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Global Environmental Studies

目　次

〈特集〉

ソフィアシンポジウム
「SDGsの実現に向けて：森の生態系サービスを生かした持続可能な地域づくり」概要について
…… 柴田晋吾（１）

地球規模の政策目標を達成するための地域的アプローチ
…… ピーター ベッソー（５）

森林カーボンオフセットプロジェクトの動機：
カリフォルニア・カーボンオフセット市場における環境社会的コ・ベニフィットの実証
…… エリン クロバー ケリー・マリサ ボンジョバンニ シュミッツ・アリール ワイスグロー（21）

「生態系サービスへの支払い」（PES）により持続可能な地域づくりを目指す
―タイにおける取り組みから
…… 柴田晋吾（39）

〈論文〉

福島第一原発建屋内のたまり水の放射性汚染状況の解析（5）
…… 大坪国順（49）

環境ラベリング制度と持続可能な開発目標（SDGs）の正の関連性の検討
…… 蔡慧穎・鈴木政史（67）

持続可能な開発目標と家族政策―育児休業制度の効果―
…… 平尾桂子（77）

並列均衡と交換経済 …… 鷲田豊明（95）

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Global Environmental Studies

CONTENTS

Sophia Symposium 2018

"Sustainable Regional Development to Achieve UN SDGs by Utilization of Forest's Ecosystem Services"
..... Shingo Shibata (1)

Regional approaches to Achieving Global Policy Objectives
..... Peter Besseau (5)

MOTIVATIONS FOR CREATING FOREST OFFSET PROJECTS: EVIDENCE OF ENVIRONMENTAL AND SOCIAL CO-BENEFITS UNDER THE CALIFORNIA CAP-AND-TRADE CARBON MARKET
..... Erin Clover Kelly, Marissa Bongiovanni Schmitz and Ariel Weisgrau (21)

Pursuing Sustainable Regional Development Through "Payment for Ecosystem Services" (PES) -Implementation Status in Thailand
..... Shingo Shibata (39)

Articles

Analysis of time variations of radioactive substances in the ponding water in the main buildings of the Fukushima Daiichi Nuclear Power Plant (5)
..... Kuninori Otsubo (49)

Exploring Positive Implications of Eco-labeling Schemes on Sustainable Development Goals
..... Huiying Cai, Masachika Suzuki (67)

Families and SDGs Goal 5:
Parental Leave Policies and Gender Equality
..... Keiko Hirao (77)

Parallel Equilibrium and Exchange Economy
..... Toyoaki Washida (95)

Sophia University

特集

ソフィアシンポジウム：
「SDGsの実現に向けて：森の生態系サービスを生かした持続可能な地域づくり」

Sophia Symposium 2018:
“Sustainable Regional Development to Achieve UN SDGs by Utilization of Forest’s Ecosystem Services”

本号においては、ソフィアシンポジウム：「SDGsの実現に向けて：森の生態系サービスを生かした持続可能な地域づくり」の特集として、本シンポジウムの概要の紹介とともに、基調講演者のピーター・ベッソー国連森林フォーラム第12期議長、およびエリン・ケリーフンボルト州立大学准教授から寄せられた原稿を掲載します。また、パネラーとして参加したタイのBEDO/MNRE（環境天然資源省・生物多様性経済公社）による「生態系サービスへの支払い(PES)」の取り組みについての解説記事をあわせて掲載しました。

なお、本シンポジウムについては、同時に開催され本研究科が後援を行った「第22回森林と市民を結ぶ全国の集い2018 in 東京」の報告書のなかにも収録されていますので、併せてご参照ください（https://www.moridukuri.jp/wp/wp-content/uploads/2018/09/tsudoi_2018_report_180616_17.pdf）。

特集

ソフィアシンポジウム：
「SDGsの実現に向けて：森の生態系サービスを生かした持続可能な地域づくり」

Sophia Symposium 2018:
"Sustainable Regional Development to Achieve UN SDGs by Utilization of Forest's Ecosystem Services"

ソフィアシンポジウム：「SDGsの実現に向けて：森の生態系サービスを生かした持続可能な地域づくり」の概要について

Overview of Sophia Symposium 2018: "Sustainable Regional Development to Achieve UN SDGs by Utilization of Forest's Ecosystem Services"

柴田晋吾
Shingo Shibata

上智大学大学院地球環境学研究科では、上智大学地球環境研究所とともに、国土緑化推進機構、森林と市民を結ぶ全国の集い2018 in東京実行委員会、上智大学国際人材育成センターの後援を得て、国内外の専門家を招いて平成30年6月17日に、「SDGsの実現に向けて：森の生態系サービスを生かした持続可能な地域づくり」をテーマとする国際シンポジウム（ソフィアシンポジウム）を開催し、450名を越える方々の参加を得ました。本稿では、本シンポジウムの概要と主な内容を紹介することとします。

○プログラム

14:30　受付開始
15:00-15:10　開会挨拶　江馬一弘　上智大学学術研究担当副学長
15:10-15:40　基調報告1　Peter Besseau（ピーター・ベッソー）
「SDGs・国連森林戦略計画の実現に向けて：「生態系サービス」を生かした持続可能な地域づくりをどう進めるか―モデルフォレストの20年＋の経験から」
15:40-16:10　基調報告2　Erin Kelly（エリン・ケリー）
「アメリカ・カリフォルニア州のケース ―森林カーボン取引などによる生態系サービスを生かした持続可能な地域づくりの推進」
16:10-16:20　休憩
16:20-17:30　パネルディスカッション
（パネラー）
Peter Besseau（ピーター・ベッソー）　国連森林フォーラム第12期議長

Erin Kelly（エリン・ケリー）　フンボルト州立大学准教授
Rujira Pongpluthong（ルジラ・ポンプルトン）　タイ国天然資源環境省生物多様性経済公社課長
温井 浩徳　横浜市水道局水源林管理所長
足立 直樹　株式会社レスポンスアビリティ代表取締役
水谷 伸吉　More Trees事務局長
井原 愛子　MAPLE BASE代表
（モデレーター）
柴田 晋吾　上智大学教授・大学院地球環境学研究科委員長

17:30-17:40　閉会挨拶　ジョン・ジョセフ・プテンカラム上智学院グローバル化推進担当理事

○シンポジウムとパネルディスカッションのハイライト

・ピーター・ベッソー氏

国連森林フォーラムや国際モデルフォレストネットワークに長年携わってきたベッソー氏から、モデルフォレストの20年+の経験から、「SDGs・国連森林戦略計画の実現を図るために、生態系サービスを生かした持続可能な地域づくりをどう進めるか」というテーマで講演いただいた。ベッソー氏は、この20年近くの間に国連や関係機関が様々な政策を打ち出してきており、政策は極めて豊富にあるものの、その反面、実行がやや乏しいという問題があることを指摘された。SDG s の実行のためには実行が不可欠であり、モデルフォレストネットワークでは早くから「景観アプローチ」によって「協働型決定」のモデルづくりを進めてきたことについて、世界各地の取り組み事例とともに紹介された。このようなアプローチは、生態系のすべての価値・利用（生態系サービス）に焦点を当てる必要があるが、我々は全ての価値と利用を同時に満たし、全てのステークホルダーを100％満足させることはできない。このため、地域のプライオリティを見出し、トレードオフ分析を行い、「実現可能なバランス」（Workable Balance）を見出さなければならない。実際、Sustainabilityというのはこのことを見出すためのプロセスである。それには、「包括的なパートナーシップ」（inclusive partnership）が鍵となる。

・エリン・ケリー氏

全ての生態系サービスは複雑に絡み合っていて、多くは計量化が困難な価格のつけられない価値であり、このことが自然資源の劣化が止まらない理由の一つである。「生態系サービスへの支払い」（PES）スキームは、他の規制的な政策を補完しつつ、受益者支払いの仕組みやサービスの提供者へのインセンティブを提供することによって、このような状況を是正することを目的としている。ケリー博士は、カリフォルニア州のPES、特に森林カーボン取引の事例に焦点を当てて、生態系サービスを生かした持続可能な地域づくりの取り組みについて、森林所有者に対するアンケート調査結果なども含めて紹介を行った。他の生態系サービスと比較すると、炭素は計測が比較的容易であるとともに地球規模での同等性があり、カリフォルニア州においては森林カーボンがキャプアンドトレード市場で取引されており、森林の他の生態系サービスは副次的な便益として扱われている。

・パネルディスカッション

モデレーターから、ベッソー氏が強調した「包括的なパートナーシップの構築」(Inclusive Partnership Building)を実現するには何が必要か、及びケリー博士が事例報告を行った「PES（生態系サービスへの支払い）と広範な生態系サービス立脚型のビジネスアプローチ」の可能性に議論の焦点を当てることが提案され、それぞれのテーマを中心に各パネラーから取り組みの紹介が行われ、それを基に質疑応答が行われた。

前者については、カナダ・バンクーバーやアメリカの西海岸地域において発生した「森の中の戦争」と呼ばれる原生林伐採を巡る激しい対立・紛争が、このような取り組みによって次第に沈静化に向かい、かつての敵がパートナーシップを組む事例も散見されるようになったことについて報告がなされた。

後者については、景観美や生物多様性に着目したPES、上下流のパートナーシップに基づく水源PES、森林炭素についてのクレジット取引、非木材森林産品に着目したブランディングによる地域振興、生物多様性に着目した企業のCSR活動などについて、国内外での現場での興味深い実践事例についての報告がなされ、短時間ながらそれらについて熱心な質疑応答が行われた。

最後に、モデレーターより本シンポジウムへの参加と数多くの貴重な現場における取り組みの紹介について感謝の表明があり、シンポジウムのキーワードである「包括的なパートナーシップの構築」(Inclusive Partnership Building)の実現と「PES（生態系サービスへの支払い）と広範な生態系サービス立脚型のビジネスアプローチ」は密接な関係があり、これらは我々のSustainabilityへの旅にとって不可欠であること、また、多様な生態系サービスに着目することがSDGsの実現につながることを確認して閉会となった。

Sophia Symposium 2018:
"Sustainable Regional Development to Achieve UN SDGs by Utilization of Forest's Ecosystem Services"

Regional approaches to Achieving Global Policy Objectives

Peter Besseau

Abstract

The United Nations Sustainable Development Goals (SDGs), universally adopted by UN member states in 2015, represent the most ambitious, comprehensive, and urgent policy architecture yet devised to provide a global blueprint for a sustainable future. Yet, nearly 30 years after the largest gathering of world leaders at UNCED, in 1992, and the adoption of the three "Rio Conventions" (Biodiversity, Climate, and Desertification) the world is awash in policy, and sorely deficient in its implementation. Additionally, our problems have multiplied in number and complexity, demanding integrated, cross-disciplinary, and multi-partner approaches to their resolution. As the SDGs are now being rolled-out, regional ("localized") approaches are being increasingly championed for their ability to mobilize the necessary partnerships, to target action effectively, and to take on-board the interconnected nature of many of these problems. Regional approaches to implementation, such as that pioneered by the International Model Forest Network – which was also launched at the Rio Summit – have a rich accumulation of experience from around the world of using inclusive partnerships operating at regional (landscape) scales to achieve important policy objectives. This experience can shed light on workable, concrete approaches to regional scale implementation of SDGs. The Model Forest experience and lessons learned over the past nearly thirty years highlights the need not only for action in our landscapes but transformative processes that ultimately change not only the landscape but ourselves, our relationships with one another and with our landscapes.

地球規模の政策目標を達成するための地域的アプローチ

ピーター ベッソー

概要

2015年に国連メンバー国によって採択された国連持続可能な発展目標（SDGs）は、持続可能な未来に向けたグローバルな将来像を作り上げるためのかつてない最も野心的、包括的かつ緊急な政策構築である。しかしながら、1992年のUNCEDという世界のリーダーが集まる最大の会議における３つのリオ条約（生物多様性、気候、および砂漠化）の後、世界には政策が溢れかえっているものの、実行が足りない状況になっている。さらに、多くの問題は数や複雑性が増加してきており、それらの解決には統合的、分野横断的、そして多様なパートナーによるアプローチが必要となってきている。SDGsが開始された現在、「地域（地理的に狭い区域の）アプローチ」は、必要なパートナーシップを促進し、行動を効率的に目標とし、また数多くの問題が相互に関連していることを踏まえながらの実施が可能であることから、ますます支持されつつある。国際モデルフォレストネットワーク（IMFN）が、リオサミットにおいて創始した「実行のための地域アプローチ」は、重要な政策目標を達成するための地域（景観）スケールの包括的なパートナーシップを用いることについて世界各地で豊富な経験を蓄積してきている。この経験はSDGsの実行の地域スケールでの実施可能かつ確実なアプローチとして光が当てられている。過去30年近いモデルフォレストの経験と教訓は、景観だけにはとどまらずに、我々自身、我々のお互いの関係や景観との関係を究極的に変えるための行動についての変革プロセスの必要性を強調しているのである*。

＊）日本語要旨翻訳は柴田晋吾

Peter Besseau: Regional Approaches to Achieving Global Policy Objectives

This paper concerns the implementation of policies that support sustainable development at a regional level and, in that context, about the lessons learned by the International Model Forest Network over the past nearly three decades in taking just such an approach. These lessons learned are a very timely illustration of possible approaches to supporting implementation of the very ambitious and equally important United Nations Sustainable Development Goals (SDG's). The SDGs were adopted by all UN members in 2015 and represent the global community's agreed-upon policy architecture through which we are to achieve a sustainable future. The paper looks first at this policy architecture and then examines some of the challenges of implemention, particularly at the regional level. Finally, the experiences of the IMFN are drawn upon to illustrate workable approaches to implementing policy at a regional level and key lessons learned from the IMFN that can be helpful to others seeking to make lasting progress on these critically important policy objectives. It stresses the importance to the success of a regional approach of marrying transactional work with transformational process. The observations and analysis provided here are drawn from the author's 25+ years in international forest policy, including nearly nearly two decades as Executive Director of the International Model Forest Network Secretariat, Director of International Affairs for the Canadian Forest Service, Chair of the Global Partnership on Forest and Landscape Restoration and Chair of the Bureau of UNFF 12.

Policy Context

Implementation of anything starts with a plan - or policy - setting out objectives and proposed actions in support of desired outcomes. For the purposes of this paper, a simplified and condensed overview of key international global policies around sustainable development provides "the plan" in question. It begins with the 1992 UNCED[1] Conference (the Rio Conference) and its three most important outcomes: the United Nations Framework Convention on Climate Change (UNFCCC); the United Nations Convention on Biological Diversity (UNCBD); and the United Nations Framework Convention on Desertification (UNFCD). With agreement on these conventions, the global community of sovereign states, the extended family of United Nations organizations, and a host of other actors, large and small, pledged to prioritize individual and collective actions in these three areas. As the end of the millennium approached, global attention also turned to the plight of the hundreds of millions of people in developing nations to whom the many remarkable advancements of the twentieth century had been largely denied. The Millennium Development Goals (MDGs) (2000 – 2015), therefore, focused on action to alleviate poverty, increase health, education, job security, and human dignity, among other important goals – along with much higher levels of resource transfer from developed to developing countries. With the conclusion of the MDGs, in 2015, and with much

1 UNCED: United Nations Conference on Environment and Development

remaining to be done, a more ambitious and universal agenda was negotiated and agreed upon – the United Nations Sustainable Development Goals (SDGs). The SDGs constitute the most comprehensive and, arguably, most ambitious framework yet devised, as indicated in the preamble to the SDG document:

> We are resolved to free the human race from the tyranny of poverty and want and to heal and secure our planet. We are determined to take the bold and transformative steps which are urgently needed to shift the world on to a sustainable and resilient path.[2]

The SDGs, to be delivered between 2015 and 2030, comprise 17 goals and 169 targets, addressing a comprehensive package of challenges – social, economic, and environmental – that threaten our earth and our societies, and include, inter alia, the objectives of the three Rio Conventions, poverty, aquatic and terrestrial ecosystems, sustainable communities, and many others (see Table I). They are described and understood to be interconnected and necessarily supported by multi-disciplinary, multi-partner approaches. While forests and forestry are not specifically cited in all of the 17 SDG goals, a careful reading of them and the associated targets makes clear that there is an important forest component in each goal and, indeed, a world with a successfully delivered SDG agenda will be one that will necessarily includes significantly larger, healthier, and more resilient forest cover.

