * C_i}$$

Overall, the addition of more criteria simply complicates the calculation without adding any material difference to the outcome of the formula.

10. Appropriateness and the allocation formula weights β_j given to individual criteria C_{ij} can be derived through stated or revealed approaches. We discuss stated ethics when we discuss weights for the individual allocation criteria.

11. The question then arises of whose revealed ethics to use and how to define and measure these ethics. One source of revealed ethics is the highest possible global authority and representation of humanity, the UN General Assembly, to develop appropriateness and income progressivity as implied by the UN General Assembly's formula for assessed contributions in a manner consistent with UNCLOS. This revealed ethics, based upon decisions made independently of the allocation problem at hand, may come close to being "strategy proof" to the extent that each UN General Assembly member (with its own private information) honestly reveals its ethics on global progressivity in an action unrelated to the progressive distribution of royalties by ISA.

12. We assume that ISA provides what its States parties view as a fair and just process of deciding upon the allocation formula and the allocation process itself. Given ISA decision-making processes, this assumption can safely be made. Given this assurance of a fair and just process of decision-making, we focus upon fair and equitable outcomes.

Weighting individual criteria to form an aggregate index

13. Differences of opinion must be reconciled to arrive at a prioritization that is agreeable to all. This prioritization forms the basis of weights as long as the sum of the weights equals one. This is the opinion aggregation or social choice problem. Some examples of approaches include ranked or cardinal voting systems, the related development of point systems (a form of priority lists), or choice experiment approaches. These could be developed by applying a Delphi approach, perhaps in a web-based method.

Voting Systems: Under voting systems, voters (here individual States party *i*) in a ranked voting system rank preferences on an ordinal scale.

Borda Voting System: If there were, for example, 5 criteria, the top-ranked criteria would receive a value of 5, the second-ranked criteria would receive a value of 4, etc. This is the Borda process, in which each voter completely ranks all options or candidates and records a score of 0 for the last ranked candidate, 1 for the next-to-last candidate, 2 for next lowest one, and so forth. The total score awarded by all voters determines the winner. The cardinal weight for the top-ranked criteria would then receive a weight of 5/ (5+4+3+2+1). Voters in a cardinal voting system give each candidate an independent rating or grade, say on a scale of 1 to 10, and each criterion then receives a weight of the sum of cardinal ratings by all voters divided by the sum of all cardinal ratings. The potential flaw to the Borda method is that an alternative can be ranked below another even though the first alternative obtains a strict majority over the second alternative. The majority alternative to the Borda method would receive a strict majority of votes when compared pairwise with every other alternative.

Condorcet's Ranking, which addresses the potential flaw to Borda's method, chooses the ranking(s) that are supported by the maximum number of pairwise votes. Condorcet's approach fails, however, if there is not a majority alternative, but does satisfy majority rule for every two adjacent alternatives (the higher-ranked alternative has a majority or ties over the lower ranked alternative).

Preferential Voting Systems: Four preferential voting systems for proportional representation, for example, include: The Hare system of single transferable vote, the Borda count, cumulative voting, and additional-remember systems. The Hare system of single transferable vote involves the successive elimination of the lowest-vote candidates, and the transfer of surplus votes of those who have already been elected to other candidates. While Arrow's Impossibility Theorem shows that

there is no completely satisfactory method for aggregating individual opinions into a social consensus, aggregation schemes are available that can provide satisfactory answers under almost all conditions. Some form of sealed bid auction is possible, in which CPCs successively bid for their preferred criterion, in which an English style starts from the bottom candidates, a Dutch style starts from the preferred candidates, and there are many options (e.g., choosing the second-best bid).[112]

Point System: A point system is a type of priority method and can be developed under certain conditions. Points are awarded to different finite number of attributes based upon some set of criteria. The points could be awarded through voting, in which a voting system results, by an appointed group of experts or representatives of the States parties, or by a survey of the States parties. The perceived fairness of the resulting priority formula depends on the legitimacy of the process by which it is established. Differences of opinion must be reconciled in order to arrive at a prioritization that represents a result perceived as a social consensus and legitimate.[113]

14. A priority method based on a given standard distributes the available units to the claimants who have the highest priority, while a point-allocation procedure is a procedure under which claimants can allocate a fixed number of points to different goods or issues that reflects, if the claimants are truthful, the importance they attach to receiving these goods or winning on these issues.

15. If the claimant types are evaluated in a finite number of attributes, and there are a finite number of distinct types of claimants, then a priority method can be represented by a point system if and only if the priority relation is separable. Separability here means the priority relation is separable in attributes 1 and 2 of the priority between t and t' is the same between as the priority between s and s'. If the priority relation is separable in every pair of attributes, it is said to be separable. Within each dimension, a point system may assign points in a linear or non-linear system. Perceived fairness of a priority formula rests on the legitimacy of the process by which it is determined.

Discrete Choice Experiment: A discrete choice experiment is a quantitative technique for eliciting individual preferences. It allows researchers to uncover how individuals value selected attributes of a program, product or service by asking them to state their choice over different hypothetical alternatives. Discrete choice experiments require respondents to state their choice over sets of hypothetical alternatives. Each alternative is described by several characteristics, known as attributes, and responses are used to infer the value placed on each attribute. In comparison to other stated preference techniques that require the individual to rank or rate alternatives, a discrete choice experiment presents a reasonably straightforward task and one which more closely resembles a real-world decision. The method has its theoretical foundation in random utility theory and relies on the assumptions of economic rationality and utility maximization. In stating a preference, the individual is assumed to choose the alternative that yields his or her highest individual benefit, known as utility. Moreover, the utility yielded by an alternative is assumed to depend on the utilities associated with its composing attributes and attribute levels.

Delphi Method: The Delphi method is a forecasting process framework based on the results of multiple rounds of questionnaires sent to States parties. Several rounds of questionnaires are sent out to the States parties, and the anonymous responses are aggregated and shared with the group after each

[112] See Brams and Taylor (1996), Moulin (2003) and Young (1994).
[113] Young, 1994.

round. The States parties are allowed to adjust their answers in subsequent rounds, based on how they interpret the "group response" that has been provided to them. Since multiple rounds of questions are asked and the panel is told what the group thinks, the Delphi method seeks to reach the correct response through consensus.

Appendix 5: Regression analysis of the impact of P_i and ω_i upon S_i

1. The impact of population share P_i and social distribution weight $\omega_i = \left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta}$, $\eta = 1$, upon S_i can be evaluated by regre ssion analysis.[114,115] The constant term is the allocated shares to the Asia-Pacific Group, so that the dummy (categorical) variables for each regional group indicate deviations of that regional group's allocated shares from the Asia-Pacific Group's allocated shares. Standard errors are heteroscedastic-consistent and clustered around each group (5 groups).

2. The following tables show the regression results. The results show that the African Group's shares are indistinguishable from the Asia-Pacific Group's shares, but that the shares of the Latin American and Caribbean, Eastern European, and Western Europe and Others Groups are all lower. The distribution weight ω_i and share of the total population of all States parties P_i are both statistically significant, but the share of the total population of all States parties P_i has a substantially bigger impact than the distribution weight $\omega_i = \left[\frac{\overline{GNI}}{GNI_i}\right]^{\eta=1}$.

3. The average marginal effects (the effect on allocated share from a one-unit change in the independent variable, i.e., group, population share, or distribution weight) are all statistically significant except for the African Group. The average marginal effect of the total population of all States parties share on the size of the allocated share for each State party P_i is 0.1084, 0.0983, 0.0765, 0.0124522 for the original, original with floor and ceiling, geometric mean, and State as the basis of the CHM formulae, respectively, and for the social distribution weight ω_i is 0.0001, 0.0001, 5.75e-07, and 0.0001498 for the original, original with floor and ceiling, geometric mean, and State as the basis of the CHM formulae, respectively (all values are always statistically significant with $P > |z| = 0.000$), indicating orders of magnitude in differential impact between P_i and ω_i, which is consistent across all three formulae.

4. In summary, the population shares P_i of the States parties is the biggest single determinant of the size of the allocated Article 140 shares S_i for any formula, with the social distribution weight ω_i making a much smaller contribution by several orders of magnitude.

5. The following tables depict correlation coefficients among allocated shares S_i, population share P_i, social distribution weight ω_i, and per capita GNI, GNI_i, with η=1. The social distribution weight and population share are always positively and statistically significantly correlated with

[114] Proportion data have values that range between zero and one, and the predicted values should also range between zero and one. One way to accomplish this is to use a generalized linear model (glm) with a logit link and the binomial family. Standard errors in the glm model are clustered around each region to give cluster-robust standard errors, which will be particularly useful if we have mis-specified the distribution family. The Stata command is: glm SWT140_1 DAFRICA DGRULAC DEEG DWEOG POPSHARE DWT140_1, link(logit) family(binomial) cluster (REGION1) nolog. A short discussion is available at (accessed March 27, 2019): https://stats.idre.ucla.edu/stata/faq/how-does-one-do-regression-when-the-dependent-variable-is-a-proportion/

[115] The parameter estimates and standard errors are very slightly biased and inconsistent, since a fractional logit model (required when the dependent variable is proportions) does not allow the allocated shares S_i to sum to one. Nonetheless, the results clearly show the relative importance of the different variables that impact the allocated shares S_i. A similar regression with a beta distribution gives virtually identical results.

Table A.5.1. Original formula regression results for impacts of groups, distribution weight, and share of global population on Article 140 allocated shares (η=1)

Variable	Coefficient	Robust Standard Error	z	P>|z|	95% Confidence Interval Lower	95% Confidence Interval Upper
Dummy Africa	0.219	0.247	0.09	0.376	-0.265	0.703
Dummy Latin America Caribbean	-1.429	0.010	-14.34	0.000	-1.642	-1.234
Dummy Eastern Europe	-1.739	0.096	-18.021	0.000	-1.921	-1.550
Dummy Western Europe	-2.959	0.089	-33.39	0.000	-3.135	-2.785
Population Share	19.788	0.715	27.26	0.000	18.386	21.190
Distribution Weight	0.025	0.005	5.33	0.000	0.016	0.034
Constant (Africa)	-5.700	0.090	-63.35	0.000	-5.875	-5.521

Note: Fractional logit regression by generalized linear model (glm) with a logit link and the binomial family. Robust standard errors clustered on each region (5 clusters). Intercept is Asia-Pacific Group. Log pseudolikelihood = -3.756751931, AIC = 0.0809102, BIC = -838.2343. Number of observations = 167, residual degrees of freedom = 164. Deviance =0.006089, Pearson = 0.0084279, scale parameter = 1.

Table A.5.2. Marginal impacts for original formula regression results for impacts of ISA regional groups, distribution weight, and share of global population on Article 140 allocated shares (η=1)

Variable	Coefficient	Robust Standard Error	z	P>|z|
Dummy Africa	0.0011986	0.001344	0.89	0.373
Dummy Latin America Caribbean	-0.0078266	0.0006222	-12.58	0.00
Dummy Eastern Europe	-0.0095253	0.0006228	-15.29	0.00
Dummy Western Europe	-0.0162077	0.0006498	-24.94	0.00
Population Share	0.1083904	0.0030193	35.90	0.00
Distribution Weight	0.0001357	0.0000263	5.16	0.00

Table A.5.3. Geometric mean regression results for impacts of ISA regional groups, distribution weight, and share of global population on Article 140 allocated shares (η=1)

Variable	Coefficient	Robust Standard Error	z	P>|z|	95% Confidence Interval Lower	95% Confidence Interval Upper
Dummy Africa	0.6308945	0.0854698	7.38	0.00	0.4633769	0.7984122
Dummy Latin America Caribbean	-0.478894	0.0814781	-5.88	0.00	-0.6385881	-0.3192
Dummy Eastern Europe	-0.554775	0.0820454	-6.76	0.00	-0.715581	-0.3939689
Dummy Western Europe	-1.117505	0.0812616	-13.75	0.00	-1.276775	-0.9582354
Population Share	12.97568	0.7934082	16.35	0.00	11.42062	14.53073
Distribution Weight	0.0000975	4.12E-06	23.68	0.00	0.0000894	0.0001055
Constant (Africa)	-5.374323	0.0840844	-63.92	0.00	-5.539125	-5.20952

Note: Fractional logit regression by generalized linear model (glm) with a logit link and the binomial family. Robust standard errors clustered on each region (5 clusters). Intercept is Asia-Pacific Group. Log pseudolikelihood = - -4.75818526, AIC = 0 .0929124, BIC = -838.6563. Number of observations = 167, residual degrees of freedom = 164. Deviance =0 .6947290693, Pearson = 0. .7617015233, scale parameter = 1.

Table A.5.4. Marginal impacts for geometric mean regression results for impacts of groups, distribution weight, and share of global population on Article 140 allocated shares (η=1)

Variable	Coefficient	Robust Standard Error	z	P>|z|
Dummy Africa	0.0037192	0.0004706	7.90	0.00
Dummy Latin America Caribbean	-0.0028232	0.0005061	-5.58	0.00
Dummy Eastern Europe	-0.0032705	0.0005135	-6.37	0.00
Dummy Western Europe	-0.0065879	0.0005394	-12.21	0.00
Population Share	0.0764941	0.0040513	18.88	0.00
Distribution Weight	5.75E-07	2.78E-08	20.71	0.00

Table A.5.5. Original formula with floor and ceiling regression results for impacts of ISA regional groups, distribution weight, and share of global population on Article 140 allocated shares (η=1)

Variable	Coefficient	Robust Standard Error	z	P>|z|	95% Confidence Interval Lower	95% Confidence Interval Upper
Dummy Africa	0.2643064	0.2023968	1.31	0.192	-0.132384	0.6609968
Dummy Latin America Caribbean	-1.417124	0.105348	-13.45	0.00	-1.623602	-1.210645
Dummy Eastern Europe	-1.732336	0.1033668	-16.76	0.00	-1.934932	-1.529741
Dummy Western Europe	-2.946661	0.0973595	-30.27	0.00	-3.137482	-2.75584
Population Share	16.73391	0.8501719	19.68	0.00	15.0676	18.40021
Distribution Weight	0.0238255	0.0032866	7.25	0.00	0.0173839	0.0302672
Constant (Africa)	-5.503984	0.0995008	-55.32	0.00	-5.699002	-5.308966

Note: Fractional logit regression by generalized linear model (glm) with a logit link and the binomial family. Robust standard errors clustered on each region (5 clusters). Intercept is Asia-Pacific Group. Log pseudolikelihood = -4.112741492, AIC = .0971586, BIC = -833.0618. Number of observations = 167, residual degrees of freedom = 164. Deviance = 1.171170022, Pearson = 1.583409055, scale parameter = 1.

Table A.5.6. Marginal impacts for original formula with floor and ceiling regression results for impacts of ISA regional groups, distribution weight, and share of global population on Article 140 allocated shares (η=1)

Variable	Coefficient	Robust Standard Error	z	P>|z|
Dummy Africa	0.001507	0.0011408	1.32	0.186
Dummy Latin America Caribbean	-0.0080803	0.0006877	-11.75	0.00
Dummy Eastern Europe	-0.0098776	0.0006968	-14.18	0.00
Dummy Western Europe	-0.0168015	7420	-22.64	0.00
Population Share	0.0954148	0.0039885	23.92	0.00
Distribution Weight	0.0001359	0.0000197	6.91	0.00

the allocated share, and the correlation is always higher for population share compared to social distribution weight. Per capita GNI is negatively correlated with the allocated shares and is statistically significantly correlated with the geometric mean and original floor and ceiling formulae but is not statistically significantly correlated with the original formula. Population share and social distribution weight are not statistically significantly correlated for all three formulae.

Table A.5.7. Correlation coefficients for allocated shares, population share, social distribution weight, and GNI η=1: original formula

	Allocated Share S_i	Per Capita Gross National Income GNI_i	Social Distribution Weight ω_i	Population Share P_i
Allocated Share S_i	1.0000			
Per Capita Gross National Income GNI_i	-0.1289 (0.0970)	1.0000		
Social Distribution Weight ω_i	0.2190 (0.0045)	-0.2997 (0.0001)	1.0000	
Population Share P_i	0.7911 (0.0000)	-0.0665 (0.3930)	-0.0223 (0.9768)	1.0000

Note: Standard errors in parentheses.

Table A.5.8. Correlation coefficients for allocated shares, population share, social distribution weight, and GNI η=1: geometric mean formula

	Allocated Share S_i	Per Capita Gross National Income GNI_i	Social Distribution Weight ω_i	Population Share P_i
Allocated Share S_i	1.0000			
Per Capita Gross National Income GNI_i	-0.2879 (0.0002)	1.0000		
Social Distribution Weight ω_i	0.4674	-0.2997	1.0000	
Population Share P_i	0.7156 (0.0000)	-0.0665 (0.3930)	-0.0023 (0.9768)	1.0000

Note: Standard errors in parentheses.

Table A.5.9. Correlation coefficients for allocated shares, population share, social distribution weight, and GNI η=1: original floor and ceiling formula

	Allocated Share S_i	Per Capita Gross National Income GNI_i	Social Distribution Weight ω_i	Population Share P_i
Allocated Share S_i	1.0000			
Per Capita Gross National Income GNI_i	-0.1877 (0.0151)	1.0000		
Social Distribution Weight ω_i	0.3720 (0.0000)	-0.2997 (0.0001)	1.0000	
Population Share P_i	0.7929 (0.0000)	-0.0665 (0.3930)	-0.0023 (0.9768)	1.0000

Note: Standard errors in parentheses.

Appendix 6: Geometric means, Cobb-Douglas aggregator functions, and consistent aggregation

1. The numerator in the original formula is multiplicative, because P_i and ω_i are multiplied together. The original formula corresponds to a Cobb-Douglas aggregator function for the numerator for each State party i: $f(Z_{ij}) = A_0 \prod_{J=1}^{M} Z_{ij}^{Aj}$, where $A_0 = 1, A_j = 1, \forall j \in M, Z_{ij} = P_i, \omega_i,$, and here $M = 2$ (an aggregator function performs a calculation on a set of values, here P_i and ω_i, to return a single scalar value, here the numerator of S_i). The resulting geometric index (here the numerator $f(Zij)$) is exact for a Cobb-Douglas aggregator function. This aggregator function can be viewed as a first-order approximation to any arbitrary function in the neighbourhood of initial values for P_i and ω_i. The key distinguishing factor in the original functional form is the linear exponent to P_i and ω_i (giving the Cobb-Douglas aggregator function is homogeneous of degree 2) where the geometric mean formula uses an exponent of $\frac{1}{M}$, i.e., $A_j = \frac{1}{M}$ and $\sum_{j=1}^{M} A_j = 1$(so that the Cobb-Douglas aggregator function is homogeneous of degree 1). The original (multiplicative) formula treats equal proportional increases in P_i and ω_i equally across States parties. The formula for the numerator of S_i roughly corresponds to the functional form of the Bernoulli-Nash social welfare function.