Figure I

The SDGs are universal – adopted by and applicable to all UN member states – as were the Rio Conventions [4] – however, rather than being thematic, or issue-based, like the Rio Conventions, the SDGs are comprehensive, interconnected, time-bound (to 2030) and supported by a more robust infrastructure of integrated action, tracking, reporting and support across the UN system and with collaborating states and entities. There is also arguably a much greater sense of urgency around them. Unfortunately, this more robust and urgent approach – while welcome and positive - does not simply represent a more mature,

2 Transforming our World: the 2030 Agenda for Sustainable Development, (preamble) p. 3

3 https://sustainabledevelopment.un.org/sdgs

4 There are two exceptions: the Holy See and the USA did not sign the three Rio Conventions, although the latter has actively supported activities related to their implementation over the years and has participated in formal discussions of them as an observer.

sophisticated approach to problem solving: in great measure it is the unfortunate result of a significant accumulation of undelivered policy objectives since 1992 and the arrival of many more vexing problems in the interim. However one looks at it, it can scarcely be denied that nearly 30 years after the Rio Conventions were adopted our world, despite being ever richer in policy, is still profoundly deficient in its implementation. This reality has obligated policy makers to devise a policy architecture to accommodate a much larger set of challenges and an approach to addressing them that recognizes their profound interconnectivity. This interconnectivity, in turn, has provoked a significant reconsideration of what implementation should look like, in particular, in a way that recognizes the essential need to implicate many more stakeholders than has been the case to date and at a scale (regional) that can produce more reliable and durable outcomes.

More positively, however, and regardless of how circumstances brought us to this cross-road, the SDGs can be seen as having good potential to bring more effective tools, approaches, and perspectives to our problems. This is particularly the case concerning opportunities for implementation at regional levels. The understanding of the SDG package as being interconnected represents an important and largely new entry point for problem solving that not simply invites but rather insists on cross-disciplinary, multi-party approaches. This latter approach, often referred to as "localization" - a form of regional implementation - in some of the most recent SDG-related documents[5], appears to be gaining traction and does represent an important departure from past delivery patterns that often resulted in unhelpfully exclusive / narrow approaches, high opportunity costs, and "turf" issues among potential delivery agents[6].

But, before looking more closely at "localization" or other regional approaches, some consideration should be given to the question as to why implementation has proven to be so very difficult.

Why has Implementation been ***So*** Difficult?

In the context of the Rio Conventions and the SDGs, implementation takes place at all levels: for example, nation states establish benchmarks for carbon emissions and many have developed cap and trade and other systems to reduce emissions of green-house gasses. They can also establish and support conservation areas, create incentive systems (taxes, subsidies, and the like) to encourage or discourage behaviour of individuals or businesses, etc. Depending upon the country (a unitary state, versus a federated union, for example), specific power to act may be delegated to sub-national units, which will effectively have the lead on policy and implementation. And, of course, at municipal, community and even individual levels informed policies and choices can be made around issues ranging from what we eat and otherwise consume to how and what

5 http://localizingthesdgs.org/about-us.php

6 The question of why we have substantially not delivered on the Rio Conventions and many other global goals is one of the most important to have a clear answer to. We need to understand our pathology of inaction because if we do not understand its nature it is very likely that we will continue down the same road and equally likely that we will be unable to devise workable solutions.

we recycle, the use and availability of public transportation, fuel efficient vehicles and so forth, all of which can positively contribute to our shared objective of a sustainable future. And, while progress has been made in these and other areas, the rate and extent of progress has consistently proven to be deficient, which begs the question, why?

There are many reasons that are frequently cited to explain the gaping disparity between objectives and outcomes. Among these, some of the following would be familiar to most people: the need for large, adequate, and predictable sums of money; the need to know precisely what to do when confronting problems previously unencountered, managing opposition from entrenched interests; navigating competing priorities; obtaining or creating suitable and affordable technology; obtaining accessible and understandable science-based knowledge to support decision-making; coordination of actions across disciplines, and many others. However, and based upon experience of the IMFN, the most intractable barrier to implementation can be traced to a consistent failure to acknowledge and/or understand the full nature of the change required. Implementation is much more than a financial, technical, scientific or managerial problem – it is fundamentally a complex social problem. Not only does it entail all and other of the very real and challenging problems itemized above, which are essentially **transactional** in nature, but it is more fundamentally about things that are **transformational** in nature. That is, it will not be enough for us to do better "things" on our landscapes – we have to change ourselves as part of the process, we need to stop some of the things we are accustomed to doing, unlearn some very bad habits, genuinely accept that there will be costs and trade-offs that will require us to change how we live – individually and collectively - and, fundamentally, we need to transform our relationship with and understanding of one another and with our world itself.

Both transactional and transformational change are needed, however, it is how transactions are conducted that can make them transformational – or not - and this is where regional approaches and the IMFN experience since Rio can shed light on effective ways to deliver more positive outcomes. The IMFN approach was specifically designed to marry transactional actions to a transformational process, or, more simply put, it married action to a deliberate idea of partnership within specific landscape settings. What was observed consistently as the IMFN developed was that this business of stakeholders working together (between government departments, NGOs and the private sector, rivals, adversaries, those who are not trusted, those who are too free with their opinions, and so on) is probably the most difficult thing that we can do, which also explains why it has been so thoroughly avoided. For good or ill, however, experience has also shown clearly that we do not have a choice – we need to find a way for those conversations to take place and for common cause, in some fashion and in some measure, to emerge. This is, not surprisingly, not a project – it is a process. This type of change is a guided process that will require at least a generation or two and will always be dynamic. However, any journey begins by taking those first steps and this is where

regional approaches offer some very exciting, very concrete opportunities in support of "implementation".

Why a Regional Approach: Implementing policy at a regional level

The term "regional level" in the context of this paper is meant to be largely interchangeable with closely related terms such as landscape approach, watershed management, integrated resource management, ecosystem approach, and many others, all of which have in common an approach that embraces three elements: a land-base large enough to be inclusive of **multiple resource sectors** (agriculture, mining, forestry, recreation, etc), **multiple values** (understood as economic, social, environmental, aesthetic, etc., and sometimes described in the context of ecosystem services [see Table II, below]), and **multiple actors** (private sector, government, communities, NGO's, rural, and urban population centres, etc.). The idea of a regional approach, as reflected by these elements, is to establish a scale for implementation that embraces, to the extent possible, the full range and complexity in which our sustainability challenges actually exist and partnerships reflective of that range and complexity. So, a landscape or regional scale, for sustainability purposes, is arguably the most efficient scale to capture all of the elements needed to move forward with tangible, concrete action across a menu of objectives. If the scale is too large it will become difficult to target actions with sufficient accuracy and difficult to engage stakeholders in that process. If the scale is too small, interesting and beneficial activities can certainly take place, but probably not with the interconnectedness of issues and actors needed to address multiple issues and opportunities. In terms of physical scale, a relatively sparsely populated country, such as Canada might work at a watershed scale comprising millions of hectares, whereas a mountainous, densely populated country, such as Japan, might also consider regional approaches within a watershed scale, recognizing that mountain watersheds in Japan can consist of fewer than 100,000 hectares. But in both of these examples, the mix of activities, values, and actors would be fully present.

To consider the benefits of a regional approach from another perspective, one can ask the question – when we talk about implementing sustainable development policies, who exactly is to do the implementing? Ultimately, if it does not engage all of the actors who have interests and impacts on the landscape, if they are somehow excluded from the process of transforming the landscape, most efforts are likely to struggle and ultimately develop as stand-alone projects, and/or risk being orphaned. The idea of a regional approach is to work at the right scale, engaging the right partners, and jointly debating, negotiating and selecting activities that are transformative of our landscapes simultaneously as they transform the institutional and human relations on the landscape.

Table II: Ecosystem Services[7]	
Supporting	Habitat for Species; Maintenance of genetic diversity
Cultural	Recreation and mental and physical health; tourism; Aesthetic appreciation and inspiration for culture, art and design; Spiritual experience and sense of place
Provisioning	Raw materials, fresh water, medicinal resources
Regulating	Local climate air quality; Carbon sequestration and storage; Moderation of extreme events; Waste-water treatment; Erosion prevention and soil fertility; pollination; Regulation of water flow; Biological control.

The regional scale, in addition to supporting the types of transactions and transformations described above, is extremely important more broadly to the implementation of the SDGs because this scale has proven, in the IMFN experience, to be manageable, represenative, replicable, and, not least important, successful in delivering results.

The IMFN Experience

The origins of the IMFN date from a period of intense conflict in Canada's forests, most notably around a place called Clayoquot Sound, in British Columbia, roughly from the mid-to-late 1980s, until the early 1990s, but certainly also including other resource-based conflicts. At issue in many cases was logging of old-growth forests that pitted a traditional partnership of government and industry against a growing alliance of parties representing different, non-industrial values who had no effective entry point into discussions or decisions about how the landscapes should be managed and for what values. Out of this period of very heated conflict, occasional mass arrest, and global media coverage there emerged a significant paradigm shift in resource management in Canada: from a period and a tradition largely dominated by a closed, economically-driven relationship between government and industry to one which started to become more transparent, accountable, inclusive and open to and accommodating of multiple values (economic, cultural, conservation, aesthetic, recreational, and so on). [8]This general milieu of conflict was also an important source of inspiration for the Model Forest program. The strength of opposition to the status quo that emerged in the late 1980s and early 1990's in Canada was such that government and industry were essentially left with two choices: either continue with business as usual and prepare for endless conflict in the forest or find a way to invite other interests and perspectives into the resource management discussion and be prepared find a way to accommodate them. From this general period of conflict emerged the outline of what became

7 http://www.fao.org/ecosystem-services-biodiversity/en/

8 This is, of course, a significant over-simplification: these changes represented many years and great effort to change deeply imbedded habits and beliefs around forest management, creating working relationships out of mistrust; and, of course, creating a new functional system of interaction, new outcomes, credible evidence-based decision-making, etc. to name just a few. Indeed, the process of evolution and maturation continues.

first, Canada's Model Forest Program, and ultimately, the International Model Forest Network, which was formally announced by Canada at the RIO (UNCED[9]) Conference, in 1992.

The six core principles that constitute the IMFN today are essentially the same as those framed by the Canadian Forest Service in the early 1990's:

1. A large, multi-use landscape with an important forest component
2. An inclusive, voluntary partnership.
3. A commitment by those partners to work together toward agreed-upon sustainability objectives
4. A programme of work reflective of the values and interests found in the landscapes
5. A governance structure that is inclusive, accountable, and transparent
6. A commitment to networking and sharing knowledge and know-how

Operating within the parameters of these six principles, partners were to develop their own "model" of sustainability. And this is perhaps the most important underlying feature of the "model": the idea that all landscapes are unique (resource endowment and history of use, population, culture, demands and pressures on the resource base and so on) and that, as a consequence of this, work in support of sustainability objectives will also necessarily be unique to any given landscape. This has very important consequences to the objective of implementation. It means, for example, that sustainability – in practice – is necessarily a sub-national activity. It means that there is no fixed recipe for sustainability – it will require a customized approach in each location that it is pursued. It means that sustainability must be a decentralized activity where responsibility is put into the hands of many people, with very diverse interests. And, because there is no universal model to follow, work toward sustainability will necessarily be a process of joint learning, exploration and doing, rather than delivering a project or product for a "client" on a fixed schedule according to a preordained planning process, as might otherwise typically be the case.

One of the challenges that framers of the model forest concept had was how to get those with tenure and authority over the land to agree to sit down and work with those without tenure or authority. Those with power had no incentive and, in fact, could be understood to be wary of potentially having to surrender power through this process or, at minimum, agreeing to an arduous, time-consuming process that held no advantage for them. This problem was overcome in the following way: the model forest partnership would be voluntary and no tenure or authority would be surrendered. However, to compensate for the potential weakness of its voluntary nature.all partners would agree to engage in an open, transparent, informed discussion about how they understood the land, its problems and ways to manage toward sustainable outcomes. Further, those with tenure and authority over the land (government, industry, private sector, farmers, for example) – who would also share their views - would agree to consider for testing, adoption, or adaptation new ways of conducting

9 United Nations Conference on Environment and Development

their affair as proposed by the broader partnership if a persuasive case were made. Through this process of discussion, exploration, action and negotiation, these diverse, non-traditional partnerships created the space to better understand one another and the legitimacy of the various perspectives and values that each held, the potential benefits of doing do things differently, and the commonalities between them that were, to that point, largely unknown and unexplored. These partnerships were often very stressful and difficult to form and manage, however, in most instances the need or desire to deal with shared problems in a new way, usually combined with a) appropriate support and encouragement from policy level, b) leadership of key, respected figures, and c) resources to initiate action, was enough to bring the partners together and focus attention on a shared package of issues. This approach to partnership, governance, and action represents the transformational aspect of the model forest – a structure that demanded an investment from stakeholders in the form of their time, good faith, attention, and willingness to learn new things, and that provided the time and opportunity for them to take ownership of the process and take it forward according to their values, interests and objectives.

These are very early days for rolling-out "localization" for the SDGs, but if one looks at some of the recent descriptions of "localization" for their delivery, such as the one from UNDP, below, one can see striking similarities with what the IMFN has been doing and, as such, excellent opportunities for learning and up-scaling such experiences in greater support of the SDGs:

*Localizing development means **taking into account subnational** contexts in the achievement of the 2030 Agenda, from the setting of goals and targets, to determining the **means of implementation** and **using indicators** to measure and monitor progress. It is also putting the territories and their peoples' priorities, needs and resources at the centre of sustainable development. There should be sustained exchanges between the global, national and local facets.*

*In the past, localization was mainly meant as the implementation of goals at the local level, by sub-national actors, in particular by local and regional governments. But this concept has evolved. All of the SDGs have targets directly related to the responsibilities of local and regional governments. That's why the achievement of the SDGs depends, more than ever, on **the ability of local and regional governments to promote integrated, inclusive and sustainable territorial development.***

***Subnational governments are policy makers**, catalysts of change and the level of government best placed to link the global goals with local communities. Localizing development is then a process to empower all local stakeholders, aimed at making sustainable development more responsive, and therefore, relevant to local needs and aspirations. Development goals can be reached only if local actors fully participate, not only in the implementation, but also in the agenda-setting and monitoring.*

*Participation requires that public policies are not imposed from the top, but that the whole policy chain is shared. All relevant actors must be involved in the decision-making process, through **consultative and***

***participative mechanisms**, at the local and national levels.* [10]

Today, the IMFN continues to use its a regional / landscape approach to deliver on a broad range of policy objectives, linked to the SDGs, across its six geographic networks (Canada, Ibero-America, Baltic, Mediterranean, Asia, and Africa), with a total of nearly 70 sites across more than 30 countries, encompassing almost 100 million hectares. The model has been as enthusiastically taken up in developed as in developing countries, in tropical and boreal ecosystems, in areas of dense human population and areas of relatively sparse population and wilderness. Notably, most Model Forests that have been created continue to operate and this despite the fact that most do not have secure, core funding from their host governments11. Indeed, the ongoing strength of model forests in developing countries – ***without core support*** – is a remarkable indicator of the significant value of the model to partners in those landscapes.

Over many years of discussion with Model Forest practitioners around the world there have been a small number of recurring explanations accounting for the longevity of the network's sites: the first is the governance system and specifically the fact that it is inclusive of all voices and interests, respectful and forward looking. Moreover, invariably over time, partners in the Model Forest process come to see these partnerships as being not optional but rather essential to achieving their goals. The second most frequently cited advantage of the model forest model is economic: virtually all Model Forests include activities to support sustainable economic outcomes for their partners. The third most important value associated with

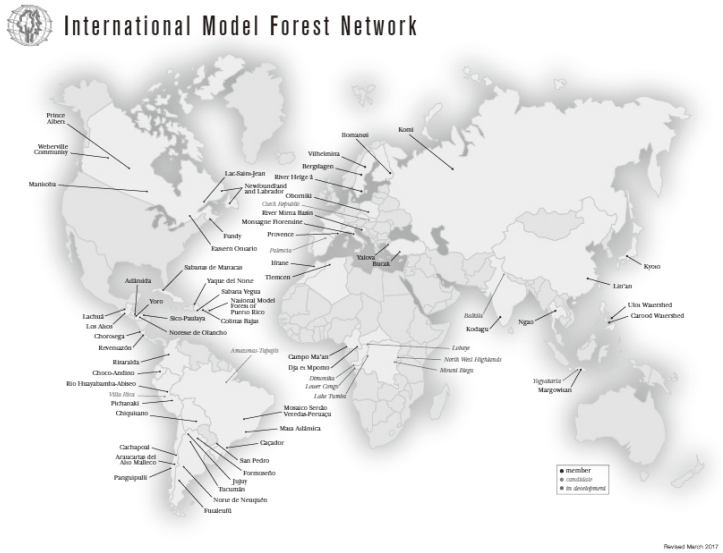

Figure Ⅱ

10 http://localizingthesdgs.org/about-us.php

11 An informal calculation indicates that as many as 18 Model Forests have ceased operation for various reasons over the years (i.e. key work had been completed; partnership failure; lack of financing, and other reasons).

the model forests is the practical nature of the work undertaken – sustainability for these partnerships is not an abstract, academic, or distant aim, but one that is tangible, relevant and achievable. Finally, the network itself is seen as a major asset to partners as it represents a community of practice and learning that can accelerate progress. As indicated in the examples cited below of individual model forest activities and accomplishments, while there are some thematic similarities in the activities (economic, restoration, tourism, etc.) of some model forests they are unique to their setting and to the values of their individual partnerships.