2. The geometric mean index decreases the level of substitutability between the dimensions (being compared), here P_i and ω_i, compared to the original geometric index (exponents of P_i and ω_i are 1). The Human Development Index uses geometric mean for this reason. Thus, a low value in one dimension is not linearly compensated by high achievement in another dimension. At the same time, it ensures that a 1 per cent decline in S_i has the same impact on the allocation as a 1 per cent decline in $\omega_i = \frac{\overline{GNI}^{\eta}}{GNI_i}$.

3. As a basis for comparisons of achievements, this method is also more respectful of the intrinsic differences across the dimensions than a simple arithmetic mean. The geometric mean is excellent for constructing composite indices, utilizing very different sorts of data that are all scored differently. The reason is that the geometric mean is indifferent to the scales used (as long as the same ones are used each time). The geometric mean, in contrast to an arithmetic mean, combines values with a product instead of a sum, and then splits them up again with an Nth root. The conceptual difference is seeing each data point as a scaling factor, which combine by increasing each other multiplicatively. The geometric mean is what any scaling factor would be if they were all the same. Moreover, the geometric mean is the only correct mean when averaging normalized results; that is, results that are presented as ratios to reference values such as S_i and ω_i.[116]

4. Other economic index numbers or aggregator functions exist, notably the quadratic-mean-of-order-r aggregator function with the corresponding superlative index, but they are not relevant in this case because two or more time periods or States parties are not directly compared (in bilateral or multilateral) indices.

Consistency in aggregation

5. The index C_i can be directly constructed in the allocation formula in a single step. The index C_i can also be constructed inn two or more stages. Multi-stage versus single-stage construction raises the issue of consistency in aggregation. An index-number formula is consistent in aggregation if the numerical value of the index constructed in two or more stages necessarily coincides with the value of the index calculated in a

[116] Fleming and Wallace, 1986.

single stage.[117] The geometric indexes, including those used in this study (which are essentially Cobb-Douglas aggregator functions) along with the Paasche and Laspeyres are consistent in aggregation.[118] The superlative indices are not.

6. Consistent aggregation, providing a perfectly satisfactory overall index that can be applied to individual periods in an intertemporal context, to individual economic entities, or to subgroups of commodities, requires homothetic weak separability of the underlying aggregator function. Thus, to justify the two-stage method of calculating index numbers for any partition of variables requires an aggregator function, such as the Cobb-Douglas, which is homothetically separable in the same partition that corresponds to the two stages. The Paasche and Laspeyres indices are consistent in aggregation since the underlying aggregator function is either linear or Leontief, the Vartia I's underlying aggregator function is the Cobb-Douglas, and the Vartia II's underlying aggregator function is the CES. If the underlying aggregator function is not separable, any attempt to construct an overall or group quantity index by using subgroup indices will result in the group quantity index varying with variations in quantities of commodities outside of that group. An implicitly separable underlying aggregator function for an index also allows consistent aggregation.[119]

Appendix 7: Inequality measures

1. A number of inequality measures exist. The Atkinson inequality measure makes inequality judgments and derives measures from social welfare functions, giving a normative basis. The Generalized Entropy (Theil) inequality measures approach the quantification of inequality through comparing probability distributions and an information theory, although it can be lined to social welfare functions. The Gini coefficient (and Lorenz curve) can also be linked, under certain conditions, to the social welfare function. Thus, the three inequality measures, Atkinson, Generalized Entropy (Theil), and Gini coefficient, not only measure relative inequality but also provide normative judgments in terms of which allocation formula for S_i provides the highest social welfare for the States parties members of ISA.

ATKINSON $y \neq 1$:

$$A_\gamma = 1 - \left[\frac{1}{N}\sum_{i=1}^{N}\left[\frac{S_i}{\bar{S}}\right]^{1-\gamma}\right]^{\frac{1}{1-\gamma}}, \quad 0 \leq A_\gamma \leq 1,$$

smaller A_γ more equal

ATKINSON $y = 1$:

$$A_\gamma = \frac{\prod_{i=1}^{N} GNI_i^{\frac{1}{N}}}{\sum_{i=1}^{N} GNI_i}, \; 0 \leq A_\gamma \leq 1, \text{ smaller } A_\gamma$$

more equal

GENERALIZED ENTROPY 1 or THEIL T:

$$GE(1) = \frac{1}{N}\sum_{i=1}^{N}\frac{S_i}{\bar{S}} ln\left[\frac{S_i}{\bar{S}}\right], \; 0 \leq \text{GE(1)} \leq \infty$$

- Smaller values are more equal.
- More sensitive to distribution of shares in higher range than Theil L.

GENERALIZED ENTROPY 0 or THEIL 0:

$$GE(0) = \frac{1}{N}\sum_{i=1}^{N} ln\left[\frac{\bar{S}}{S}\right], \; 0 \leq \text{GE(0)} \leq \infty$$

- Smaller values are more equal.
- More sensitive to distribution of shares in lower range than Theil T.

GINI COEFFICIENT :

$$\frac{1}{2N^2\bar{S}}\sum_{i=1}^{N}\sum_{j=1}^{N} S_i - S_j, \; i \neq j, 0 \leq G \leq 1$$

[117] Vartia, 1974.
[118] Vartia, 1976.
[119] Blackorby et al., 1978.

- Smaller values are more equal.
- Lorenz Curve is graphical representation of Gini.

2. Atkinson inequality index values can be used to calculate the proportion of total income that would be required to achieve an equal level of social welfare as at present if incomes were perfectly distributed. For example, an Atkinson index value of 0.20 suggests that we could achieve the same level of social welfare with only 1–0.20=80 per cent of income. The theoretical range of Atkinson values is 0 to 1, with 0 being a state of equal distribution. The Atkinson index incorporates a sensitivity parameter (γ). This parameter γ can range from 0 (meaning that ISA is indifferent about the nature of the income distribution), to infinity (where ISA is concerned only with the income position of the very lowest income group), i.e., $0 \leq \gamma \leq 1$. Atkinson argued that this index was a way to incorporate Rawls' conception of social justice into the measurement of income inequality. In practice, γ values of 0.5, 1, 1.5 or 2 are used; the higher the value of γ, the more sensitive the Atkinson index becomes to inequalities at the bottom of the income distribution.

3. The Generalized Entropy (Theil) inequality index measures an entropic "distance" the population is away from the egalitarian state of everyone having the same income. The numerical result is in terms of negative entropy, so that a higher number indicates more order that is further away from the complete equality. For lower values of α, the measure is more sensitive to changes in the lower tail of the distribution, and, for higher values, it is more sensitive to changes that affect the upper tail.[120] The most common values for α are 0, 1, and 2. The more positive α (the sensitivity parameter; −1, 0, 1 or 2) is, the more sensitive $GE\ (a)$ is to inequalities at the top of the income distribution. The theoretical range of $GE\ (a)$ values is 0 to infinity, with 0 being a state of equal distribution and values greater than 0 representing increasing levels of inequality, i.e., $0 \leq GE\ (a) \leq \infty$. Another beneficial property of the $GE\ (a)$ measure is that it is decomposable; that is, it can be broken down to component parts (i.e., population subgroups). This enables analysis of between- and within-area effects.

4. The Gini coefficient is a relative inequality measure largely associated with the descriptive approach to relative inequality measurement, although it can be linked to social welfare functions and social welfare analysis. The Gini coefficient attempts to distil a two-dimensional area (the gap between the Lorenz curve and the equality line) down into a single number, it obscures information about the "shape" of inequality. In particular, the Gini coefficient measures the ratio of the area between the Lorenz curve and the equi-distribution line to the area of maximum concentration. The generalized Gini coefficient is dependent upon the degree of relative inequality aversion, but neither the generalized Gini coefficient nor Gini coefficient as the primary social welfare measure are developed or used here. Instead, the report instead uses the Atkinson and Generalized Entropy (Theil) inequality measures with different values of inequality aversion to evaluate social welfare impacts of alternative allocations S_i.

5. More on the Atkinson index: In the words of Atkinson (1970), $A\gamma$ is 1 minus the ratio of the equally distributed equivalent level of income to the mean of the actual distribution. If $A\gamma$ falls, then the distribution has become more equal—we would require a higher level of equally distributed income (relative to the mean) to achieve the same level of social welfare as the actual distribution. The measure $A\gamma$ has the convenient property of lying between 0 (complete equality) and 1 (complete inequality). Moreover, this new measure

[120] Atkinson and Bourguignon (2015).

has considerable intuitive appeal. If $A\gamma$ = 0.3, for example, it allows us to say that if incomes were equally distributed, then we should need only 70 per cent of the present national income to achieve the same level of social welfare (according to the particular social welfare function). Or we could say that a certain plan for redistributing income would raise social welfare by an amount equivalent to an increase of 5 per cent in equally distributed income. This facilitates comparison of the gains from redistribution with the costs that it might impose, such as any disincentive effect of income taxation, and with the benefits from alternative economic measures.

6. Given any income distribution, therefore, GNI_{EDE} can be easily calculated for different levels of inequality aversion. Different levels of inequality aversion γ give different values of GNI_{EDE}. For γ = 0, the equally distributed equivalent income is simply the average level of income. With $\gamma > 0$, GNI_{EDE} decreases (for convex social welfare function, its level is always below average income) and $A\gamma$ increases. For example, if with $\gamma = 2$, $A\gamma\,(\gamma = 2) = 0.379$, the interpretation is that society is disposed to release 37.9 per cent of the size of the cake to have equal slices. If $\gamma \to \infty$, the Rawlsian criterion is used, i.e., the social welfare function becomes more and more inequality averse.

7. The Atkinson Index is predicated upon an iso-elastic social welfare function: $W(U) = \left[\frac{1}{1-\gamma}\sum_{i=1}^{N}[(U_i)^{1-\gamma}]\right]$. When the SWF is a direct function of income, Y_i, the SWF is written: $W(Y) = \left[\frac{1}{1-\gamma}\sum_{i=1}^{N}[(Y_i)^{1-\gamma}]\right], \gamma \neq 1$ When $W(Y)\ \gamma = 1, W(Y) = logY_i$. For both SWFs, the relative inequality aversion parameter γ is a constant and $W(Y) \quad 0 \leq \gamma \leq \infty$ with quasi-concavity of the SWF (strict concavity gives < instead of $\leq$). The term $\frac{1}{1-\gamma}$ ensures that U_i rises with income, no matter whether γ is above or below unity. The coefficient of relative inequality aversion is: $\gamma = -U_i \frac{\frac{\partial^2 W(U)}{\partial U_i^2}}{\frac{\partial W(U)}{\partial U_i}}$.

8. Different values of the relative inequality aversion parameter γ give different SWFs. When $\gamma = 0, W = \sum_{1=1}^{N} U_i$ or $= \sum_{1=1}^{N} Y_i$, i.e., the utilitarian SWF. When $\gamma \to \infty, W = min(U_1, U_2, \dots, U_N)$ or $W = min(Y_1, Y, \dots, Y_N)$, i.e., the $= min(Y_1, Y, \dots, Y_N)$ i.e., the Rawlsian SWF. When $\gamma \to 1, W = \prod_{i=1}^{N} U_i$ or $W = \prod_{i=1}^{N} Y_i$ i.e., the Bernoulli-Nash (Cobb-Douglas) SWF for total utility (or $\left[\prod_{i=1}^{N} U_i\right]^{\frac{1}{N}}$ or $\left[\prod_{i=1}^{N} Y_i\right]^{\frac{1}{N}}$ the geometric mean for average utility or income). When $\gamma = 1$ $W = \sum_{i=1}^{N} lnU_i$ or $W = \sum_{i=1}^{N} lnY_i$, the SWF treats equal proportional increases in utility, income or consumption equally across countries/individuals. That is, the SWF $W = \sum_{i=1}^{N} lnU_i$ treats an x% increase for the poorer country the same as for a better-off country. When $\gamma > 1$, the SWF treats an x% increase for the poorer country as more welfare increasing than x% for the better-off country. As γ increases toward infinity (the Rawls SWF), small increases in income or utility for the worst-off get weighted much more than large increases in income or utility. In the limit, the Rawlsian case, increases in income or utility for the better-off do not impact welfare.

9. The parameter γ, is as noted above, $\gamma = -U\frac{\partial^2 W(U)/\partial U^2}{[\partial W(U)/\partial U]}$, where $\partial^2 W(U)/\partial U^2$ reflects the rate at which the marginal social utility declines with higher levels of utility and $\partial W(U)/\partial U$ is marginal social utility or the change in social welfare with a change in utility. The parameter γ indicates the amount by which welfare declines with an increase in income, i.e., the relative inequality aversion. The higher γ is, the higher the relative aversion to inequality in utilities. The higher γ is, the faster the rate of proportional decline in welfare to a proportional increase in income (or utility). γ captures the extent to which the

social planner wants to place higher values on monetary gains accruing to various countries, i.e., the inequality-aversion coefficient captures the moral/ethical principles of a social planner who prefers to give some priority to utility changes affecting worse-off countries rather than simply aggregating utilities in a utilitarian manner.

10. The relative inequality aversion parameter γ is related to the elasticity for the social marginal welfare of income $\eta = \varepsilon + \gamma(1-\epsilon).\eta$ is a function of two parameters, the coefficient of relative inequality aversion γ and elasticity of the private marginal utility of income (or consumption) ε. The elasticity for the social marginal welfare of income, which is assumed to be the same for every country's income, is defined as: $\eta = -Y_i \frac{\frac{\partial^2 W(Y)}{\partial Y_i{}^2}}{\frac{\partial W(Y)}{\partial Y_i}}$. The elasticity for the social marginal welfare of income η indicates the concavity of the composite function $W(Y)$ with respect to its argument, income γ and the overall social preference for income redistribution. η contains both the relative risk aversion parameter ε and relative inequality aversion parameter (both intra- and inter-generationally) γ, and is thus a mixture of risk aversion and ethical values. However, usually only one parameter is used, intra-generational distribution, so that relative risk aversion and inter-generational income distribution are implicitly held constant.

11. Atkinson's inequality index is predicated upon the concept of Equally Distributed Equivalent (EDE) income. EDE is that level of income that, if obtained by every individual in the income distribution, would enable the society to reach the same level of welfare as actual incomes.

12. The EDE level of income GNI_{EDE} is the level of per capita income which, if equally distributed, would give the same level of social welfare as the present distribution. The Atkinson Inequality Index $A\gamma$ is then defined as:

$$A_\gamma = 1 - \frac{GNI_{EDE}}{\overline{GNI}},$$

where $GNI_{EDE} = \left[\frac{1}{N}\sum_{i=1}^{N} GNI_i^{1-\gamma}\right]^{\frac{1}{1-\gamma}}$ and GNI i.e., the arithmetic mean of GNI.

Using the explicit formula for the iso-elastic social welfare function and substituting the terms just defined gives:

$$A_\gamma = 1 - \left[\frac{1}{N}\sum_{i=1}^{N} \left[\frac{GNI_i}{\overline{GNI}}\right]^{1-\gamma}\right]^{\frac{1}{1-\gamma}}$$

When $\gamma = 1$, $GNI_{EDE} = \prod_{i=1}^{N} GNI_i^{\frac{1}{N}}$, i.e., the geometric mean of GNI. When $\gamma = 1$, then

$$A_\gamma = \frac{\prod_{i=1}^{N} GNI_i^{\frac{1}{N}}}{\sum_{i=1}^{N} GNI_i},$$

or, in words, the ratio of the geometric mean of GNI to the arithmetic mean of GNI.

Appendix 8: Additional allocations: indivisible goods and the priority principle[121]

1. ISA may decide to use DSM royalties for purposes other than direct distribution to ISA States parties. Such purposes could entail, for example, projects to mitigate adverse environmental impacts or build scientific capacity through funding scientific research and scientific institutions. These alternative uses represent competing claims for the DSM royalties.

2. Principles of fairness and equity can also be applied to these other ISA distribution questions. Allocating funds among competing claims or uses, such as projects, can invoke fair and equitable division of the

[121] This Appendix draws directly from Young (1994).

DSM royalties among indivisible, multiple and heterogeneous claims or uses. This case contrasts with the distribution of DSM royalties among States parties representing the global population in which all persons have an equal claim upon the homogeneous and perfectly divisible royalties (a single "good" to be allocated) and which inherently can be cardinally measured for entitlement through a common metric. The parties no longer have equal claim upon the heterogenous projects or other uses, simple metrics to measure differences in entitlements are no longer available, and Aristotle's proportionality principle no longer applies.

3. Moreover, the allocation system for new projects can have distorting incentive impacts on the claimants' behaviour. The incentive impacts are an important consideration when the claims are generated by voluntary action. One impact is multiple claimants consolidating their claims to increase their total claim and/ or increase influence over the allocation. A collusion-proof claims allocation rule is one that arises if consolidating the claims of several individuals into one claim does not change the total amount these claimants receive. Aristotle's proportionality principle is the unique allocation rule that is impartial and collusion-proof. Another impact arises if the claims represent assertions by the claimants about how much they deserve. Under the proportionality principle, there is an incentive to inflate one's claim as much as possible. What is desired is an allocation formula that does not incentivize splitting or consolidating claims among various groups of claimants. The allocation rule should ensure that claimants are motivated to behave in a manner that is consistent with the optimal solution by revealing and acting according to their true preferences, i.e., is incentive compatible.