Selected Model Forest Accomplishments:

All model forests have broad-based programmes of work, and within them, flagship activities that are of central importance to the partnership. To cite just a small number of cases, here are some of the main areas of activity and accomplishment of selected Model Forests.

In **Canada, the Eastern Ontario Model Forest,** in place since 1991, has become an accredited organization for forest certification under the Forest Stewardship Council. This has allowed it to support thousands of individual woodlot owners who would not otherwise have been able to afford FSC certification.

In **Morocco's Ifrane Model Forest,** partners there have focused on combating desertification and addressing poverty and sustainable economic development based upon their natural resource sector.

On the densely populated island of **Puerto Rico, the Tierras Adjuntas Model Forest,** partners, including the island government, were successful in developing and having passed a Model Forest Law which legislated measures to reduce forest fragmentation (increase forest corridors) and increase biodiversity.

In **France (Provence, Alpes, Cotes d'Azure Model Forest),** multiple regional governments banded together to better support sustainable rural agriculture and strengthen the role of wood and non-wood products in the regional economy, in part, to reduce rural out-migration.

In northern Europe, **Sweden's Vilhelmina Model Forest** saw partners work to reconcile traditional reindeer herding across northern landscapes with the interests of private land owners.

In **Cameroon's Campo Ma'an Model Forest** its main objectives were to diversity the agricultural and resource-based economies, improve agricultural productivity and incomes, and establish agricultural production chains, all of which would reduce poverty while taking pressure off of the forest resource.

In the **Philippines' Carood Waterhsed Model Forest,** a partnership led by 7 municipalities, 13 peoples organizations and multiple other partners are working on major projects to restore a significantly degraded

ecosystem, including rehabilitation of steep slopes and mangrove forests, reintroduction of native species, improved irrigation systems, nature-based tourism, livelihood development based upon local capacities, interests and resources and many other areas.

In Japan's Kyoto Prefecture Model Forest, a model unique to the IMFN saw the creation of a network of public and private forests that draws heavily on prefectural corporations to provide leadership, together with volunteer citizen groups to address climate, forest, water and related policy objectives, support healthy engagement of citizens in nature and conservation, and reinforce the strong historical and cultural ties between the people and nature of Kyoto Prefecure.

Finally, by way of example, the **Chorotega Model Forest, in Costa Rica,** built on and expanded an initiative of local farmers and leaders in a watershed that had been severely degraded (88% of forest cover removed, severe degradation of water quantity and quality, resulting in significant population decline as young people and families left the watershed). Through their actions they were able to acquire degraded land, restore forest cover, including with native and commercial species, strengthen the local economy, improve water supply and quality and halt out-migration.

Each of the activities itemized above represents only part of a broader program of work in the respective model forests and also represent concrete actions for implementation of one or several of the SDGs, national policies **and** the priorities of regional partners. But the most important thing to note on the above is that each of these activities is being shaped, selected, and delivered by individual regionally-based partnerships based upon the model forest construct: the IMFN framework provides the form while the partnership determines the content.

Lessons learned:

If regional/landscape approaches are indeed now seen as among the most highly recommended approaches to achieving the SDGs (including closely related approaches, such as localized, watershed, ecosystem-based, and others) then what lessons does the IMFN experience have that might help others successfully put in place such constructs? In addition to several observations already made, some of our most helpful lessons would include the following:

1. Although noted above, it bears repeating here: **Recognize that each landscape and its approach to implementation is necessarily unique:** Regional or landscape approaches by definition mean that the specific approach, the priorities and the partnership that shapes them will be unique to that landscape. As such, while implementation can be guided (frameworks such as the IMFN, tools, etc.) it cannot be imposed from outside and it cannot be prescriptive. Implementation is ultimately cross-sectoral, multi-actor, and unique to its

setting. Implementation therefore requires tailored approaches to fit each unique landscape.

2. **Establish priorities**: No regional initiative can possibly address all 17 SDG goals and all 169 targets simultaneously. Priorities and choices need to be made based upon open dialogue, sound science, landscape values and interests, and technical considerations, as well as clear relevance to policy.

3. **Doing, Not Doing, and Un-doing**: Implementation is as much about doing what needs to be done, as it is about not doing, or stopping activities that are harmful or counter-productive, and un-learning and un-doing the things that created our problems. In Model Forest experience, this very important evolution in learning and critical thinking begins with the formation of the partnership and development of the critical listening and learning skills that are key to moving forward.

4. **Ensure the Partnership is Inclusive**: Create a partnership as complex as the values and uses of the landscape and a forum where open and respectful dialogue on difficult issues can take place. It is not uncommon that different departments within the same government, and different levels of government do not work together and are even adversarial to one another. Equally, indigenous people, local communities, and the poor are often overlooked as potential partners. These groups have important contributions to make and must also be beneficiaries of efforts to achieve sustainable outcomes.

5. **Link to policy and policy-makers**: Make the work relevant, and known, to higher-level policy makers and to local groups and interests. Ideally, the partnership will want to include policy-level actors as a member of the partnership. This not only allows a partnership to broadcast its relevance, but it also provides opportunities for up-scaling and replication and may also provide an important source of support and financing.

6. **Clearly identify benefits**: Most, if not all partners, will want to participate in a regional initiative because they have a stake in outcomes that reflect their interests. These "stakeholders" will remain part of the initiative so long as benefits – even those that are long-term – are well articulated in ways that are clear and meaningful to them and when the path to realizing them is clearly set forth and effectively communicated.

7. **Understand that healthy partnerships are dynamic, life-like things**: Partnerships need to be nurtured, supported, recognized, celebrated and guided. Trust can be difficult to establish. Over time, interest can wane, particularly as complex and/or longer-range objectives are slow to materialize. Because of this, strategies and approaches should be devised to build trust, and to sustain, nourish and invigorate the partnership, including ensuring that short-term milestones, outcomes and successes are clearly identified, achieved and celebrated.

8. **All partners should be considered equal, but that does not mean that they are the same**: Some partners will have little or no experience working, negotiating, collaborating or even promoting and defending their own interests. It is important to be patient with and support less experienced partners who need time to learn how to engage in the process. Indeed, it is in the best interest of the partnership that all are able to effectively participate. At the other end of the spectrum, partners who are experienced and who are accustomed to leading and directing often have a difficult time listening, following others, and being open to learning. This too is vital to a healthy partnership and takes time to evolve and mature.

9. **Give it time**: sustainability is a process - not a project. Learning and adapting is a permanent feature of sustainablity across all landscapes. Additionally, these partnerships will almost always draw together historical adversaries, those who have no previous working relationship, and there will be an absence of trust among many. Partnerships take time and specific action in order for trust to emerge. Without that trust, the partnership will not last.

10. **There are no shortcuts and it will be difficult**: Recognize that achieving desired outcomes will be difficult but recognize equally that there are no shortcuts – we have to work with one another to achieve these outcomes, and this includes working with those we are unaccustomed to working with, and those we frequently choose or prefer not to work with.

11. **Regional approaches and the partnerships that support them are not self-financing**: Predictable, adequate core funding is essential. While funding **is absolutely necessary, too much can cause more problems than it solves**: Having too much money for an initiative can attract "fair weather friends", those who are quite happy to join the partnership and help spend its money on projects and activities of their liking, only to leave the partnership when funds are spent. The impact of such partners can be toxic to a partnership and needs to be managed carefully and in the overall interest of agreed-upon outcomes.

12. **Cultivate and encourage ownership**: Sustainability, as an actively pursued goal, must be "owned" by the people who will win or lose based upon what is done. Put the challenge of sustainability into as many hands as possible. Make it part of people's lives. Let them own it, guide it, benefit from it, worry over it. Who else but communities, and multiple other interests in a given landscape are best placed to sort out the actual trade-offs, synergies, benefits and losses? This includes partners ranging from government and industry to landless peasants and every interest in between.

13 **Link with like-minded practitioners and initiatives outside of your region**: The work of sustainability is difficult and frequently under-appreciated, with the rewards often slow to materialize. Also, because the work is, by its nature, very focused on local

circumstances, it can be also somewhat isolating. We have found that there is great strength in linking with the broader global community of practice that is working with regional approaches. Linking with that community provides confirmation that their partnership approach is valid, reassurance that their efforts are worth the investment, rich learning opportunities, and much needed encouragement to continue this work.

14. **Recognize the fundamentally social nature of what we are doing**: Achieving global goals in support of sustainable development is definitely about restoring and conserving our environment, about striking a balance between what we take from the environment, what we leave untouched, what we rehabilitate, and so on. It is also about funding, policies and projects. But successful implementation will ultimately depend less upon projects and more about a change in culture, meaning that sustainability, ultimately, is not about changing our landscapes – although it requires this – it is about changing ourselves, our relationship with our landscapes and with one another, and it is about understanding the impacts and trade-offs of our resource management and use and consciously modifying our actions in order to have a better chance of achieving a balance between what we need to live sustainably and what the landscapes need to remain healthy, dynamic, and productive.

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MOTIVATIONS FOR CREATING FOREST OFFSET PROJECTS: EVIDENCE OF ENVIRONMENTAL AND SOCIAL CO-BENEFITS UNDER THE CALIFORNIA CAP-AND-TRADE CARBON MARKET

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Abstract:

Forest carbon offset projects, one type of payment for ecosystem services (PES), have been successfully developed under the California cap-and-trade program. As with many PES markets, forest offset project development and implementation has potentially created co-benefits, or benefits in addition to carbon sequestration. Through interviews with market participants, we assessed motivations for developing forest offset projects, and linked these motivations to co-benefits. We found that landowners and managers joined the market to diversify revenue, generate revenue from restricted lands and non-harvest (conservation) activities, generate revenue when other (timber) values were diminished, implement a patient investment strategy on cutover or degraded lands, and/or demonstrate the viability of forest offset projects under a cap-and-trade market. Using these motivations as a starting point, we hypothesize the potential creation of ecological (e.g., preventing fragmentation) and social (e.g., rural job creation) co-benefits under the market. These co-benefits extend beyond the explicit purposes of the market and thus our paper offers a starting point for thinking about the wide range of ecological and social co-benefits that are possible with forest carbon offset markets.

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森林カーボンオフセットプロジェクトの動機：
カリフォルニア・カーボンオフセット市場における環境社会的コ・ベニフィットの実証

エリン クロバー ケリー・マリサ ボンジョバンニ シュミッツ・
アリール ワイスグロー

要旨

「生態系サービスへの支払い（PES）」の一形態である「森林カーボンオフセットプロジェクト」は、カリフォルニア州のキャップアンドトレードプログラムにおいて成功裡に構築されてきている。他の多くのPES市場と同様に、森林オフセットプロジェクトの構築と実施が、コ・ベニフィットあるいは、炭素固定以外の便益をもたらしてきている可能性がある。市場参加者へのインタビューを行い、森林オフセットプロジェクトの動機を分析し、これらの動機をコ・ベニフィットに結びつける試みを行った。その結果、土地所有者や管理者が市場に参加するのは、収入の多角化を図る、制限のある土地や保全活動によって収入を得る、他の（木材の）価値が低下した際に収益を上げる、伐採地や荒廃地において忍耐強い投資戦略を実行する、キャプアンドトレード市場において森林オフセットプロジェクトの可能性を示すなどの動機があることが分かった。これらの動機を出発点として、生態的コ・ベニフィット（断片化の防止など）と社会的コ・ベニフィット（地域の雇用創出など）の創設の可能性について検討を行った。これらのコ・ベニフィットは市場の直接的な目的をはるかに上回るものであり、本稿の知見は森林カーボンオフセットプロジェクトが提供する広範な生態的かつ社会的なコ・ベニフィットについて検討する足がかりとなるであろう。

（和訳者　柴田晋吾）

MOTIVATIONS FOR CREATING FOREST OFFSET PROJECTS: EVIDENCE OF ENVIRONMENTAL AND SOCIAL CO-BENEFITS UNDER THE CALIFORNIA CAP-AND-TRADE CARBON MARKET

1 Introduction

Payments for Ecosystem Services (PES) are voluntary transactions that seek to ensure provision of ecosystem services such as carbon sequestration or watershed protection (Wunder 2005). PES markets are still emerging and their potential for providing social, economic, and ecological benefits are uncertain. PES markets have the potential to create co-benefits, which are environmental and social benefits not directly related to the particular good being traded in the PES market, resulting in greater environmental sustainability and social equity (Bulte et al. 2008). These co-benefits are positive externalities: that is, they benefit third parties who are not directly involved in the PES market, including the general public. PES operates under the assumption that environmental conservation of an ecosystem service can be encouraged by privatizing and assigning ownership, thus "internalizing" a previously externalized cost (Robertson 2007). Forest offset projects under the California cap-and-trade carbon market ("forest offset projects") are one type of PES in which forest landowners enter all or part of their forests into the market to offset emissions of carbon-polluting entities. This paper is an exploratory, preliminary assessment of potential co-benefits under the forest offset market based on interviews. We evaluate whether (and which) environmental and social co-benefits are potentially being created based on who is entering the forest offset market, and their motivations for entering the market. Some environmental co-benefits are built into the market, namely under the "Natural Forest Management" requirements for projects, which have certain biodiversity and forest stand structure requirements, as well as a 100-year permanence (or maintenance of carbon) requirement. Other co-benefits are not required, but are incentivized by protocol design, including provisions that encourage third-party certification and/or the existence of a forest management plan. Our paper focuses on other co-benefits that depend on discretionary choices. We explore these choices as they relate to participants' broader goals and objectives for managing forestland, as well as their motivations for entering California's carbon market.

The California cap-and-trade (or "compliance") market has created a much higher price for forest offsets than previous (voluntary) markets, which means that a large number of landowners may be motivated to develop forest offset projects. Proposed motivations for joining the market include diversification of revenue sources (Caldwell et al. 2014), doing the "right thing" in terms of climate change mitigation (Markowski et al. 2011), or alignment between carbon market objectives and existing landowner objectives (e.g., conservation) (Ruseva et al. 2017). But most studies have used hypothetical samples of landowners and asked whether landowners would join the market under different conditions; the current research focuses on landowners and project developers actually in the market, and asks why they joined. Part of the purpose of this research was to assess the potential co-benefits from the market.

Before the establishment of forest offset projects under the California cap-and-trade market, some observers speculated that carbon markets would produce co-benefits—including biodiversity and maintenance of marginal forest lands (Wayburn et al. 2000). But biodiversity and carbon sequestration are not mutually assured. Phelps et al. (2012) outlined five different ways to approach the dual objectives of biodiversity and carbon sequestration under different assumptions: 1. Prioritizing seamless win-win carbon sequestration and biodiversity protection, assuming that such opportunities exist; 2. Separating carbon sequestration and biodiversity protection entirely and approaching them as two separate policies; 3. Adding on biodiversity conservation as part of carbon market policies through voluntary and incentive programs; 4. Adding on biodiversity conservation through payments for "co-benefit optimization"; and 5. Making biodiversity conservation central to carbon markets, potentially creating large costs and high barriers to entry. These five policy approaches highlight that biodiversity does not necessarily just emerge from carbon markets, but depends on policy design, site, and other factors. Beyond biodiversity co-benefits, most social scientists are concerned with social co-benefits, including equity and livelihood concerns (Visseren-Hamakers et al. 2012). Similar to ecological co-benefits, these social co-benefits do not arise automatically from carbon markets, but may be incorporated into market design or may be excluded or seen as tangential to the market functioning.