4. The fair division problem with multiple, indivisible and heterogenous claims revolves around how differences in claims (uses of the DSM royalties) should be evaluated. The projects (claims) are no longer perfectly divisible, and instead are lumpy and indivisible. The uses (claims) are no longer homogeneous, but instead differ and are thereby heterogeneous. The claims are no longer a single use – distribution of DSM royalties to ISA States parties – but rather multiple uses. A simple metric of funds (US$) allocated to each State party no longer exists, since each project has its own merit that might be defined and measured in different ways, some of which cannot even be directly measured and quantified by some cardinal measure, but rather by an ordinal measure (a cardinal number indicates how many of something there are, or describes the quantity, such as one, two or three, and an ordinal number specifies the relative position of something on a list or sequence, such as first, second or third).

5. Decisions in these circumstances can be made by developing lists of objective criteria to make comparative judgments. Each priority list captures a notion of equity based upon priority rather than the Aristotelian concept of proportionality. Aristotle's proportionality principle simply does not apply when a claimant can either receive funding or not (the claims are indivisible). Priority is an ordinal rather than cardinal principle since priority does not indicate the amount by which one deserving claimant is preferred to another – by how much more one claiming is deserving to another. Instead, priority simply indicates that one claimant (use of DSM royalties to fund a project – a claim) is preferred to another, whereas the proportionality principle can indicate how much more of the good (DSM royalties) one claimant receives compared to another.

6. Fairness in the priority case becomes a question of designing a procedure for dividing the DSM royalties among competing indivisible and heterogeneous claims for the royalties that strikes an

equitable balance among diverse points of view and that the claimants believe to be visibly fair. Equity principles become the instruments by which States parties resolve the distributive bargains by establishing a plausible and justifiable basis for the agreement. Equity and fairness then coordinate the expectations of States parties to establish a plausible basis for agreement. Equitable ways exist (reviewed in Appendix 6) to aggregate individual opinions into a consensus, called the opinion aggregation or social choice problem. Such aggregation occurs through giving weights – relative rankings – to individual criterion to provide an aggregate ranking or score, as discussed in Appendix 6.

7. The concept of equity and fairness in this case becomes the priority principle. The priority principle requires that allocations among competing claims are made based upon a predetermined ranking of claimants (here use of the DSM royalties among competing projects or uses) – creating a priority or claims list. The claimants are not treated equally, but rather in most situations some claimants will have a stronger a priori claim on the good in question than other claimants do. The relative strengths of a claim depend upon various observable characteristics. This approach establishes priority among competing uses, ordered from highest to lowest priority, based upon a mixture of prioritized mixture of criteria and various equity principles, including compensation, reward, fitness and even voting rules (e.g., Borda, Condorcet). Each individual criterion is weighted to give a total score that ranks alternatives and a standard of comparison. This approach is widely used, for example, to allocate organ transplants such as kidneys. Points systems are one method to score the criteria or attributes and prioritize allocation when there is no complementarity between the attributes that is not captured by the points system.

8. If the claimant types are evaluated in a finite number of attributes, and there are a finite number of distinct types of claimants, then a points system represents a priority method if and only if the priority relation is separable. The priority method can be deterministic or stochastic.

9. The priority principle requires two additional principles of equity, impartiality and consistency, in the criteria used to prioritize claims. An allocation criterion is impartial if the solution depends only upon the description or type of the claimants (projects, uses) in several dimensions or attributes and the total quantity of the good (here funds) to be distributed. For example, a quantity of DSM royalties might be allocated among competing research projects or institutes that can be characterized by some commonly agreed upon dimensions or attributes. Consistency requires that distinctions according to type should be consistently made. An allocation criterion is pairwise consistent if the decision between two claims is always made the same way independently of the other claimants present and how much they receive. The other claimants may affect the number of units the two claimants have to share or to be allocated to them, but it does not determine how the claimants share the amount to be distributed. A standard of comparison is then a list of all types of claimants (projects, uses), ordered from highest to lowest priority. The priority principle can also satisfy the equity principle of resource monotonicity, which states that no individual loses from an increase in resources.

10. In sum, priority methods consistently, impartially and with resource monotonicity allocate the DSM royalties over the different indivisible claimants based upon multi-dimensional criteria or attributes that assess each claimant's situation. The claimant with the greatest claim deterministically receives the "good" over other claimants (projects, uses, impacts). The priority principle is

particularly applicable when there are indivisible, heterogeneous, multiple claims and simple metrics to measure differences in entitlements are unavailable, since each claim has its own merit defined cardinally or ordinally and measured in different ways. Using relative rather than absolute ranking of welfare levels, the priority principle in some sense approximates egalitarianism rather than prioritarianism.

11. The priority method by itself (as discussed above) is an ordinal rather than cardinal principle since priority does not indicate the amount by which one deserving claimant or claim is preferred to another. The priority index PI_i when ranked, creates an ordinal measure. PI_i can be left in original units or normalized on the maximum value giving $0 \leq PI_i \leq 1$.

12. Multiple weighted priorities can be geometrically aggregated to provide PI_i, which could be used as a non-welfarist (not depending upon utility) distribution weight $\omega_i'' = PI_i = \prod_{j=1}^{M} PI_{ij}^{\beta j}$, β_j weights PI_{ij}, $0 < \beta_j < 1$, $\beta_j \sum_{j=1}^{M} \beta_j = 1$ (linear homogeneity for consistency in aggregation), and geometric mean if $\beta_j = \beta_k = \beta_j = \beta_k = \frac{1}{M}$, $j \neq k$, $\forall j,k \varepsilon M$. PI_i can be constructed in single or multiple stages, requiring consistency in aggregation.[122] The geometric aggregator function $PI_i = \prod_{j=1} PI_{ij}^{\beta j}$ is exact Cobb-Douglas and can be viewed as a first-order approximation to any arbitrary function in the neighbourhood of initial PI_{ij} values. Weights β_j can vary[123] and face issues.[124]

13. The geometric index readily utilizes different sorts of differently scored data, since it is indifferent to the scales used, as long as the same ones are used each time. It gives diminishing returns to PI_i for one-unit increases in PI_{ij}, since $0 < \beta_j < 1$. . It satisfies a number of desirable index number properties ("tests").[125] Other index numbers or aggregator functions give distributions varying in relative inequality aversion, e.g., Atkinson's or superlative indices.[126] Linear, additive indices are not scale-invariant and give perfect substitution between PI_{ij}.

Appendix 9: Review of organizations

UNEP – United Nations Environment Programme

Objective:
Mission is to provide leadership and encourage partnership in caring for environment by inspiring, informing and enabling nations and people to improve quality of life without compromising that of future generations.

Key features:
Works mainly to offer advice, coordinate and enhance funding for projects. Works with member countries, possibly joining efforts on regional projects. Covers large number of areas in environmental protection. To be mentioned in the context of SSF: the UNEP Finance Initiative. This might be a potential partner for projects under SSF.

Link with ISA:
Not yet any meaningful activity in the ABNJ. Unclear who could sponsor projects in the Area.

Take-away:
- Sound financial management and control.
- Availability of extensive repository.
- Extensive evaluation practice following standard presentation and analysis

[122] Balk (2008).
[123] Seth and McGillivray (2018).
[124] Greco et al. (2019).
[125] Balk (2008).
[126] Atkinson (1970); Balk (2008).

tool for focus domains: Theory of Change (ToC).[127]
  - ToC helps design monitoring and learning related to interventions by making mental models and finding out the causal logic that underlies a specific intervention.
  - Very detailed, requires practice to use the tool/process.
- Well-developed and standardized business tools for project analysis and for evaluation: UNEP Environmental, Social and Economic Review Note (ESERN). This enables UNEP to anticipate and manage emerging environmental, social and economic issues.
- Special feature: The UNEP Finance Initiative (UNEP FI) is a global partnership established between UNEP and the financial sector.

GEF – Global Environment Facility

Objective:

Mobilize financial means in order to tackle major environmental challenges on a global scale, by partnering with 183 countries, international institutions, civil society organizations and private sector. Focus is on climate change mitigation.

Key features:

Established on the eve of the Rio de Janeiro Earth Summit (in 1992). GEF is a strategic partnership of 18 agencies (including UNEP) and is the only financial mechanism that serves a number of environmental conventions (such as UNFCCC, CBD, UNCCD and Stockholm Convention on POP).[128] The partnership with the agencies, themselves highly organized institutions, enables GEF to outsource technical work and increases GEF's global presence.

Link with ISA:

GEF approves US$ 27 million of US$ 700 million work programme (~0,4%) to FAO-led Common Oceans Program (in ABNJ) with an overall objective to "promote sustainable use of ABNJ living natural resources and strengthened biodiversity conservation in face of a changing environment".[129]

Take-away:

- Blended finance: GEF has a history of using non-grant instruments, such as debt, equity and guarantees, as blended finance in the area of climate change mitigation. In this way GEF creates leverage to mobilize private sector funds. GEF's experience has shown that blended finance is a potent instrument. In 2013–2014 GEF provided US$ 175 million for blended finance, mobilizing US$ 1.1 billion from the private sector.[130]
- STAP (Scientific and Technical Advisory Panel): independent advisory body to GEF Council and recognized part of GEF's structure. Provides strategic scientific and technical advice and builds networks with scientists. At the level of the organizational set-up, the use of agencies is a clever way of mobilizing resources of other institutions, see also national recognized partner or similar.
- IEO (Independent Evaluation Office): recognized part of GEF's structure. The IEO Director is accountable directly to the GEF Council for the work of the office. GEF follows a project of transformational change. It attempts to be self-learning. It states in one of its documents that it must continue to evolve.[131]

[127] Theory of Change Primer – 57th GEF Council Meeting (GEF/STAP/C057/Inf.04, 2019).
[128] Art. 21(3) UNFCCC; Art. 39 (CBD); Art. 20(2) UNCCD; Art. 14 (Stockholm Convention on Persistent Organic Pollutants).
[129] Common Oceans – Sustainable utilization and conservation of biodiversity in areas beyond national jurisdiction.
[130] http://www.thegef.org/topics/blended-finance.
[131] Delivering Transformational Change – The Journey of the Global Environment Facility, 2020.

GCF – Green Climate Fund

Objective:
Mobilize financial means to developing countries in order to reduce their greenhouse gas emissions and enhance their ability to respond to climate change.

Key features:
Established within framework of UNFCCC in 2010 during COP16 in Cancun. GEF and GCF are both financial mechanisms of Climate Convention. The difference is that in addition to climate adaptation, GCF funds climate mitigation-related activities. The aim is to deliver equal amounts to mitigation and adaptation activities.

GCF is unique because of its ability to engage directly with both public and private sectors in transformational climate-sensitive investments.

Working with accredited entities who partner with GCF to implement projects and submit funding proposals to GCF Board.

Link with ISA:
Funding projects covering seabed activity does not fall within GCF's objectives.

Take-away:
- Blended Finance: GCF offers a wide range of financial products including grants, concessional loans, subordinated debt, equity and guarantees. This enables it to match project needs and adapt to specific investment contexts, including using its funding to overcome market barriers for private finance.
- Independent Evaluation Unit (IEU): ensures GCF is accountable and open to continuous learning. Operates independently from the GCF Secretariat and instead reports directly to the Board. Work plan and budget are developed with advice from the GCF Board. Part of the core structure of the Fund.
- National Designated Offices (NDAs): provide country ownership. Government institutions that serve as interface between each country and GCF. NDAs provide strategic oversight of the GCF's activities in the country and communicate the country's priorities for financing.

CGIAR

Objective:
Ending hunger by 2030, through science to transform food, land and water systems in a climate crisis.

Key features:
Global partnership that unites international organizations engaged in research about food security.

Link with ISA:
Funding projects covering seabed activity does not fall within CGIAR's objective.

Take-away:
- Fragmented funding approach across three fund windows (W1: portfolio investments; W2: program investments and W3: project investments) plus bilateral contributions directly to specific projects at CGIAR Research Centers (outside the fund).
- Transition to "One CGIAR" as partnership of 15 independently operating Research Centers was becoming an obstacle. "One CGIAR" implies a unified management and governance.
- Desired shift to multi-year funding commitments with transition to One CGIAR. This enables multi-year allocations from CGIAR Trust Fund to projects (more reliable and predictable funding).

JPI Oceans

Objective:
Strives to increase the impact of national investments by aligning national priorities and implementing joint actions. An important role of JPI Oceans is to support development of effective policies with robust and independent scientific advice.

Key features:
JPI Oceans is a platform for alignment of national and regional research strategies and investments but does not have a dedicated programme budget. Platform is open to all EU Member States and Associated Countries who invest in marine and maritime research.

Link with ISA:
One of JPI Ocean's 10 Strategic Areas dedicated to "Exploring Deep Sea Resources". ISA receives scientific input for Exploitation Mining Code from JPI Oceans project "Mining Impact 2".

Take-away:
- Different tools to launch joint actions including joint calls, co-fund actions, joint public procurement, research alliances, knowledge hubs, bilateral agreements, shared research infrastructures (e.g., ship time) and supporting actions (e.g., organizing workshops).

IOC-UNESCO – Intergovernmental Oceanographic Commission

Objective:
Responsible for supporting global ocean science and services by enabling 150 Member States to work together by coordinating, planning and promoting programmes.

Key features:
Established in 1960 and recognized through UNCLOS. Body with functional autonomy within UNESCO.

Partners with various agencies and participates in joint programming where participating Member States offer resources and involvement.

Link with ISA:
Ocean Biodiversity Information System (OBIS) was adopted as a project under IOC-UNESCO's International Oceanographic Data and Information (IODE) programme in 2009. Creation of Deep-sea OBIS node (data portal), which aims "to provide a single integrated access point to high-quality data and information on the diversity, abundance and distribution of all deep-sea organisms and their ecosystem properties, including habitat and environmental characteristics".[132]

The development of the data portal is a shared responsibility. This is something that ISA could contribute to.

Take-away:
- Success stories on a big scale, e.g., Global Tsunami Warning Network.
- Ocean Teacher Global Academy: platform providing web-based training, covering a range of topics related to the IOC programmes, and supports both face-to-face learning (in regional and specialized training centres), blended training as well as online training.
- Detailed Capacity Development Strategy (2015–2021)[133] highlighting capacity development as the primary catalyst by which IOC will achieve its objectives.

[132] https://obis.org/node/6f3223e3-50a6-4ba5-b02c-0037ae3863ce.
[133] IOC Capacity Development Strategy, 2015-2021.

Box: Mining impact 2 (2018–2022): national funding provided under framework of JPI Oceans

- Studies environmental impacts and risks of deep-sea mining (observed during industrial trial by DEME-GSR). Aim is to deliver independent scientific input into the Exploitation Mining Code currently developed by ISA.
- Multi-national, interdisciplinary consortium of 30 partners from 9 EU countries and ISA.
- Project has its own project office with executive board reporting to JPI Oceans, steering committees and a general assembly.

ICCAT – International Commission for the Conservation of Atlantic Tunas

Objective:
Responsible for conservation of tunas and tuna-like species in the Atlantic Ocean and adjacent seas.

Key features:
Intergovernmental organization, in force since 1966.

Link with ISA:
Projects covering seabed activity do not fall within ICCAT's objective.

Take-away:
- Meeting Participation Fund: allows scientists from developing countries to attend scientific meetings and to become part of the scientific community. Financed by Working Capital Fund (250,000 euros in 2015) and voluntary contributions by contracting parties (e.g., EU from its Fund for Capacity Building).
- Performance evaluation exercise undertaken every five years (effort by all Tuna RFMO). In case of ICCAT done by independent three-person Performance Review Panel (legal, scientific and fisheries management expert). Regular follow-up of the recommendations.

ISSF – International Seafood Sustainability Foundation

Objective:
Undertake science-based initiatives for the long-term conservation and sustainable use of tuna stocks, reducing bycatch and promoting ecosystem health.

Key features:
Non-profit partnership among the tuna industry, scientists and WWF. Provides RFMO's with scientific recommendations and helps nations combat and monitor illegal and unregulated fishing.

Link with ISA:
Projects covering seabed activity do not fall within ISSF's objective.

Take-away:
- Membership fees form largest part of budget. Application fee of US$ 50,000 and annual dues between US$ 100,000 and 600,000 (calculated based on tuna revenue) for full membership.

CCAMLR – Commission for the Conservation of Antarctic Marine Living Resources

Objective:
Conserving Antarctic marine life. Conservation includes rational use.

Key features:
Established by international convention in 1982 in response to increasing commercial interest in Antarctic krill resources.

Link with ISA:
There has been discussion if a CHM regime would be better to protect the Antarctic environment. Currently the Antarctic Treaty System is in place.

Take-away:
- CCAMLR Scientific Scholarship Scheme: open to scientist of all CCAMLR members.
- Non-compliance in most cases caused by non-Members. Membership is important tool to ensure compliance.
- Funding and scientific input mainly originate from relatively small number of Member States.

Oil Pollution Compensation Fund

Objective:
Offer a compensation to victims of oil spills.

Key features:
- Intergovernmental organization providing compensation for oil pollution damage resulting from spills of persistent oil from tankers.
- Financed by contributions paid by entities that receive crude or heavy fuel oil by sea transport. Contributions are based on amount of oil received in the relevant calendar year. Expected claims and costs of administering the fund are covered.

Link with ISA:
Theoretically seabed activity could be covered, but unsure who could claim the damages if pollution is in the ABNJ.

Take-away:
- May be a source of inspiration for procedures.

WHO – World Health Organization

Objective:
Improving the health of the world population. This is specified in concrete objectives at programme level (e.g., protection against emergencies, enjoying better health for 1 billion extra people, 2021 improving health coverage).

Key features:
Directing and coordinating authority on international health within the United Nations system.

Link with ISA:
Projects covering seabed activity do not fall within the WHO's objective.

Take-away:
- Member States are grouped into six regions, with each region having a regional office. WHO makes big efforts to establish local presence.
- WHO's performance on outputs is summarized by a balanced scorecard that shows scores for six dimensions. Can be used at each level of the organization.
- WHO Academy: state-of-the-art training centre for lifelong learning for global health sector. It will consist at the beginning of an online learning experience platform (from May 2021 onwards) and later on this will be extended to onsite training at a campus in France (~2023) and at regional facilities around the world.

UN Joint Staff Pension Fund

Objective:
Fund covers entitlements of UN staff and staff of associated organizations which are admitted as members in the fund for retirement, death, disability and other types of benefits. The fund serves more than 200,000 people.