The aim of this paper is not to justify the legitimacy of PES markets as we recognize that many PES markets, including forest offsets, simplify and commodify complex ecosystems and social relations (Corbera 2012). But we wish to offer some initial lessons from California's forest offset program in the context of global attempts to create forest offset programs, such as under the United Nations Reducing Emissions from Deforestation and Forest Degradation (REDD+). As these schemes are developed, they can look to the experiences of California's program, and some may also wish to integrate with California's market. In this paper, we address two questions: what are motivations for joining the carbon offset market, and what can these motivations teach us about potential co-benefits? We build on previous work by Anderson et al. (2017) who reviewed project design documents for forest offset projects in the California compliance market and coded them for co-benefits, including mention of watershed improvement or habitat for threatened or endangered species. This paper asks similar questions, but we assume that motivations for entering the market can offer important insight that might not be available in project design documents, which are often written by third party developers and which serve a specific purpose, i.e. successfully passing registration and verification procedural requirements.

1.2 Background: California's cap-and-trade market and the role of forest offset projects

California has largely forged its own path on climate policy after the US left international climate change agreements, first exiting the Kyoto Agreement in 2001 and then the Paris Accord in 2017. In 2001, the state established the California Climate Action Registry to record carbon emissions and establish baseline conditions; this state-run agency eventually became a non-profit organization that registers offset projects in the cap-and-trade market. In 2006, Assembly Bill 32 (AB32) passed in California, which set standards for carbon emissions reduction for the state: to 1990 levels by 2020, and a further 80% by 2050. One tool of

AB 32 was the proposed cap-and-trade market, which was launched in 2013 after years of protocol design and baseline carbon emissions measurements. Under the cap-and-trade market, offset projects (including forestry but also agriculture, landfill, and other projects) are purchased by "capped" (carbon-polluting) entities to offset their emissions. Offsets provide some flexibility for capped entities to offset their emissions, supplementing allowances (purchased from the state or other capped entities) and investments in carbon-reducing technology.

Cap-and-trade markets are not new in the United States; they are seen as more politically palatable than regulatory (simple cap) or tax approaches because they give businesses more flexibility to find greenhouse gas reduction strategies. Several regional partnerships were established in the early 2000s to create carbon markets (the Regional Greenhouse Gas Initiative with ten states, the Western Climate Initiative with seven states and four Canadian provinces, and the Midwestern Greenhouse Gas Reduction Accord, with six states and one Canadian province) (Rabe 2016). Many of the states and provinces withdrew from these regional partnerships, though RGGI has remained intact. As of 2018, while RGGI has continued, California's market has developed along a different path, with a more complex and comprehensive market, and with higher regulatory hurdles than other markets (Bang et al. 2017). This is in part because of the exceptional nature of California as a state: it has an unusual political context, with much stronger environmental laws and a more competent administrative branch than most other jurisdictions, creating the conditions necessary for a successful cap-and-trade market (Bang et al. 2017).

Under California's market, offsets can only be used to offset 8% of an entity's emissions, and forest offsets are only one type of offset. Therefore, we are focusing on a relatively small part of the cap-and-trade market. Despite being a small part of the cap-and-trade market, forest offsets are complex and can be contentious because of the difficulty of ensuring that they are "real" – that is, they are sequestering carbon and contributing to the overall objective of reducing emissions of greenhouse gases.

Forest offset projects in California's market may be developed in any state in the US, but generally only forests that are not owned by the federal government. There are three types of forest offset projects: reforestation, avoided conversion, and improved forest management. Within the market, improved forest management (IFM) projects are the most common type of project, and are the focus of this paper. The IFM protocols are complex, but there are three components that are central to understanding project development: 1. Permanence, 2. Verification, and 3. Additionality. To achieve permanence, forest offset projects must be maintained for 100 years past the last date of carbon sale. Verification requires that qualified third-party actors verify that projects are, indeed, sequestering the promised amount of carbon.

Additionality is central to the functioning of forest offsets; it is a concept that seeks to differentiate between background or "typical" carbon sequestration that takes place in absence of any forest offset project, and additional carbon sequestration that results from participation in the carbon markets. Before forest offset projects enter the market, developers conduct in-depth inventories of carbon stocking, and these inventories are compared to nearby similar forests as measured under the nationwide Forest Inventory and Analysis (FIA) program, which is maintained by the US Forest Service. This allows for national participation because FIA is a standardized, nationwide dataset. Carbon stocking standards are established based on these

FIA data among forests similar in terms of species and geographic context, creating a "common practice" for the region, which constitutes the foundation of the baseline for forest offset projects.[1] If proposed forest offset projects are above common practice, then they are able to generate immediate revenue, which is calculated as the difference between the carbon stocking on the project and the carbon stocking of common practice. If proposed offset projects are below common practice, they must wait to generate revenue, until the projects exceed common practice.

2 Methods

Initial in-person interviews (n=25) were conducted with both project developers and protocol designers focused on the development of the forest offset protocols, who participated in their design, and how the design changed over time. Through the process of interviewing and coding, we discovered common motivations for projects to enter the market, and began to theorize project typologies based on how entrants were leveraging their market participation, and in some cases, how carbon revenue was utilized. We then looked for patterns in our database of projects that could confirm, undermine, or expand upon these hypothesized motivations and strategies.

Table 1. Interviewee types by landowner, developer type, geography, and plans to harvest timber. Landowner types: NIPF = non-industrial private forest (i.e., "family" forest owners), TIMO = Timberland Investment Management Organization.

Landowner types		Developer types		Geography (USFS region)		Harvesting timber?	
Conservation	16	In-house	16	Southwest (California)	23	Yes	21
NIPF	6	Consultant	12	Northeast	7	No	14
Industry	8	Contract (professional carbon developer)	7	Southeast	2		
TIMO	2			Northwest	3		
Miscellaneous	3						
TOTAL	35		35		35		35

We followed this with additional interviews (n=21) with project developers and/or landowners—i.e. people identified as responsible for forest offset project development. These twenty-one people represented thirty-five projects that differed by landowner type, developer type, geography, and whether the projects involved harvesting timber (Table 1). The sample was not representative of all the projects in the market

1 Other baseline components can include legal and economic considerations (e.g., conservation easements) but for the purposes of this paper, "common practice" is equated with baseline.

(Figures 1 and 2) but offered a wide range of project types. Fifteen interviews were conducted by phone; six were in-person. In our initial outreach emails, we offered a list of potential motivations and asked interviewees to identify the motivations that best fit their projects. This list changed over time as more options were added during discussions. Therefore, while we find the interviews to be illustrative of strategies and motivations to enter the market, we caution that we cannot generalize quantitatively.

We also compiled a database of IFM projects using publicly-available records from two registries: the Climate Action Reserve and American Carbon Registry. We classified landowners into types based on land ownership and read all publicly-available documents regarding project design. We included a total of 158 listed projects (updated in the summer of 2017), including all projects that had filed preliminary paperwork to enter the market, some of which had already been awarded offset credits. We utilized this database to assess total market participation (Figures 1 and 2) and to calculate the number of projects below common practice.

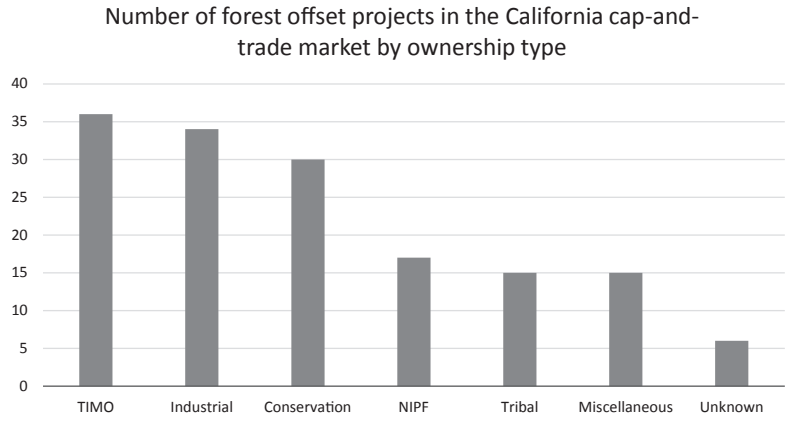

Figure 1. Forest offset projects in the overall market, by ownership type.

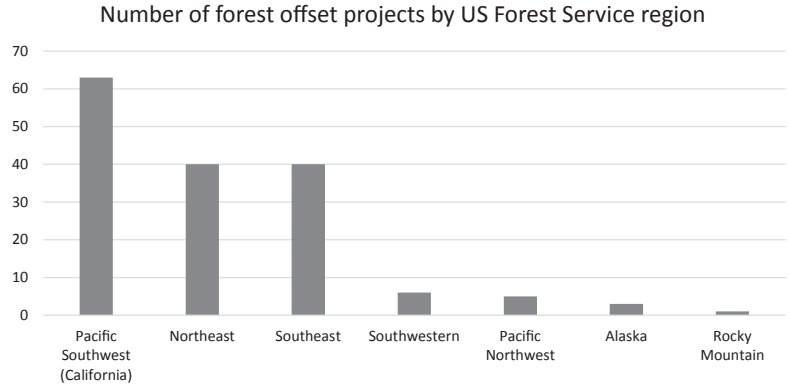

Figure 2. Forest offset projects in the overall market, by region.

3 Results: Motivations for joining the market

Through initial interviews and subsequent follow-up interviews with project developers, we developed a template of motivations for landowners and project developers to enter forests into the offset market (Table 2). Many interviewees identified multiple motivations, or variations on suggested motivations. The list of motivations changed as a result of interviewee input, and therefore numbers across interviews are not comparable. We found that the list served as a starting point for discussions about why projects were being enrolled.

Table 2. Identified motivations for landowners and project developers to develop forest offset projects under the California cap-and-trade market.

Motivations
Revenue Diversification: Management objectives include diversification of forest revenue. Forest offsets, wood products, and conservation easement dollars may be utilized together for economic and forest management objectives.
Conservation focus: Timber harvesting is economic and feasible, but is secondary to conservation objectives or contrary to objectives. Carbon is attractive as a non-extractive revenue alternative.
Highest and Best Use (HBU): The most valuable use of the land and timber is in the carbon market, whether because mills are distant, market value for timber species is low, or because grading makes harvest infeasible.
Restricted Lands: Projects have regulatory restrictions or easements existing on the property before project development, limiting timber income opportunities.
Patient Growth: Project stocking is below, at, or moderately above Common Practice; projects patiently wait for carbon to grow and accumulate.
Demonstration of market viability: Projects are used to test and demonstrate the feasibility of carbon-offset projects in the market. May fit with participants' objectives and values or may be in response to trying to meet conventions to reduce carbon footprint or protect the environment.

3.1 Revenue diversification

By far the most common motivation identified by interviewees was revenue diversification. This was described as managing forests for a range of financial benefits alongside forest offset revenues, including wood products and/or other conservation funding such as from easements. In interviews, twenty-one projects were identified as involving "revenue diversification" as a motivation. Of those, fourteen projects were actively managing for timber and seven were not.

This category, which often placed forest offset revenue alongside timber harvest, highlights that managing for carbon means different things for different landowners and project managers. It includes everything from no-harvest preservation-style projects to traditional production forestry. Most interviewees who were harvesting timber indicated they had not changed their silviculture or harvesting behavior, because the carbon market was complementary to harvesting or to their previous management objectives. Several interviewees did indicate they had changed their harvesting behavior: three said they harvested less because

of a forest offset project, and one said they harvested more—because prior to the carbon market, they had not considered harvest, but in bringing in consultants for the project, they became interested in harvesting as a restoration tool.

One reason for revenue diversification was cyclical returns within the timber market – that is, the fluctuating prices of timber. In the words of one project developer, "Before the [carbon] market, money was made from timber harvests. There was lots of pressure from the [timber] market to harvest more intensely and more frequently… it's hard for owners to manage for the long term, but the [carbon] market is complementary with sustainable forestry. The [carbon] market was a counter to the traditional model."

Not all projects were diversifying income from timber production; for example, one project, located in an agricultural area, used their carbon revenue to diversify multiple revenue streams, including recreation, leased land, Christmas trees, and orchards.

3.2 Conservation focus

For some projects, interviewees indicated that carbon revenue fit conservation objectives related to reduced harvesting. In the words of one interviewee, the strategy was to monetize ecosystem services to supplement revenue and "take the pressure off harvesting." In this sense, the revenue from having a forest offset project allowed other (conservation) objectives to be achieved, and sometimes filled important funding gaps, when other revenue opportunities became scarce. As one interviewee stated, "I think a lot of land trusts are starting to realize that there is value in the property that we have, and we have a head start because we own the land. Let's make it work for us and enhance it at the same time. Not be begging at the troughs of government agencies for grants. Because frankly those monies have dried-up."

A number of conservation ownership interviewees pointed to the need for carbon income because of loans acquired during land purchase. As one indicated, the carbon market helped to "bridge a funding gap" that existed; others said that carbon market revenues went directly to loan repayment. In fact, one interviewee pointed to carbon revenues as a way to gain funding for further land acquisitions: "We're considering using carbon offsets on an acquisition project… as a portion of the funds to pay for the acquisition…it will be one of the legs of a three legged stool: one will be carbon offset proceeds, another will be grant funding, and the other will just be donors in the area. A three legged approach to buy the property."

There were a small number of projects that interviewees indicated could engage in timber harvesting, but they elected not to altogether. We termed this sub-category of the conservation focus as "non-extractive" in terms of motivations. In one interviewee's words, they were "focused on conservation, not forestry" and their motivation was to protect a watershed. While none of these projects were actively harvesting timber for commercial purposes, most interviewees who identified "non-extractive" motivations did remove trees for other purposes, such as habitat, wildfire risk reduction, or restoration.

3.3 Highest and Best Use

Interviewees said that some projects demonstrated that carbon was the "Highest and Best Use" (HBU) of the forest, and pointed to a lack of timber markets (e.g., because of distant mills or low species value) or

infeasible harvests (e.g., because of steep slopes). Another reason identified was stumpage prices – when stumpage prices are low, carbon may become the HBU because the opportunity costs are less. A total of nine projects identified carbon as HBU, and five of these did not engage in timber harvest, but four did, indicating that while timber harvests are marginal for some HBU projects, they are still possible.

One interviewee indicated that their forest property was in its fifth generation of family ownership. They watched as timber markets changed and mills closed in their region, eventually resulting in carbon as the best economical use of their land. As with many landowners and managers who indicated that carbon was the HBU, they supplemented carbon revenues with other sources of income.

3.4 Restricted lands

In contrast to HBU projects, some interviewees noted that they worked on projects wherein timber harvest was restricted not by markets but by legal restrictions, either existing conservation easements or because the lands were in a designated protected status. One interviewee indicated that their project was developed on property which had been designated a recreation area and set aside for the carbon market, while timber harvests continued elsewhere on the ownership. Another interviewee suggested that they developed projects in already-restricted riparian set-asides. This suggests the possibility that landowners can carve-off pieces of larger ownerships, enrolling only those in the carbon market that have little or no timber harvest.

One interviewee indicated that he thought that developing a forest offset project "makes more sense on encumbered land than unencumbered land" because "by selling a carbon encumbrance you're already restricting the land." He explained that landowners and project developers could essentially layer on encumbrances, netting revenue through different conservation sources.

3.5 Patient growth

Patient growth was described as a motivation by only a few interviewees, though we view it as potentially very important for the market. Projects can be established on cutover, degraded lands with low stocking that may have low purchase price, and very patient investors can then wait to produce credits (and income) under the carbon market. Two projects in the database were established on very low-stocked lands, which an interviewee said would not generate timber returns for "ten to fifteen years." Under this scenario, if a landowner has sufficient patience (and revenue flows elsewhere), they can enroll their project in a market which will eventually produce returns.

Our database confirmed the possibility of this "patient growth" strategy, as thirteen projects were listed below Common Practice standards. Of these, six projects had conservation landowners, which may indicate the willingness of conservation landowners to purchase and rehabilitate degraded timberlands.

3.6 Demonstration of market viability

This category was created after several early interviewees identified demonstration of market viability as an important motivation for entering the market. Two separate interviewees labeled themselves as "guinea

pigs" for the market, explaining that their forest offset projects were intended to demonstrate that the market could work. One interviewee who had developed industrial projects specifically noted that they wanted to demonstrate the viability of industrial projects within the market, and to demonstrate the feasibility of "stewardship management" within the timber industry, using the market as a tool.