Key features:
Established in 1949 by a resolution of the UN General Assembly.

Link with ISA:
ISA is an associated organization of the fund since 1998.

Take-away:

- Good example of how common financial wealth can be managed efficiently.
- Active investor policy following ESG considerations.
- Leverage through power of portfolio (proxy voting and engagement).
- Possibility for SSF to associate with Pension Fund to manage the portfolio or Pension Fund could perform advisory service for SSF.

Appendix 10: User manual for web-based model

bit.ly/dsm-distribution-model

Overview

The model is designed to support ISA Technical Study 31 by enabling the user to review and evaluate the impact of alternative formulae for fair and equitable allocation of a notional sum of royalties available for distribution.

In the model, the three alternative formulae are named as follows:

- Original functional form (formula proposed in July 2019 report presented to Finance Committee).
- Original form with floor and ceiling (same formula but applying the floor and ceiling as proposed in April 2020).
- Geometric mean functional form (as explained in Part IV of the present report the geometric mean is a better way of constructing composite indices when utilizing different sorts of date and increases the overall equity of the distribution).

For comparison purposes, the model also outputs the results of distributions using unweighted population shares, equal division and equal population weights.

These are not presented as a basis for equitable distribution, but simply as a point of comparison.

Usage – Country and Group Outcome Comparisons

The tab **Country_comparison** is the primary product. It asks for a few basic model parameters (in orange boxes) which are pre-filled with default options listed in the report.

The user chooses:

- Country selection (dropdown list).
- Elasticity of marginal utility of consumption (η) which is estimated to a value of 1 in the report (dropdown values from 0.5 to 2).
- Share floor which is 0.001%.
- Model share ceiling is based on 22% but maximum ISA share is 16.31% as of 2021.
- A hypothetical pay-out, $500 million is hypothesised, but dropdown values from $250 million to $1 billion are allowed.
- The Atkinson inequality parameter which is usually 1 (dropdown values of 0.5, 1, and 2).

The model output:

- A country's relevant demographics including the resulting GNI-based distribution weight.
- Expected distribution shares under 3 proposed distribution functional forms and 3 comparison forms.
- Total and per capita pay-outs for the selected hypothetical total pay-out.
- The group's Gini coefficient and Atkinson inequality index under each distributional form.
- Lorenz curves under each distributional form.

Data – Primarily World Bank and UN Data

All calculations are based on 5-year averages, 2015–2019, of population and *GNI* data unless otherwise noted. The data are also available from the World Bank, United Nations and other sources.

REFERENCES

Acemoglu, Daron and James A. Robinson. *Why nations fail, the origins of power, prosperity and poverty*. London: Profile Books Ltd., 2012.

Adler, M. "Benefit-Cost Analysis and Distributional Weights: An Overview". *Review of Environmental Economics and Policy* 10, no. 12 (2016): 264–285.

Adler, Matthew D. *Well-Being and Fair Distribution: Beyond Cost-Benefit Analysis*. Oxford: Oxford University Press, 2012.

Adler, Matthew D. *Measuring Social Welfare: An Introduction*. Oxford: Oxford University Press, 2019.

Alesina, Alberto and George-Marios Angeletos. "Fairness and Redistribution: US vs. Europe." American Economic Review 95 (2005): 913-35.

Aristotle. *Nicomachean Ethics*. Oxford: Oxford University Press, 2009.

Asheim, G.B. "Inter-Generational Equity". *Annual Review of Economics* 2 (2010): 197-222.

Atkinson, Anthony B. "On the Measurement of Inequality". *Journal of Economic Theory* 2 (1970): 244–263.

Atkinson, Anthony B. and François Bourguignon. *Handbook of Income Distribution*. Amsterdam: North-Holland, 2015.

Balk, B. *Price and Quantity Index Numbers*. Cambridge: Cambridge University Press, 2008.

Bellù, L. G. and P. Liberati. *Social Welfare Analysis of Income Distributions: Ranking Income Distributions with Lorenz Curves*. Rome: Food and Agriculture Organization of the United Nations, 2005. Available at (accessed January 23, 2020): http://www.fao.org/3/a-am390e.pdf

Bellù, L. G. and P. Liberati. *Describing Income Inequality: Theil Index and Entropy Class Indexes*. Rome: Food and Agriculture Organization of the United Nations, 2006. Available at (accessed January 23, 2020): http://www.fao.org/3/a-am343e.pdf

Bellù, L. G. and P. Liberati. Inequality Analysis: *The Gini Index*. Rome: Food and Agriculture Organization of the United Nations, 2006. Available at (accessed January 23, 2020): http://www.fao.org/docs/up/easypol/329/gini_index_040en.pdf

Bellù, L. G. and P. Liberati. *Welfare Based Measures of Inequality: The Atkinson Index*. Rome: Food and Agriculture Organization of the United Nations, 2006. Available at (accessed January 23, 2020): http://www.fao.org/3/am344e/am344e.pdf

Blackorby, C., D. Premont and R. R. Russell. *Duality, Separability, and Functional Structure*. New York: North-Holland Publishing Company, 1976.

Boadway, R. and N. Bruce. *Welfare Economics*. Oxford: Basil Blackwell, 1984.

Brams, S. J. and A. D. Taylor. *Fair Division – From Cake-Cutting to Dispute Resolution*. Cambridge University Press, 1996.

Chircop, Aldo and Bruce Marchand. *International Royalty and Continental Shelf Limits: Emerging Issues for the Canadian Offshore,* Canadian Petroleum Law Association seminar, September 2003.

Cowell, F. A., and K. Gardiner. "Welfare Weights". Suntory and Toyota International Centres for Economics and Related Disciplines, London School of Economics, 1999. Available at (accessed 28 July 2021): http://darp.lse.ac.uk/papersDB/Cowell-Gardiner_(OFT).pdf

Cowell, Frank A. "Measuring Inequality". Oxford University Press, 2009. Available at (accessed 23 January 2020): http://darp.lse.ac.uk/papersdb/Cowell_measuringinequality3.pdf

d'Aspremont, C. and L. Gevers. "Social Welfare Functionals and Interpersonal Comparability". In *Handbook of Social Choice and Welfare Vol. 1*, edited by K. Arrow, A. Sen and K. Suzumura, 459–541. Amsterdam: Elsevier Science, 2002.

de Borchgrave, S. *Marine genetic resources in ABNJ: common heritage of mankind or not?* ULB, 2019.

Dietz, S., C. Hepburn and N. Stern. "Economics, Ethics, and Climate Change", 2008. Available at SSRN: https://ssrn.com/abstract=1090572 or http://dx.doi.org/10.2139/ssrn.1090572

Drèze, J. and N. Stern. "Policy Reform, Shadow Prices, and Market Prices". *Journal of Public Economics* 42 (1986): 1–45.

Drèze, J. and N. Stern. "The Theory of Cost-Benefit Analysis". In *Handbook of Public Economics*, Vol. 2, edited by A. J. Auerbach and M. Feldstein, 909–989. Amsterdam: North-Holland, 1987.

Ecorys, Finance for Impact, Pescares and Habile. *Unsustainable Finance in the Blue Economy: Where Does the Money Come From?* European Commission, 2020.

Evans, D. "The Elasticity of Marginal Utility of Consumption: Estimates for 20 OECD Countries". *Fiscal Studies* 26, no. 2 (2005):197–224.

Evans, D., E. Kula and H. Sezer. "Regional Welfare Weights for the UK: England, Scotland, Wales and Northern Ireland". *Regional Studies* 39, no. 7 (2005): 923–937.

Fehr, Ernst, and Klaus M. Schmidt. "A Theory of Fairness, Competition, and Cooperation." *The Quarterly Journal of Economics* 114, no. 3 (1999): 817-68. Accessed July 30, 2021. http://www.jstor.org/stable/2586885

Fleming, Philip J. and John J. Wallace. "How not to lie with statistics: the correct way to summarize benchmark results". *Communications of the ACM*. 29, no. 3 (1986): 218–221. doi:10.1145/5666.5673

Fleurbaey, M. and F. Maniquet. "Optimal Income Taxation Theory and Principles of Fairness". CORE Discussion Paper, 2017. 85 pages.

Fleurbaey, M. and R. Abi-Rafeh. "The Use of Distributional Weights in Benefit-Cost Analysis: Insights from Welfare Economics". *Review of Environmental Economics and Policy* 10, no. 2 (2016): 286–307.

Foley D. "Resource Allocation and the Public Sector". *Yale Economic Essays* 7 no. 1 (1967): 45–98.

Freeman, M., B. Groom and Zachary M. Turk. "A Study to Determine the Appropriate Social Discount Rate for the International Seabed Authority". Kingston: International Seabed Authority, 2020. Available at: https://isa.org.jm/files/files/documents/Freeman%20Groom%20and%20Turk%20%282020%29%20Social%20Discount%20Rates%20-%20Post%20Review.pdf

Greco, S., A. Ishizaka, M. Tasiou and G. Torrisi. "On the Methodological Framework of Composite Indices: A Review of the Issues of Weighting, Aggregation, and Robustness". *Social Indicators Research* 141, no. 1 (2019): 61–94.

Groom, B. and M. Freeman. "New Estimates of the Elasticity of Marginal Utility for the UK". *Environmental and Resource Economics* 72 (2019): 1155–1182.