In the words of one interviewee, they wanted to demonstrate market viability because the market "places a value on the forest as a forest," rather than as a commodity producer. A number of interviewees also indicated that they wanted to demonstrate viability in order to contribute to a lower carbon footprint, or "move the needle" on climate change and emissions. This demonstration of market viability extended to providing lessons for other project developers in order to teach them how to enter the market, as one interviewee stated: "we wanted to model this and prove the concept so that people could see how it worked and hopefully learn from, that it would help in the adoption and participation by others."

This identified motivation to enter the market in order to demonstrate viability speaks to skepticism that the sale of forest offsets could actually function as a marketplace, providing real revenue to participants, as well as to the difficulty of getting forest offset projects into the protocols at all. Most cap-and-trade markets have not included forest projects because of concerns related to the uncertainties of forest management, particularly unintended reversals (e.g., insect infestations and wildfires), leakage (e.g., harvesting more intensely outside the project area to compensate for reduced harvests within the project area), and the difficulties of precisely capturing carbon sequestration through field measurements.

4 Discussion: Potential co-benefits

Under the framework suggested by Phelps et al. (2012), there are multiple ways that carbon markets can incorporate co-benefits. In the California market, some co-benefits (e.g., preference for native species and a 100-year permanence requirement) are built into market protocols. Another co-benefit created through the development of the market itself has been the creation of new jobs in forestry, such as carbon consultants, inventory specialists, growth and yield modelers, carbon financiers and aggregators, project auditors, and market registry staff (Kelly and Schmitz 2016). This is because ecosystem markets are expert-dependent, creating high demand for human capital with understanding of the technical and complex aspects of quantifying ecosystem services within forests. New professional opportunities within forestry may be especially important in a context of declining timber markets, and a need to re-establish the relevancy of forestry as a profession through changing consumer demands and social values.

But other co-benefit production depends on choices made by market participants. These choices are reflective of participants' wider goals and objectives for managing forestland, as well as their motivations for entering California's carbon market. Anderson et al. (2017) reported on a range of ecological co-benefits on forest offset projects in the California carbon market, based on voluntary reporting in project design documents. Their research provides an important snapshot of ecological co-benefits, particularly as they relate to program requirements. Our results based on interviews suggest broader-level co-benefits that are both ecological and social, and which extend beyond program requirements. We now outline some of these co-benefits (Table 3) and discuss implications for policy-makers, particularly as they relate to understanding

the full ecological and social implications of using forest carbon markets as tools for climate mitigation.

Table 3. Potential social and ecological co-benefits generated by the forest offset market, based on landowner motivations.

Potential co-benefit: Motivation:	Maintaining forest lands as forest lands = Economic benefits for rural places (particularly jobs), reduction of fragmentation	Creating opportunities for conservation finance/ revenue sources = more conservation capacity	Reducing pressure to harvest timber = longer rotations, older forests, less harvest in ecologically sensitive areas	Creating social license = corporate social responsibility,
Revenue Diversification:	x	x	x	x
Conservation focus:		x	x	x
Highest and Best Use:	x	x		
Restricted Lands:		x	x	
Patient Growth:	x	x		x
Demonstration of market viability:		x		x

4.1 Maintaining forest land as forest land

The ability of forest offset programs to help maintain forest land as forest land, i.e. to reduce forest fragmentation, is one of the most likely co-benefits of forest offset projects under the California market. This is important because maintaining forest cover creates a range of ecosystems services, including production of wildlife habitat and watershed improvement, as well as quality-of-life benefits, such as recreation, view-shed, and maintenance of open spaces (Millennium Ecosystem Assessment 2005). Maintaining forest land also contributes to rural economic co-benefits, including contributions to remaining timber economies, and to the sustainability of rural places and ways of life.

Because of the exceptionally long permanence requirement built into the California protocols, all lands entered into the carbon market have a measure of insurance that lands will stay forested; forest offset projects can be canceled, but only with repayment of revenue earned, plus a penalty if canceled within the first fifty years. However, we found that by offering another source of revenue, carbon offsets can especially help maintain forest cover for economically marginal properties by defraying the costs of owning and maintaining forestland and/or by improving the economic appeal of forest management in the face of compelling land-use alternatives. Economically marginal properties include those owned by landowners who might otherwise sell forest land into real estate or other purposes, such as family forest-owners (Hatcher and Greene 2013), as well as particular forest types, such as those in regions that have lost timber processing capacity and infrastructure, or because they have been previously harvested or do not contain economically

viable species.

4.2 Increasing opportunities for conservation finance

Increased opportunities for conservation finance is an important co-benefit of offset projects in the California market. In part because forest offsets provide non-extractive revenue, with reduced pressure to harvest timber, there are increasing opportunities for conservation landowners (e.g., land trusts), tribes, family forest owners, and other landowners with multiple objectives. Specifically we found that carbon-revenue provided two types of benefits for conservation-minded landowners: funding for new land acquisition, and revenue that can be used for ongoing stewardship and restoration, such as management to reduce invasive species and/or to restore older forest conditions. This is in part because forest offsets typically provide an initial lump sum of revenue, which can be used for property acquisition, followed by smaller but consistent payments for new forest growth, which can fund restoration and/or contribute to debt service on acquisition loans.

One interesting finding was that the existence of the California forest offset market improved some landowners' access to public and/or private loans for property acquisition, and in some cases, development of forest offset projects became a stipulation to receive funding. For conservation NGOs in particular, offset revenue fills a gap left by diminished public grant monies for conservation generally; and, because carbon revenue is ongoing, it has the added potential to provide funds for stewardship on properties that conservation landowners are increasingly tasked with managing long-term. The availability of non-extractive revenue also opened opportunities for conservation NGOs to participate in commercial forestry markets, which was not always available with traditional timber markets, because offset revenue was viewed as more socially acceptable to the community and/or in closer harmony with organization goals. A unique benefit of increased conservation finance that applies to tribes includes greater capacity for these landowners to re-acquire customary homelands, which we found to be the case on several projects.

4.3 Reducing pressure to harvest due to non-extractive revenue potential

Due to offset revenue, landowners and land managers who have enrolled forests in the California program may have reduced pressure to harvest trees. This can offset over-harvesting for landowners who prefer or require a steady forest income (for example, if they harvest at low market prices), or for landowners who need an influx of income. The carbon market alleviates over-harvesting under these circumstances because there is not a need to harvest to maintain revenue; rather, landowners may balance timber harvest with sale of carbon credits, in order to better facilitate forest regrowth or other ecological objectives, or to more strategically time timber harvest sales, e.g. by extending rotation ages/cutting cycles if stumpage prices are low, and instead selling carbon, until timber markets rebound.

At a broader level, the introduction of a legitimate revenue stream not based on timber extraction has the potential to facilitate a transition already underway within US forestry towards management for multiple objectives (McQuillan 1993). Forestry is a service-oriented profession that seeks to meet the evolving goals and objectives of society (Hull 2011), but within the confines of existing market opportunities. Timber

extraction and creation of wood products has long been the sole reliable income stream for most forest types—with exceptions for certain properties with unusual conservation or recreation value—and the primary driver of management decisions. The possibility of carbon revenue can thus increase the range of management options open to landowners, for instance by allowing practitioners to engage in more experimentation with management and/or to employ strategies that might align with management goals and objectives, but which require a basic level of revenue generation. This could include extending harvest rotations to produce higher quality wood products, reducing harvest in ecologically sensitive areas such as wetlands or within stream buffer zones, and/or reducing erosion as roads are used less often and vegetation is allowed to remain on site for longer periods. Sale of forestry offsets may also allow for use of smaller harvest units, resulting in reduced clear-cut sizes and more options for less-intensive silvicultural methods, e.g. single-tree and group selection, rather than even-aged methods.

We note, however, that managing for timber does not preclude co-benefit production; it facilitates some co-benefits (such as restoration and fire management), and contributes to rural livelihood and community resilience. Combining timber and carbon fits with forestry that aims to achieve multiple benefits.

4.4 Creating social license

An interesting finding of this research is that forest offset market participation has the ability to create or improve social license among timber companies. This is important because of declining public approval for commercial timber harvest in the US during the environmental movement of the last half century, with critiques focused on degrading logging practices, harvest of iconic old growth trees, and destruction of habitat for threatened and endangered species (Salwasser 1990). Public disapproval led to lawsuits against timber companies and direct action by environmentalists aimed at halting logging (Widick 2009), and facilitated policy changes that increased the stringency and oversight of forestry regulation. Forestry practices have evolved since this period of high controversy, but negative public perceptions remain, particularly in certain regions of the US, such as the Pacific Northwest. Carbon market entry represents one way to lend environmental credibility to timber companies, by improving their image as prudent land stewards with long-term commitments to sustainability. Specific benefits of greater social license include: improved public relations with communities and with regulatory bodies, fewer environmental-legal challenges, more autonomy with forest management decision making, and improved market value of forest products. Many timber companies, including for instance Timberland Investment Management Organizations, are pairing carbon market entry with other markers of environmental stewardship, including participation in certification schemes, such as the Sustainable Forestry Initiative (SFI), and sale of conservation easements.

4.5 Equity: A missing co-benefit

Thus far we have highlighted numerous co-benefits provided by or open to forestry offset market entrants. However there were a number of ways that the market was missing anticipated co-benefits, the most glaring of which is a lack of equity within the market in terms of landowner participation. This is because only relatively large acreages or those with high carbon stocking can join the market (Kerchner and Keeton

2015). This means that many of the most economically marginal landowners, particularly non-industrial (family) forest landowners are unlikely to join the market, whether because of high barriers to entry (high costs), or lack of capacity or desire for a 100-year commitment (Kelly et al. 2017). This is reflected in the relatively small proportion of NIPF landowners in the market. While the California market may not be suitable for NIPF landowners, this means that they do not fully benefit from this new revenue source, and many of their forest lands remain vulnerable to fragmentation. Meanwhile, landowners who may be most economically comfortable and have the most options (e.g., timber industry) have a new source of revenue.

This raises important questions about the additionality and co-benefit potential of forest offset projects owned by large timber producers. One concern is that, if carbon market participation fits seamlessly into the regulatory requirements of commercial timber producers, these projects may not offer substantial greenhouse gas reduction or other co-benefits. However, Anderson et al. (2017) find just the opposite, concluding that conservation landowners are "non-additional" while industrial projects are "additional," based on assumptions that timber companies actually need to alter their management to enter the carbon market. These questions deserve further research that can consider nuance and complexity, and which acknowledges that no landowner demographic is monolithic. Our research highlighted above, however, suggests that carbon-based revenue is likely to create co-benefits even for large timber producers who may practice business-as-usual forestry, insomuch as it increases the viability and competitiveness of US timber companies in the face of wood product market declines and global competition, which have led to forestry mill closures and loss of capacity since the 1990s.

Conclusions

This paper offers a starting-point for thinking about the range of ecological and social co-benefits that are possible on forest offset projects. Some co-benefits, such as improved watershed quality or habitat improvement, are likely to be shared by all participants, by virtue of policy requirements or because of the many ecosystem services inherently produced by forests, but other co-benefits will vary project-by-project and by region and will be influenced by landowner motivations for market participation, as well as by landowner goals and objectives for forest management more broadly. Future research comparing differences among geographic regions and landowner types can improve our understanding of forest offset co-benefit potential. In addition, comparative research that investigates co-benefit production across multiple carbon offset programs may illuminate the factors that influence the types and magnitude of co-benefits that are possible with forest offset projects.

Many of the lessons of the California market are not transferable to other places. For example, land tenure is well-established in the United States relative to many places where competing land claims, often between the state and indigenous people, remain unresolved. But the motivations for project development and related co-benefit production still offer insights for policy makers considering forest offsets as tools for climate mitigation. In particular: this research may help policy-makers evaluate competing offset options—e.g., dairy methane digestion, rice methane capture, or rangeland soil carbon sequestration—by stimulating

discussions on the wide range of longer-term social and ecological implications of alternative land-based greenhouse gas reduction options. In a context of concerns about whether offsets provide 'real' climate mitigation (Lohmann 2009), research on ecological and social co-benefits can also provide policy makers with a fuller picture of the direct and indirect outcomes that are possible from forest offset programs, regardless of whether they provide ton-for-ton carbon sequestration exchanges.

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「生態系サービスへの支払い」（PES）により持続可能な地域づくりを目指す
―タイにおける取り組みから

柴田　晋吾

概要

国家経済社会開発計画に「生態系サービスへの支払い（PES）」が位置付けられたタイでは、天然資源環境省生物多様性経済公社（BEDO/MONRE）がPESスキームの仲介者となって、生物多様性が高くかつ複数の生態系サービスを有している箇所をターゲットとして各地でPESの取り組みを進めている。本稿で紹介したTung Jao上流地域（チェンマイ郡）、Khlong Prasong准地域（クラビ郡）、およびMae Sa流域（チェンマイ郡）の３つの事例についての評価は時期尚早であるが、いくつかの成果や課題が見えつつある。これらの取り組みは、AerniやEngel and Wunscherらの云うハイブリッド型のPESと考えられ、地域の新たな社会的ネットワークの形成やビジネスの契機の提供によって、持続可能な発展を促すことが期待される。

Sophia Symposium 2018:
"Sustainable Regional Development to Achieve UN SDGs by Utilization of Forest's Ecosystem Services"

Pursuing Sustainable Regional Development Through "Payment for Ecosystem Services" (PES)
-Implementation Status in Thailand

Shingo Shibata

Abstract

In Thailand, "Payment for Ecosystem Services" (PES) is incorporated in the National Economic Social Development Plan, and PES activities are conducted to target areas of high biodiversity and multiple ecosystem services by Biodiversity-Based Economy Development Office/Ministry of Natural Resources and Environment. In this article, implementation status is overviewed for the upper stream of Tung Jao Watershed (Chiang Mai Province), Khlong Prasong Sub-District (Kurabi Province) and Mae Sa Watershed (Chiang Mai Province). Although it is too early to evaluate these activities, some positive outcomes and challenges can be observed. These PES activities can be categorized as hybrid-type defined by Aerni, Engel and Wunscher, etc., and they are expected to help to promote sustainable development through fostering new social network and business opportunities in the region.

「生態系サービスへの支払い」（PES）により持続可能な地域づくりを目指す
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1．はじめに

貧困、食料不安、政治的不安定などの問題が絡み合っていることが多い開発途上国においても、UNCED 以降は農業環境政策を強化し、農業の環境への影響を低減させるための環境法が各国で制定され、ドーナーによって、様々な「生態系サービスへの支払い」（Payment for Ecosystem Services, 以下 PES と称する）スキームが行われるようになった。食料安全、生物多様性、水源、文化などの農業のプラスの外部経済に着目した欧州型の資産形成タイプのものから、野生生物保護、森林保全、生物多様性などの農業以外の環境への負の外部経済を低減させるアメリカ型の利用制限タイプのものまで様々な形態で行われるようになった [Aerni. 2016]。

タイでは、2010 年に名古屋で開催された CBD、COP10 などを受けて、2012-2016 年の第 11 期国家経済社会開発計画、および 2017-2021 年の第 12 期国家経済社会開発計画に PES が位置付けられた。第 12 期国家経済社会開発計画には、「PES の考え方は、地域の天然資源の保全を行う地域コミュニティが追加的な収入を生む生物多様性に根ざした経済開発のもう一つの方法である」と記された。これを受けて、タイ国内各地で国際ドーナーや NPO、および政府機関によって PES プロジェクトの取り組みが実施されている。とりわけ、天然資源環境省生物多様性経済公社（BEDO/MONRE）はタイ国内での主要な PES の実施機関となっており、BEDO が自ら PES スキームの仲介者となって、生物多様性が高く、複数の生態系サービスを有している箇所をターゲットとして各地で取り組みを進めている。特に、タイ北部においては、BEDO は同じく天然資源環境省の国立公園局（DNP）や郡の水局（Provincial Waterworks Authority, PWA）などと協定を結んで連携しつつ PES に取り組んできている。

BEDO の PES の取り組みは、①対象区域の同定と生態系サービスの評価、②販売可能な生態系サービス、販売予定者、購入予定者の見極め、③ PES の原則の策定と問題点の解決、④交渉と合意の実行、の 4 段階に分けて実施されている [Pongplutong et.al. 2015]。本稿においては、BEDO の主要な取り組み地域である 1）Tung Jao 上流地域（チェンマイ郡）、2）Khlong Prasong 准地域（クラビ郡）、および USAID LEAF の支援を受けている 3）Mae Sa 流域（チェンマイ郡）の事例、の 3 つの事例についての取り組みの概要を見ることとする。

2．取り組み事例

1）Tung Jao 上流地域（チェンマイ郡）

チェンマイ郡、Mae Taeng 地域、Pa Pae 准地域、Tung Jao 流域において、2012 年から水源地域の PES の実施のための生態系サービスの評価などの準備活動が開始された。その結果、Baan Hua Lo という少数民族カレン族の集落が実施区域として選ばれた。Baan Hua Lo は山々の間に平らな土地が存在し、豊かな水を利用した棚田と住居が広がっている。集落民は森林に依存して生活してきており、森林と耕地は明確に分けられている。Tong Jao 流域はピン川に注いでいる。Tong Jao

には18の村落が存在し、総人口は5489人であり、その内訳はカレン族が3078人、リス族が980人、モン族が680人、ラフ族が5人、タイ人が746となっている。1557の世帯の68％の1058世帯が農業に従事し、28％の435世帯が雇用労働者となっている。年間の平均世帯収入は1000ドルであるが、一家族の平均貯金額は33ドルに過ぎない。

PESの販売者はBaan Hua Loの人々であり、購入者はチェンマイ水局（Provincial Waterworks Authority, PWA）とされた。PWAはMea Tang准流域の水を非処理水としてタイ国の北部地域に供給する水道水の生産に使用している。

具体的には、2013-2017年に、PWAが上流の販売者を雇用し、6つのチェックダムの建設と維持管理、40キロメートルの防火帯の設置と山火事防止のための森林巡視を行うという内容で、これらの活動に年間17万タイバーツ（5230ドル）が費やされた。これに対して75名のBaan Hua Loの人々が参加した。参加した人々はチェックダムの建設に年間1500バーツ（41ドル）の支払いを受け、平均で人々の年収の約9%の増加が図られた。

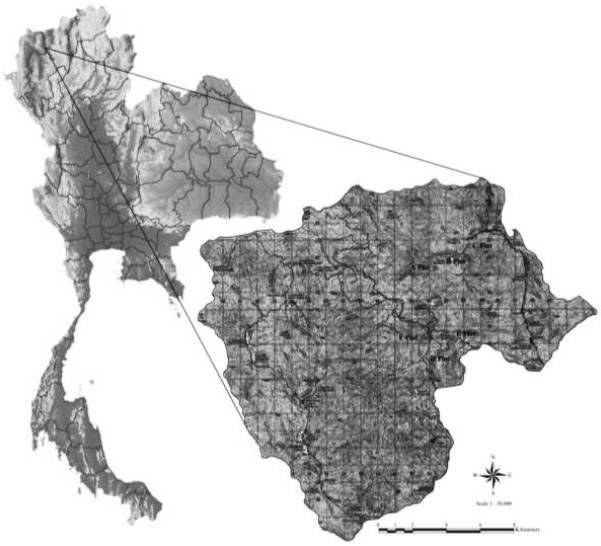

図1　Tung Jao upstream watershed, Pa Pae sub-district,
Mae Taeng district, Chiang Mai province of Thailand [BEDO. 2016]

また、2014-2016年には、PWAが2万バーツの予算で10名の集落民を雇用して植樹と植栽木の手入れを行った。また、チェックダムの維持管理、防火帯の設置、山火事防止のための森林巡視もあわせてこれらの人々の仕事となった。この結果、一人当たり年間2000バーツの追加収入となったが、これは人々の年収の12%に相当する額であった。著者は、2016年8月にPWAの担当者と会い、また現地の集落を訪れる機会があったが、集落の人々とBEDOやPWAなどの関係者との強い信頼が生まれているということが、現地での関係者との会話を通じて感じ取ることができた。

写真1　タイ・チェンマイ郡、Hua Lo集落の景観。棚田と森林の間に
清流が流れるカレン族の暮らす山あいの村（2016年8月撮影）。

写真2同。Hua Lo集落のカレン族の人々。Ms Pongplutong（BEDO/MONRE）（2016年8月撮影）。

本PESプロジェクトの現在までの実行の成果としてWerachai and Pree-ravee[2018]は、1）PWAにとって、持続可能な保全のための取り組みについて多くを学ぶことができたこと、2）プロジェクト関係者の強い結びつきや保全のためのネットワークが形成されたこと、3）PWAや集落住民が本PESのプロジェクトに強いコミットをしたことを挙げている。

2）Khlong Prasong准地域（クラビ郡）の事例

マングローブ地域の減少はタイも例外ではない。タイでは、1961年に3678900ヘクタールのマングローブが存在していたとされるが、経済開発、インフラ開発、ツーリズムなどによる開発のため、2007年のランドサットによる調査では229619ヘクタールと3割以上の減少が起こって

きているとされている。本プロジェクトの対象とされているクラビ郡においても同様な状況である。クラブ郡、Muang 地域、Khlong Prasong 准地域には、沿岸デルタ地域にマングローブが広がっているがエビ養殖の放棄地などによる喪失箇所が虫食い状に存在している。

図2　Krabi 周辺のマップ。沿岸部のマングローブの消失の状況が明瞭にわかる [BEDO. 2016]

BEDO は、美しいマングローブの景観によって恩恵を受けているホテル（Island Eco village resort）、ボート（Khao Kha Nab エコツーリズム）、オートバイ、レストランなどなどを購入者として組織化し、地元の保全組織（マングローブ森林保全協会）を販売者として、マングローブの修復活動を行う PES スキームを 2012 年に開始した。購入者グループがマングローブの修復のための PES 基金を設立し、購入者グループは毎月 15.38 ドルを支払いという契約を締結した。Pongplutong[2018] によればその後の支払いは順調に行われていない状況にあるため、ホテルの宿泊客も巻き込む仕組みも含めた何らかの改善策が必要な状況となっている。

写真3　タイ・クラビ郡デルタ地域には、かつてのエビ養殖跡地の荒廃地が多く存在している（2016年8月撮影）。

写真4　タイ・クラビ郡デルタ地域の外れにあるホテルでは、
近年沿岸部の木々の根が高波による浸食を受けている（2016年8月撮影）。

3）Mae Sa流域の事例（Aura-PES）

本地域は、1977年にユネスコMae Sa-Kog Maバイオスフィアリザーブに指定され、人々と自然、生態系、自然資源をステークホルダーの参加によって持続可能な取扱いを目指している地域である。Mae Sa流域はチェンマイ郡のMae Rim地域に位置し、チャオプラヤ川の8つの支流のうち最大であるピン川流域に注いでいる。流域面積は13,880ヘクタールあり、チェンマイ市の北西18-43キロメートルに位置している。上流部の平均傾斜は14-54％であるが、下流域になると0.64％と緩やかになっている。農業、ツーリズム、水企業、産業などの取水によって水量は変動が大きくなっている。

流域の約三分の二は森林地域となっており、50140ライ（57.8％）は保全林とされ、3436ライ（4％）は経済林である。森林以外の箇所は、フルーツの果樹園（39％）、商品農業（38％）、花生産地（9％）など市場目的の農業のために集約的に利用されている。流域の4つの准地域にある22ある村落のうち20の村落が農業を中心として村である。この20村落に住む3046世帯は、中流および下流に住むタイ人（76.6％）および上流の高地に住む少数民族のモン族（23.4％）である。43％（1309世帯）は農業に従事しており、平均で6.67ライを所有している。Mae Sa流域の森林は常緑熱帯降雨林である。森林減少が大きな問題となっており、1997年から2006年までの間に平均で8.63％の森林が減少し、流域の提供する生態系サービスの低下を招いている。森林減少が23.75％にも及ぶ小流域もある。

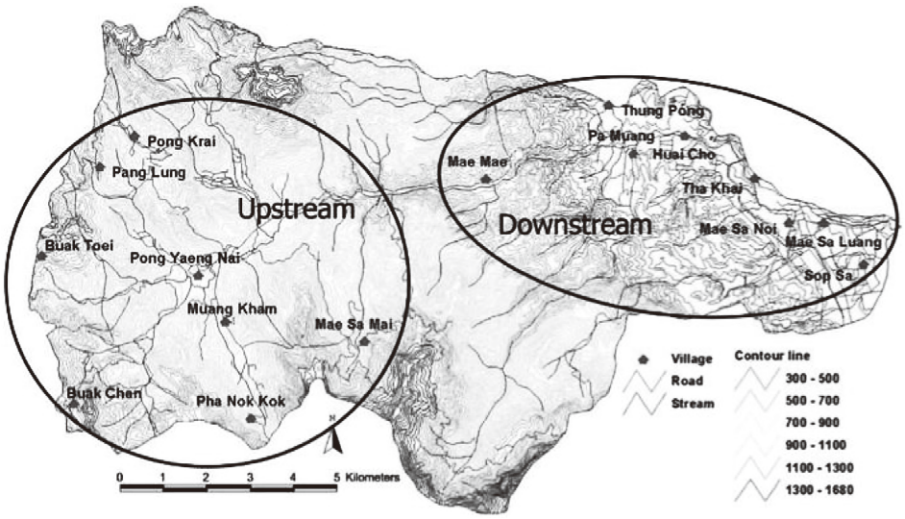

図3 Mae Sa Watershed と集落の状況 [出典：LEAF. 2016]

Mae Sa 流域においては、USAID LEAF プロジェクトの一環として国営企業（Tipco 食品。ミネラルウオーター AURA を販売、唯一の購入者）と Phongkhrai コミュニティ（販売者）が参加して PES スキームに取り組まれている。Pongkhrai コミュニティは Mae Sa 流域の 22 の村落のうちの一つであり、Pongkhrai 准流域の唯一のコミュニティによる Phongkhrai 准流域における 10 ライ（rai）の再植林が主要な活動である。2 年間で 1 ライあたりの樹木密度を 500 本以上とするために、1660 本の土着樹種のほかに 3340 本の苗木が植栽された。総費用は 20 万バーツ（2 万バーツ / ヘクタール、40 バーツ / 苗木）となっている。015 年 6 月以降、二年間の間、購入者から 20 万バーツが直接コミュニティに対して支払いが行われた。2015 年 6 月からモニタリングと実行の仲介を行うために Aura-PES 調整委員会が設置されている。

写真5　USAIDの支援による水源PESを実施しているTepco（AURA）国営企業。

写真6　AURA-PESの販売者であるPongkhraiコミュニティでの聞き取り調査の状況（2017年8月）

3．現在までの取り組みの評価

BEDOのPESの取り組みは2012年から開始されたばかりであり、実施内容やスケールは限定的･小規模であること、また、Aura-PESも極めて最近開始されたものであるため、これらのスキームの影響を総括するには未だ時期早尚であるが、Pongplutong[2018]は現在までの取り組みについて以下のように評価している。

① 環境管理への経済手法の適用についての、ステークホルダーの態度が積極的になってきているという変化が見られる。
② 地域のコミュニティの彼らの周りの自然資源と環境についての制御や権利についての考え方が積極的に変わった。
③ 地域の民間セクターが従来よりもずっと積極的に自然資源管理に参画するようになった。
④ 自然資源と環境管理が従来よりもずっと統合的に行われるようになった。

また、Pongplutong[2018]は2012年以降現在までの取り組みにおいて、以下の諸点が実行上困難であった点であるとしている。

① ステークホルダーのPESの考え方についての知識が不十分であったこと。
② PESサイトのアセスメントを行うにあたっての各種資源が不十分であったこと。
③ 潜在的な購入者の購入意思が不確実であったこと。
④ 金銭取引についての交渉技術が必要とされるが、サービスの供給者にはそれがないこと。
⑤ サービスの供給者にとって、産物のデザインと開発、プロジェクト提案書の作成、費用の試算などの能力が必要であること。
⑥ 土地の権利関係が複雑であること。
⑦ タイにおいては、PESの実行についての法的、経済的な動機づけがないこと。

を挙げている。

以上のような困難の経験をもとに、今後のPESのスムーズな実施のために必要な点として

Pongplutong[2018]が挙げるのは以下の二点である。

① ステークホルダーのPESの考え方やプロセスについての知識と技術についての訓練が必要である。それは以下のような点を含む。
- PESの考え方と実行プロセスについての実務的な知識
- データの収集方法とサイトアセスメント
- 生態系サービスの見極めと価値評価
- 産物のデザインと開発
- プロジェクト提案書の作成
- 費用試算
- 交渉技術

② パイロットサイトにおいてPESの実施のための動機が不足していることが問題であることから、中央政府レベルにおいてPESの動機を作ることが必要。環境目的環境手段法（Act on Environmental Measures for Environment）が制定されれば、PESなどの経済的手法が法定化されることになる。また、地方政府に環境管理を分権させる法律規制が制定されれば、地方政府のPESの実行の法的な動機を与えるとしている。

4. おわりに

Aerni[2016] は、ネオクラシカル厚生経済学に基づく Coasean タイプの PES 理論を古典的な PES とし、古典的な PES は地域における改革や事業性を無視していたと指摘し、それに代わるハイブリッド型の PES が増加してきていること、そしてこのタイプの PES が持続可能な地域づくりにとって大きな役割を果たすことを指摘している。Aerni はハイブリッド型の PES について明確な定義は行っていないが、従来の厳密な PES の理論に縛られないもので、上下流連携、公･民パートナーシップの醸成などによって PES が地域の新たな社会的ネットワークやビジネスの契機を提供し、地域の持続可能な発展につながるものを指してこのように称している。ハイブリッド型 PES では、農民に対しての補償は行うが、革命的な地域の起業などに対してよりオープンなものとなり、彼らの収入を増やそうという意思が生態系サービスを増やそうという公的な利害と一致し、財政的持続可能性につなげることができるとしている。一方、Engel and Wunscher[2015] は、PES スキームをその性格と購入者などによって、①受益者支払い型（Coasean タイプ）、②政府支払い型（Pigouvian タイプ）、③ハイブリッド型にタイプ区分している。ハイブリッド型は、市民社会組織、国際機関、政府などの第三者が一定の役割を果たしているものであり、多くの PES プログラムがこのタイプに含まれるとし、第三者の果たす役割は、所有権の明確化、取引費用の削減、ただ乗りや不完全な情報の克服など多岐に及んでいるとされる。この Engel and Wunscher. [2015] のハイブリッド型の PES は、第三者の仲介者の存在など構成の複雑性に着目した定義であるが、これらはいずれも Wunder[2005] の定義による古典的な完全型の PES ではなく、公･民パートナーシップなどが強調されているなどの点において、実質的には Aerni[2016] の云うハイブリッド型の PES とほぼ類似のグループを指す概念であると考えられる。

上記で見たタイにおいて実施されている PES も政府系機関である BEDO が仲介機関となって、地域のステークホルダーが購入者、販売者などの一定の役割を果たすなかで、地域の社会的ネットワークやビジネスの契機を提供することで地域の持続的な発展に資することを目指しているものであることから、Aerni[2016] や Engel and Wunscher[2015] の云うハイブリッド型の PES であるということができるであろう。今後、中央政府レベルにおける PES の法制化の動きも見込まれるところ、今後の動向に注目したい。

注） 本内容の一部は、上智大学ブランディング事業：「河川域」をモデルとした学融合型国際共同研究の成果である。

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福島第一原発建屋内のたまり水の放射性汚染状況の解析（5）

大坪　国順

概要

本稿は、福島第一原発建屋内のたまり水の放射性汚染について2018年10月末までの状況を明らかにしようとするものである。東京電力からの原子炉建屋内のたまり水の貯蔵および処理の現状についての報告資料を整理した結果、この一年間で新たに判明したことは以下のようである。

（1）原子炉冷却に伴う放射性汚染水の処理は順調に進んでいる。現在、一時貯蔵タンクに貯留されている約110万m^3の汚染水の約86％は、トリチウムを除く全ての放射性物質が除去された状態にある。しかし、2018年内にその比率が100％になる見込みは薄い。

（2）たまり水中のセシウム137とトリチウムの放射線強度は、事故当時に比べて100分の1程度まで低減していたが、2016年10月以降は上昇に転じ、2018年7月以降にようやくその上昇が止まった感がある。特に、トリチウムは、初期放射線強度の約1/2にまで上昇し、新たな懸念材料となっている。両者の放射線強度上昇の主な要因は、建屋に流入する地下水量を100 m^3/day程度まで絞りこんだことと、主建屋（原子力建屋とタービン建屋）以外に貯まった汚染水をプロセス建屋もしくは高温焼却炉建屋に移送したためと考えられる。セシウム137については放射線強度上昇の対策が講じられているが、トリチウムについては対策がない。

（3）塩素イオン濃度については、変動はあるものの2016年11月までに200 ppmまで下がった。2016年12月になって上昇に転じ、2018年8月には700 ppmを記録し、その後上昇が止まった感がある。2016年1月以降の上下変動のパターンは、基本的にはセシウム137やトリチウムの放射線強度の変動パターンと同様なものとなっている。

Analysis of time variations of radioactive substances in the ponding water in the main buildings of the Fukushima Daiichi Nuclear Power Plant (5)

Kuninori Otsubo

Abstract

This paper shows the latest results of time variations of radio-active substances in the ponding water in the main buildings of the Fukushima Daiichi Nuclear Power Plant. It has passed almost one year from the previous publishing of my paper on this issue. During the period, the weekly data of cesium 137, tritium, and chloride ion of the ponding water have been kept reported by Tokyo Electric Power Co. Ltd. Time variations of the three parameters have shown the following tendencies.