Harberger, A. C. "On the Use of Distributional Weights in Social Cost-Benefit Analysis". *Journal of Political Economy* 86, no. 2, pt. 2J (1978): S87–S120.

Harberger, A. C. "On the Use of Distributional Weights in Social Cost-Benefit Analysis: Reply". *Journal of Political Economy* 88 (1980): 1050–52.

Harberger, A. C. "Basic Needs versus Distributional Weights in Social Cost-Benefit Analysis". *Economic Development and Cultural Change* 32, no. 3 (1984): 455–474.

Harrison, M. "Addressing Wellbeing in the Long-Term: A Review of Intergenerational Equity and Discount Rates in Climate Change Analysis". In *Measuring and Promoting Wellbeing: How Important is Economic Growth? Essays in Honor of Ian Castles and A Selection of Castle's Papers*, edited by A. S. Podger and D. Trewin, 629–661. Canberra: Australian National University, 2014.

Härdle, W. Applied Nonparametric Regression. Econometric Society Monographs. Cambridge: Cambridge University Press, 1990.

Heffernan, O. "Deep-Sea Dilemma - Mining the ocean floor could solve mineral shortages, and lead to epic extinctions in some of the most remote ecosystems on Earth". *Nature* 571 (2019): 465–468.

Holtug, N. "Prioritarianism". In *Egalitarianism: New Essays on the Nature and Value of Equality*, edited by N. Holtug, and L. Lippert-Rasmussen, 125–156. Clarendon Press, 2006.

International Seabed Authority. *Implementation of Article 82 of the United Nations Convention on the Law of the Sea: report of the International Workshop convened by the International Seabed Authority in collaboration with the China Institute for Marine Affairs in Beijing, the People's Republic of China, 26-30 November 2012*. Kingston: International Seabed Authority, 2013.

International Seabed Authority. *Key findings of the assessment of the Contractor Training Programme*. Kingston, Jamaica: International Seabed Authority, 2020.

Kaplow, L. "Discounting Dollars, Discounting Lives: Intergenerational Distributive Justice and Efficiency". (Working Paper 12239, National Bureau of Economic Research, Washington, D.C., 2006). Available at (accessed December 12, 2019): https://www.nber.org/papers/w12239.pdf

Kaplow, L. "Concavity of Utility, Concavity of Welfare, and Redistribution of Income". *International Tax and Public Finance* 17 no. 1 (2010): 25–42.

Lemaître, M. "Fair Sharing of Earth Observing Satellite Resources Pleiades System". (FairDiv Summer School, Grenoble, France, July 15, 2015). Available at (accessed December 4, 2018): http://research.illc.uva.nl/COST-IC1205/documents/Grenoble-2015-Slides/Lemaitre.pdf

Lemaître, M., G. Verfaillie, H. Fargier, J. Lang, N. Bataille and J.-M. Lachiver. « Equitable Allocation of Earth Observing Satellites Resources". Available at (accessed December 4, 2018): ftp://ftp.irit.fr/IRIT/ADRIA/PapersFargier/odas03

Little, I. M. D. and J. A. Mirrlees. *Project Appraisal and Planning for Developing Countries*. London: Heinemann Educational, 1974.

Lodge M., Segerson K. and Squires D. "Environmental Policy for Deep Seabed Mining". In *Environmental Issues of Deep-Sea Mining: Impacts, Consequences and Policy Perspectives* edited by Rahul Sharma. Springer, 2019.

McIntyre, O. "Utilization of Shared International Freshwater Resources – The Meaning and Role of 'Equity' in International Water Law". *Water International* 38 (2013): 112–129.

Mirrlees, J. A. "Social Benefit-Cost analysis and the Distribution of Income". *World Development* 6 (1978): 131–38.

Moulin, H. *Axioms of Cooperative Decision Making*. Cambridge University Press, 1988.

Moulin, H. *Cooperative Microeconomics, A Game-Theoretic Introduction*. Prentice Hall, 1995.

Moulin, H. *Fair Division and Collective Welfare*, Cambridge: M.I.T. Press, 2003.

Nicola, P. C. *Efficiency and Equity in Welfare Economics*. Lecture Notes in Economics and Mathematical Systems 661. Berlin, Heidelberg: Springer-Verlaag, 2013. DOI 10.1007/978-3-642-30071-4 2.

Nordquist, Myron, Satya Nandan and Shabtai Rosenne, eds. *United Nations Convention on the Law of the Sea, 1982: A Commentary, vols. I-VII*. Dordrecht, The Netherlands: Brill Nijhoff, 1985–2011.

Okereke, C. "Global environmental sustainability: Intragenerational equity and conceptions of justice in multilateral environmental regimes". *Geoforum* 37 (2006): 725–738.

Parfit D. "Equality or priority?" The Lindley Lecture. University of Kansas, November 21, 1991. Kansas: University of Kansas, 1991. Reprinted in *The Ideal of Equality* edited by M. Clayton and A. Williams. St. Martin's Press, 2000.

Pitt, J., J. Schaumeier, D. Busquets, and S. Macbeth. "Self-Organising Common-Pool Resource Allocation and Canons of Distributive Justice". *IEEE* (2012): 119–128.

Rawls, J. *A Theory of Justice*. Oxford: Oxford University Press, 1972.

Ray, A. *Cost-Benefit analysis: Issues and Methodologies*. Baltimore: Johns Hopkins University Press, 1984. Available at: http://documents.worldbank.org/curated/en/110261468767097509/pdf/multi-page.pdf

Roemer, J. *Theories of Distributive Justice*. Cambridge: Harvard University Press, 1996.

Rossi, S. "Energy and Matter from the Sea". In Sergio Rossi, *Oceans in decline*, 307–310. Springer, 2010.

Saez, E. "Using Elasticities to Derive Optimal Income Tax Rates". *Review of Economic Studies* 68 (2001): 205–220.

Saez, Emmanuel. "Generalized Social Marginal Welfare Weights for Optimal Tax Theory". *American Economic Review* 106, no. 1 (January 2016): 24–45.

Sen A. K. *On Economic Inequality*. Oxford: Oxford University Press, 1997.

Seth S. and M. McGillivray. "Composite indices, alternative weights, and comparison robustness". *Social Choice and Welfare* 51 (2018): 657–679.

Soltau, F. *Fairness in International Climate Change Law and Policy*. New York: Cambridge University Press, 2009.

Squire, L. and H. G. van der Tak. *Economic Analysis of Projects*. Baltimore: Johns Hopkins University Press, 1975. Available at: http://documents.worldbank.org/curated/en/954731468156870423/pdf/794880PUB0Econ00Box377372B00PUBLIC0.pdf

"Economics and Economic Justice". Stanford Encyclopaedia of Philosophy, 9 June 2009. Available at: https://stanford.library.sydney.edu.au/archives/sum2010/entries/economic-justice/

Thomson, W. "Fair Allocation Rules". In *Handbook of Social Choice and Welfare* Vol. 2, 393–506. Elsevier, 2011. Available as: Thomson, W. "Fair Allocation Rules". Working Paper 539, Rochester Centre for Economic Research, 2007. Available at: http://idei.fr/sites/default/files/medias/doc/conf/ere/papers_2009/thomson-paper.pdf

Thomson, W. and H. Varian. "Theories of Justice Based on Symmetry". In *Social Goals and Social Organization* edited by L. Hurwicz, D. Schmeidler and H. Sonnenschein, 107–129. Cambridge: Cambridge University Press, 1985.

United Nations General Assembly Resolution 2749 (XXV), *Declaration of Principles Governing the Sea-bed and Ocean Floor and the Subsoil Thereof, beyond the Limits of National Jurisdiction* (17 December 1970).

United Nations General Assembly, Committee on the Peaceful Uses of the Sea-bed and the Ocean Floor Beyond the Limits of National Jurisdiction, *Possible Methods and Criteria for the Sharing by the International Community of Proceeds and Other Benefits Derived from the Exploitation of the Resources of the Area Beyond the Limits of National Jurisdiction*, A/AC.138/38 (1971).

United Nations, *Agreement relating to the Implementation of Part XI of the United Nations Convention on the Law of the Sea of 10 December 1982, 28 July 1994,* A/RES/48/263 (17 August 1994).

United Nations Convention on the Law of the Sea, Montego Bay, 10 December 1982. In force 16 November 1994, 1833 UNTS 397.

Van Poppel, J. "De diepzee is straks een industriegebied zonder dat we weten wat daar left". *De Correspondent*, 19 October 2020.

Varian, H. "Equity, Envy, and Efficiency". *Journal of Economic Theory* 9 (1974): 63–91.

Vartia, Y. O. "Relative Changes and Economic Indices". Licentiate thesis, Univ. Helsinki, 1974.

Vartia, Y. O. *Relative Changes and Index Numbers*. Helsinki: Research Institute of the Finnish Economy, 1976.

Weymark, J. A. "Social Welfare Functions". In *The Oxford handbook of Well-Being and Public Policy* edited by Matthew D. Adler and M. Fleurbaey, 126–159. New York: Oxford University Press, 2016.

Young, P. *Equity: How Groups Divide Goods and Burdens Among Their Members*. Princeton: Princeton University Press, 1994.

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