(1) At present, about 1,100,000 m^3 of the contaminated water has been reserved in the tanks and all radioactive substances except for tritium have been removed from 86% of the reserved water.

(2) The strengths of radiation of cesium137 and tritium have been decreasing to one-hundredth of the initial strengths up to October, 2016, then, they turned to increase and kept increasing until now. Especially the degree of increase of tritium has been remarkable. The causes of those increases are considered that the daily amount of groundwater flowing into the main buildings has been decreasing to 100 m^3 from 400 m^3 and some amount of highly contaminated water ponding in other buildings has been transported to the pond in the main buildings. As for cesium137, a countermeasure has been undertaken; however, as for tritium, there was no effective countermeasure for the increase.

(3) The concentration of chloride ion decreased to 200 ppm momentary and began to increase as of March, 2017 and kept increasing up to now. As of February, 2016, time variation pattern of chloride ion concentration has been similar to those of the strengths of radiation of cesium137 and tritium except for the period of between October, 2016 and March, 2017.

福島第一原発建屋内のたまり水の放射性汚染状況の解析（5）

はじめに

2011年3月11日から既に7年半が過ぎた。本稿は、福島第一原発建屋内のたまり水の放射性汚染水について2018年10月末までの状況を明らかにしようとするものである。

同じテーマでの研究報告は本稿で5稿目となる。本テーマを取り上げた最初の動機は、たまり水の放射線汚染強度と塩素イオン濃度の時間的経過を追跡することによって、燃料デブリの所在が追跡できないかと考えたからである。これまで検討してきたところによれば、原子炉内の燃料デブリの物理化学的状態は安定しており、当初生成した放射性物質のうち、初期に溶け出さなかった残留分がゆっくりと冷却水中に放出されていると推察される。しかし、全ての燃料デブリが格納容器内に収まっているということの確たる論証は得られていないことも事実である。

この一年で、放射性汚染水の挙動に関して前報までの考察をさらに裏付ける観測データが得られる一方で、前報までの考察内容に変更を迫られる報道資料データも掘り起こした。本稿ではこれらについて整理して考察を加えた。

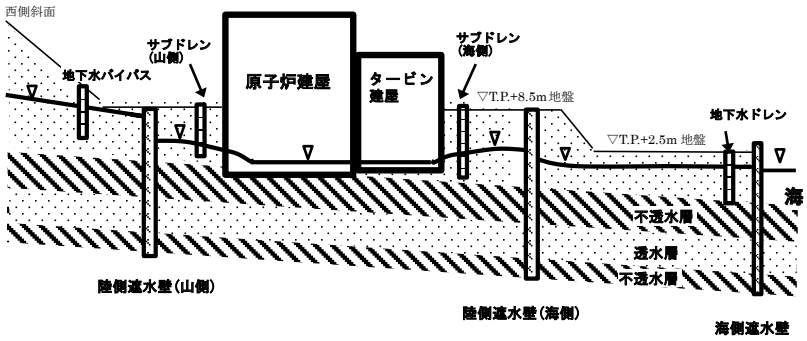
本稿での検討に使われたデータについては全て東京電力から公表されているものである。原子炉建屋内の地下に存在する水（たまり水と呼ばれる）の汚染状況については、東京電力からプレス・リリース資料として毎週公表されている。その資料には、毎週の冷却水量と処理水量（セシウム137と塩分）、地表一時貯蔵タンク内の汚染水の累積貯蔵量、併せて、たまり水のセシウム137の放射能（ここでは放射線強度と呼称）や塩素イオン濃度が公表されている[1)]。たまり水のトリチウム放射性強度については、「福島第一原子力発電所周辺の放射性物質の分析結果―水処理設備の放射能濃度測定結果―」として毎月インターネット上で更新されている[2)]。

これらのデータを整理し、2018年10月までのセシウム137とトリチウムの放射線強度や塩素イオン濃度の時間変化について、この一年間で新たに判明したことを中心に検討を加えることとする。

2．原子炉建屋周辺の地下水の概要

（1）建屋周辺の断面の概略と地下水制御施設の概要

図－1は福島第一原発の建屋（1～4号機）周辺の断面（東西方向）と地下水制御施設の概要を模式的に示したものである。原子力建屋（以下、R/Bと呼ぶ）とタービン建屋（以下、T/Bと呼ぶ）は不透水層の上に建造されている。不透水層の下の透水層は被圧地下水層となっている。R/Bの山側近傍とT/B海側近傍に数十本に及ぶサブドレンが設置されている。サブドレンを囲む形で陸側遮水壁（凍土壁）が複数の不透水層を突き抜ける形で設置されている。更に西の山側には地下水バイパス施設が設置されている。一方、T/B海側のT.P.+2.5 m（O.P.+4 m）地盤には地下水ドレンが数多く設置されており、更にその海側には海側遮水壁（鉄鋼矢板）が張り巡らされている。（ここで、T.P. (Tokyo Peil)：東京湾平均海面、O.P.：現地平均海面である。）



図－１　福島第一原発の建屋周辺の断面と地下水制御施設の模式図

(2) T.P. +8.5 m地盤における地下水の挙動

東京電力の資料[3]によれば、1, 2, 3, および4号機が立地するT.P.+8.5 m地盤では、西の山側斜面から約1.4 kmの幅で約1,000 m^3/dayの地下水が流れ込むとされる。原発事故前は、原子炉主建屋を囲むサブドレンにより約800 m^3/dayが揚水されて海に排出され、残りの約200 m^3/dayの地下水が海に自然流出していたものとされる。

現在は、凍土壁の西の山側に掘削された12本の地下水揚水用井戸から、300～350 m^3/day程度の地下水が揚水され、放射性濃度をチェックして高い場合は目標濃度以下に浄化された上で、R/BとT/Bを迂回して海に排出されている[4]（地下水バイパス）。

2015年9月以降、サブドレンは主建屋（R/BとT/B）周辺の地下水位を調整するために常時稼働している。サブドレンで汲み上げられた地下水は、水質が運用目標未満まで浄化された後に海に排水される。

表－１　凍結開始前からの陸側遮水壁内側(T.P.+8.5m地盤)の水収支の変遷

	2016年 1月−3月 凍結開始前	2017年 9月 凍結完了時	2018年 9月 現在
	m^3/day	m^3/day	m^3/day
凍土壁内側への地下水流入量　F	810	630	400
降雨涵養量（建屋周辺地盤）　E_1	−50	−105	−110
降雨涵養量（建屋屋根）　E_{1r}	−30	−65	−70
サブドレン揚水量　A	420	510	440
閉合範囲外への鉛直移動量　D	0	0	0
建屋への流入量　B	180	120	140
凍土壁から海側への地下水流出量　C	310	110	60
地下水変動への寄与量　E_2	−20	50	−60
$A+B+C+D+(E_1+E_1r) + E_2$	810	620	400

＊ここで、A：実測値、B：実測からの推定値、C：実測からの推定値、D：仮定、(E_1+E_{1r})：実測からの推定値、E_2：実測からの推定値（－値は地下水位上昇を示す）

＊＊建屋屋根降雨の内、周辺地盤への浸透分がE_{1r}であり、屋根損傷部からの建屋直接流入分はBに含まれる

地下水位データ、雨量データ、及び、サブドレン揚水量の実測値などを基に推定された三期間（凍結開始前、凍結完了時、及び、2018年9月）のT.P.+8.5ｍ地盤における水収支は、表－1のようになる[5]。凍結完了により、サブドレンの揚水量は400 m^3/day程であまり変化がないが、凍土壁内側への地下水流入量は800 m^3/dayから400 m^3/dayに減少し、それに応じて、主建屋への地下水流入量は約50 m^3/day、また凍土壁から海側への地下水流出量は約250 m^3/day減少した。

(3) T.P. +2.5ｍ地盤層における地下水の挙動

T/B東側のT.P. +2.51 m地盤層（原子炉建屋の海側地盤）には数多くの自由地下水観測井が設置されている。セシウム137は地層を移動中に土壌粒子に吸着されるのでそれほど高い濃度は検出されないが、トリチウム、全β及びストロンチウムが無視できない濃度で検出される観測井が点在する。下部透水層の水質結果については、2014年7月の公表資料[6]以後は見当たらないので、前報で述べた懸念は払拭されない[7]。

地下水位データ、降水量データ、ウェルポイント揚水量、及び地下水ドレン揚水量の実測値などを基に推定された三期間（凍結開始前、凍結完了時、及び、2018年9月）でのT.P. + 2.5 ｍ地盤の水収支は、表－2のようになる[8]。凍土壁の効果により、凍土壁から海側への地下水流出量が250 m^3/day程度減少した結果、ウェルポイントや地下水ドレンからの揚水量が220 m^3/day程度減少した。

表－２　凍結開始前と現状の陸側遮水壁外側(T.P.+2.5m地盤)の水収支の評価

	2016年 1月−3月 凍結開始前	2017年 9月 凍結完了時	2018年 9月 現在
	m^3/day	m^3/day	m^3/day
凍土壁から海側への地下水流出量　C	310	110	60
降雨涵養量（T.P.+2.5m 地盤）　R	−40	−80	−60
ウェルポイント汲み上げ量　W	80	20	10
地下水ドレン汲み上げ量　G	240	150	90
閉合範囲外への鉛直移動量　D	0	0	0
海への地下水流出量　S	30	30	30
地下水変動への寄与量　E_g	0	0	−10
R ＋ W + G + D + S + E_g	310	120	60

＊ここで、R：実測からの推定値、W：実測値、G：実測値、D：仮定、S：実測からの推定値、およびE_g：実測からの推定値（－値は地下水位上昇を示す）

3. 放射性汚染にかかる諸水量の概要

(1) 原子炉内での放射性汚染水の発生

原子炉は冷却水により低温安定状態に保たれているとされるので、燃料デブリから新たな各種放射性物質の生成はないことになる。現在は、当初生成したもののうち、初期に溶け出さなかっ

た残留分がゆっくりと冷却水中に放出されていると考えられている（長期FPソースタームと呼ばれる[9]）。

(2) 原子炉冷却水量と放射線汚染処理水量の推移

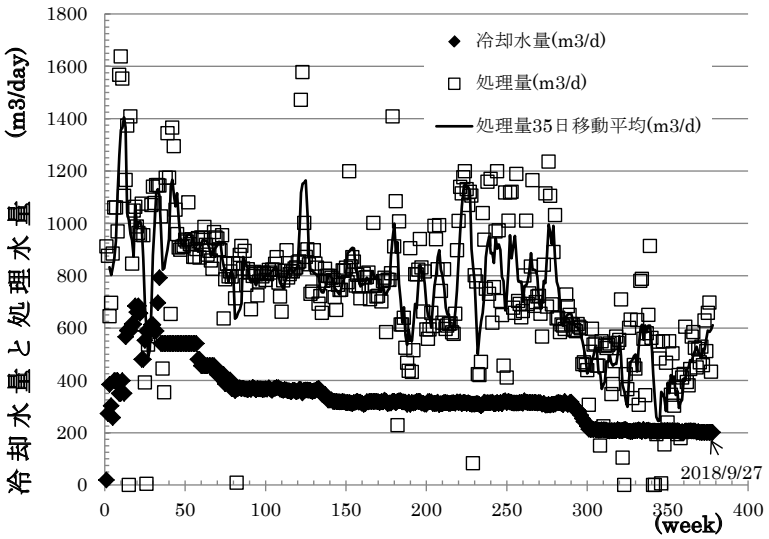
2011年6月以降、循環式冷却システムが正式稼働している。主建屋（R/BとT/B）内の汚染水が周辺の地層に漏れ出さないように、周辺地下水位はT.P.+2.5 m (O.P.+4.0 m)以下にならないように、主建屋内の滞留槽の水位はT.P.+1.5 m 前後に保持するようにポンプにより操作がなされてきた。

循環冷却システムのコンパクト化の一環として、2016年3月から1号機R/Bの水位をT.P.+1.7 m以下まで低下させ、1号機のR/BとT/Bの間で汚染水が連結しない状況を維持している。東京電力は、将来的には3つの原子力建屋の循環冷却システムを独立させるとしている。

図－2は、2018年9月までの冷却水量とセシウム除去処理水量の週変化[1]を示したものである。図中の実線は処理水量の35日移動平均値である。冷却水量は、4つの段階を経て2017年3月下旬以降は約205 m^3/dayで落ち着いている。一方、セシウム除去処理水量の方は週変動が大きい。その原因として、メンテナンスで装置停止があること、三つの除去装置を用いることなどが考えられる。

表－3は、放射線汚染水の発生量の要因別実績の変遷をみたものである。汚染水発生量の総量は、2016年度の400 m^3/dayから2018年度4月−7月期間の190 m^3/dayに半減している[10]。減少の最大の要因は、T.P.+2.5 m地盤からの建屋移送量が175 m^3/dayから15 m^3/dayに減少したことである。その原因は、凍土壁の凍結完了である。凍土壁から海側への地下水流出量が310 m^3/dayから60 m^3/dayに大幅に減少したことが大きい。降水起源の建屋流入量も180 m^3/dayから120 m^3/dayに減少している。2018年内に建屋流入地下水量を100 m^3/dayに抑制する目標が達成されたことになる。

東京電力は、サブドレンの水位低下、トレンチ閉塞、T.P.+8.5 m地盤海側（陸側遮水壁外）のカバー・フェーシング、薬液注入水の代替などにより、2020年中に汚染水発生量を150 m^3/dayまで低減させたいとしている[11]。

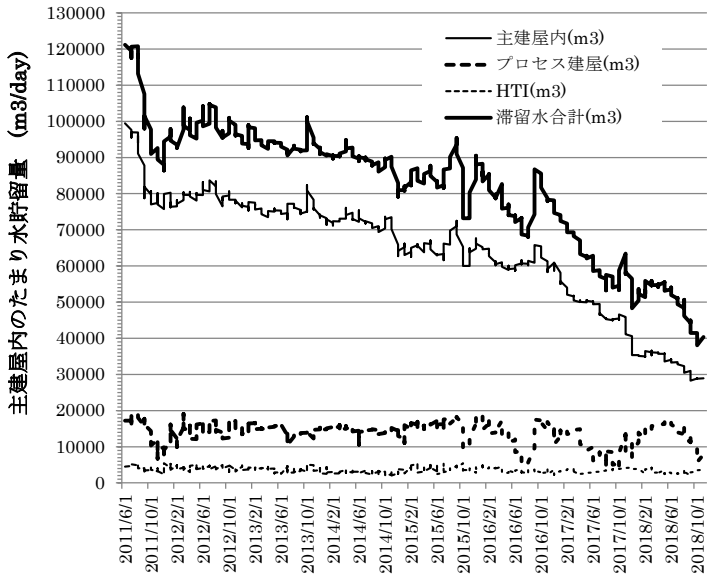


図－2　原子炉への冷却水供給量とセシウム137汚染水の処理量の週変化

表－３　放射線汚染水の発生量の要因別実績の変遷

汚染水発生の要因	2016 年度 実績 (m^3/day)	2017 年度 実績 (m^3/day)	2018 年 4 月－7 月 (m^3/day)
建屋流入量（地下水等の流入）	150	95	90
建屋流入量（屋根損傷箇所からの流入）	30	35	30
T.P.+2.5m 盤からの建屋移送量	175	35	15
薬液注入量	20	20	15
廃炉作業に伴い発生する移送量	25	35	35
汚染水発生量	400	220	190
参考：降雨量　(mm/d)	3.7	3.8	3.6

図－3は、主建屋内のたまり水量、プロセス建屋内のたまり水量、高温焼却炉建屋（以下、HTIと呼ぶ）内のたまり水量、およびそれらの合計水量の週変化を示したものである[1)]。プロセス建屋とHTIのたまり水量は、変動はあるものの特段の増加傾向も減少傾向もないといえる。一方、主建屋内のたまり水量には明らかな減少傾向が認められる。特に、第275週あたり（2016年10月）からの減少率が大きい。それを反映してたまり水総量もほぼ同様な傾向を示している。



図－３　主建屋内のたまり水の貯留量の週変化

図－2の基となったデータから2017年度の処理水量の日平均値を求めると約440 m^3/dayである。一方、図－3の基になったデータから2017年度の建屋内滞留水日低減量の平均値を求めると約30 m^3/dayとなる。この値と日冷却水量205 m^3/dayおよび汚染水発生量平均値220 m^3/day（表－3）の

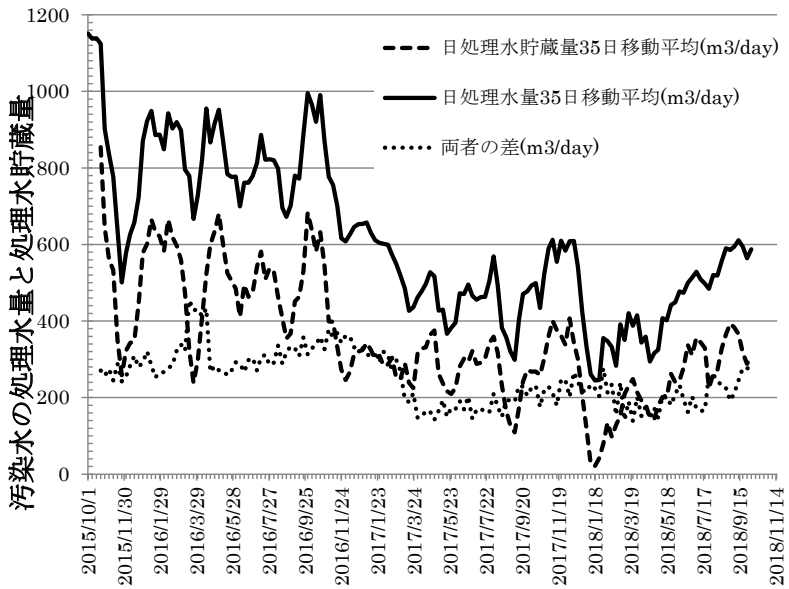
合計量は日処理量に対応している。

2018年4月中旬から、滞留水中の放射強度を低減させることを目的に、セシウム除去装置による処理水の余剰分を直接主建屋に注水するライン（滞留水浄化設備）が稼働している。この期間の日冷却水量は205 m^3/dayであり、主建屋内滞留水の低減量の平均値は約45 m^3/dayである。汚染水発生量平均値を190 m^3/dayとすると、三者の合計量は約440 m^3/dayとなる。この合計量と日処理水量（510 m^3/day）との差、約70 m^3/dayが滞留水浄化設備に回されていることになる。今後、この量がどの程度になるかは不明であるが、現在の倍程度に増加する余地は十分にあると考えられる。

(3) 一時貯蔵タンクの処理水量の推移

セシウム除去処理水は塩分が除去された後、一部は循環式冷却システムを維持するために冷却水として循環され、残りが系外に貯えられることになる。貯蔵される水は、セシウム137とストロンチウム以外の各種放射性物質により汚染されているので、多核種放射性物質除去設備（以下、ALPS等と呼ぶ）でトリチウム以外の各種放射性物質が除去された上で一時貯蔵タンクに保存される。

図－4に汚染水の日処理水量と日処理水貯蔵量の推移を示した。



図－4　汚染水の日処理水量と日処理水貯蔵量の推移

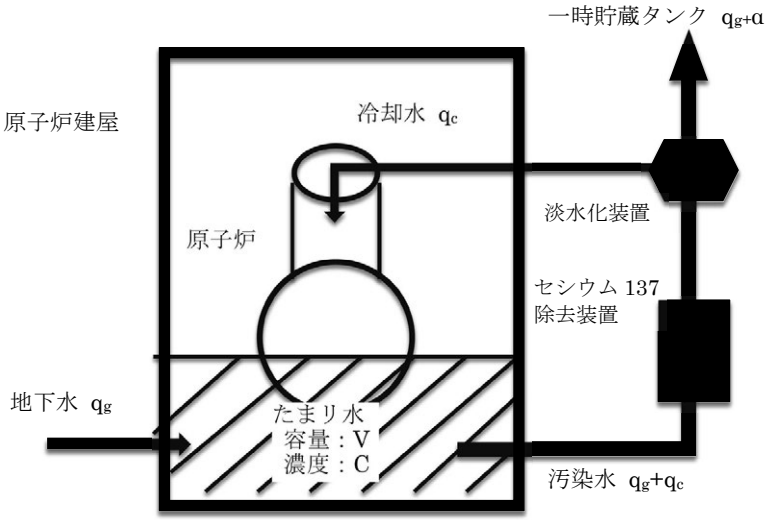
一時貯蔵タンクに貯蔵される処理水の増加速度（日処理水貯蔵量）は、大きく変動するが、セシウム137日処理水量の変動に良く対応し、2017年4月以降の平均値は約260 m^3/dayとなっている。

2018年10月現在、ALPS等により処理された水の量は約94万m^3、ストロンチウム処理水（塩分とセシウムとストロンチウムのみが除去された汚染水）の量は約15万m^3となっている[12)]。

4. 原子炉建屋内の汚染水の濃度変化の解析

(1) 循環式冷却システムの概要

図－5は循環式冷却システムの概要説明図である。原子炉は現在は毎日205 m^3程の水で冷却されている。冷却に使われた水は、一旦、各R/BおよびT/Bの地下室に貯留される。両建屋内のたまり水は、設定水位を維持するために地下水流入分と冷却水分に相当する量がプロセス建屋もしくはHTIに移送される。これらには状況に応じて主建屋以外からも汚染水が移送されてくる（表－3を参照のこと）。これら建屋に滞留する汚染水はポンプアップされ、セシウム137とストロンチウムが除去された後、塩分が除去される。

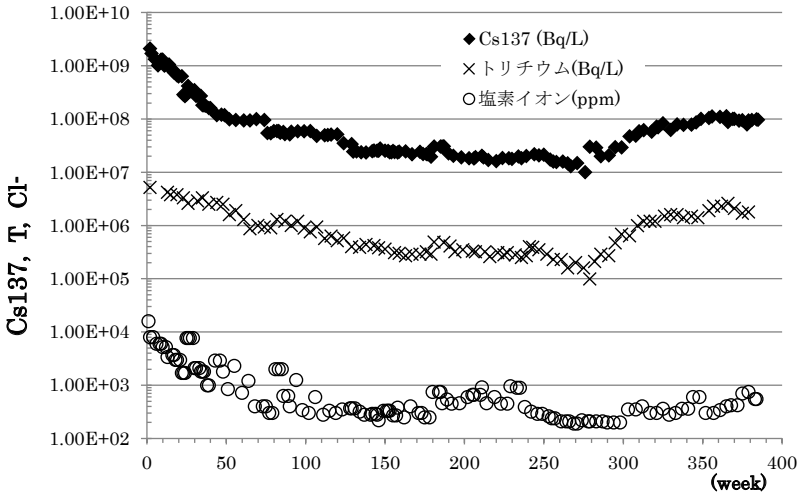


図－５　循環式冷却システムの概要説明図

2018年4月初旬までは、図－5のように、処理水の一部は冷却水として循環され、残りが系外の一時貯蔵タンクに貯えられてきた。しかし、2018年4月中旬以降は、処理水の余剰分を直接主建屋に注水するライン（滞留水浄化設備）も併せて稼働している。

(2) 原子炉たまり水中の汚染物質の濃度（強度）の推移

滞留タンク中のセシウム137（Cs_{137}）の放射線強度と塩素イオン（Cl^-）濃度については、プレス・リリース用資料として毎週公表されている。ここでは、2011年6月15日から毎週公表されている385週分のデータを整理した結果を示す[1)]。汚染水のサンプリングと分析は、毎週ではなく、およそ1ヶ月間隔でなされている。トリチウム（T）の放射線強度の時間変化については、2011年9月から東京電力のWebサイトに約1ヶ月間隔で公表されるデータを用いる[2)]。図－6は、Cs_{137}およびトリチウム（T）の放射線強度とCl^-濃度の週変化を半対数紙表示（濃度値を対数で表示）で示したものである。Cs_{137}放射線強度、およびCl^-濃度は2011年7月5日から2018年11月1日まで、T放射線強度は2011年9月20日から2018年9月20日までとなっている。なお、300週以降のHTIのCs_{137}濃度については、東電のWeb上での資料2)に記載されている値で代用した。



図－６　セシウム137強度、トリチウム強度および塩素イオン濃度の週変化

1）セシウム137の放射線強度

図－6によれば、Cs_{137}の放射線強度は2011年7月5日には2.1×10^{9} Bq/Lあったものが半対数紙表示で直線的に低減し、第80週あたりから低減率が小さくなり、第125週辺りからは一定値（約1.9×10^{7} Bq/L）に漸近していく様態を示した。その後、第240週辺り（2016年2月）から、再び、下降し始め第278週辺り（2016年10月中旬）には1.0×10^{7} Bq/Lまで急落した。

しかし、第279週には、3.0×10^{7} Bq/Lに跳ね上がった。原因は、第1号機T/Bの復水器内の高濃度汚染水をプロセス建屋に移送したためである[13)]。その後濃度上昇が続き第360週辺り（2018年6月）には1.14×10^{8} Bq/Lまで達し、それ以降1.0×10^{8} Bq/L前後で推移している。

図－6に示されるCs_{137}の放射線強度は、プロセス建屋とHTIのたまり水の放射線強度と滞留量から求めた平均値である。第278週以前は、両建屋に移送される汚染水は主建屋内のたまり水だけだったので、この平均値は主建屋内のたまり水の放射線強度と考えてよいが、第279週以降は主建屋以外からの汚染水が移送されて来ているので、平均値は厳密には主建屋たまり水のCs_{137}濃度ではない。

2）トリチウムの放射線強度

図－6にはたまり水に含まれるTの放射線強度の変化も示されている。分析に用いられたたまり水は、淡水化装置の入口で採取されたものである。T放射線強度は、2011年9月20日には4.2×10^{6} Bq/Lあったものが半対数紙表示で直線的に低減し、第160週（2014年7月上旬）あたりから約3.0×10^{5} Bq/Lに漸近しつつあった。その後、第250週辺りから低減が続き、第278週目採取サンプルでは1.0×10^{5} Bq/L迄下がった。その後上昇に転じ第360週辺り（2018年6月）には2.6×10^{6} Bq/Lまで上昇した。その後2.0×10^{6} Bq/L T前後で推移している。この値は、トリチウムの初期汚染濃度の約1/2に達し、懸念材料の一つになりつつある。前報の検討を訂正し、トリチウムの場合も第279週以降の図－6の値は主建屋内たまり水の放射線強度を正しく反映していない。

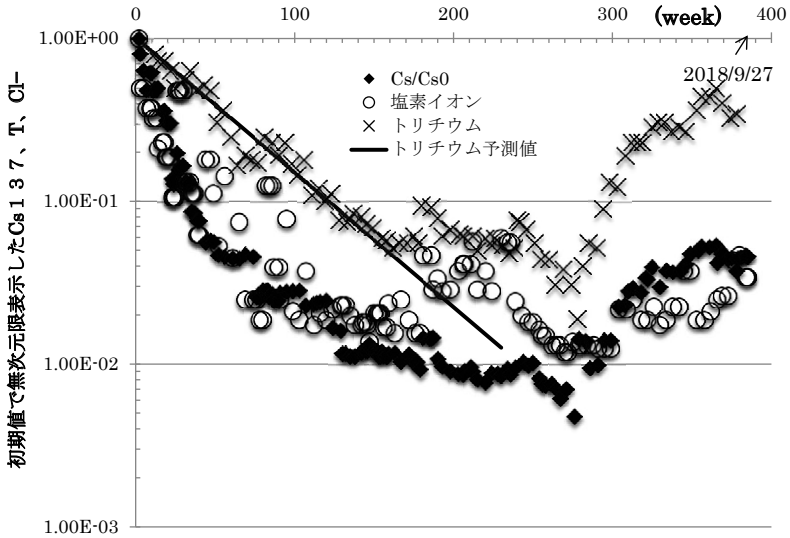
3）塩素イオン濃度

Cl^-濃度は、2011年7月5日に16,000 ppmあったものが、半対数紙表示で直線的に低減し、第80週(2013年1月1日)あたりから約300 ppmに漸近していく傾向があったが、第180週（2014年12月9日）あたりから徐々に上昇に転じて、第230週辺り（2015年12月）には960 ppmを記録した。しかし、第239週（2016年1月14日）を境に低下し続け、第280週辺り（2016年11月）の時点では約200 ppmまで下がった。その後、約350 ppm前後まで上昇し、第340週（2017年12月）辺りからは650 ppmを越えるようになった。

図－6で示されているCl^-の濃度は、淡水化処理装置入り口で採水された汚染水の濃度である。第278週以前は、プロセス建屋とHTIに移送される汚染水は主建屋内のたまり水だけだったので、図－6のCl^-濃度は主建屋内たまり水のCl^-濃度と考えてよい。しかし、第279週以降は主建屋以外からの汚染水がプロセス建屋もしくはHTIに移送されてくるので、図－6のCl^-濃度は主建屋内のたまり水のCl^-濃度そのものではない。

(3) たまり水の汚染物質濃度変化の無次元表示

図－7は、Cs_{137}およびTの放射線強度とCl^-濃度の週変化をそれぞれの初期濃度値で無次元化して示したものである。



図－7　無次元表示の塩素イオン濃度、セシウム137放射線強度、およびトリチウム放射線強度の週変化（初期値で無次元化）

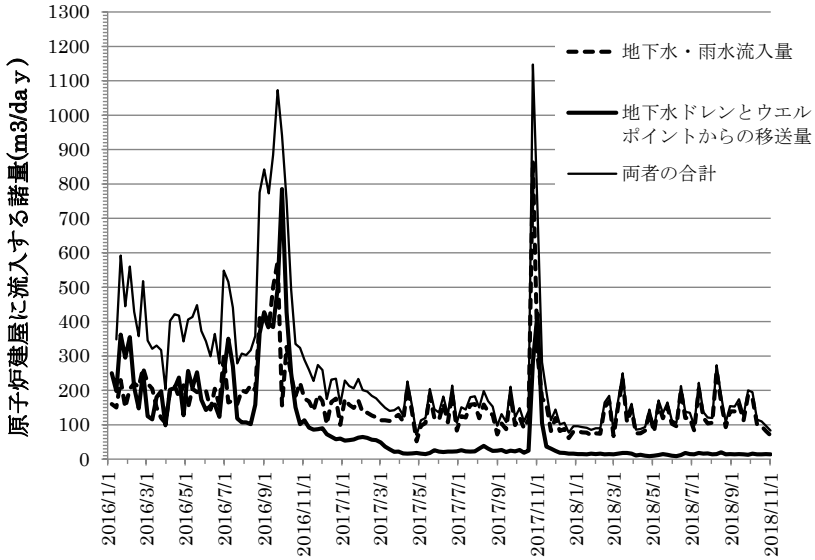
Tの放射線強度の場合、第150週までの減水率を用いて2011年7月5日の値を逆算しその値を初期値とした。図中の直線は、東京電力が、長期FPソースタームがないと予測したTの放射線強度の週変化[14]の無次元表示である。第160週以降は実測値との乖離が大きくなっており、長期FPソースタームの存在を示唆している。

三者の第330週までの週変化については、過去4報（福島第一原発建屋内のたまり水の放射性

汚染状況の解析（1）～（4）[15), 16), 17), 7)]も参照されたい。

1）たまり水の汚染物質濃度変化の要因に関する考察

図－8は、原子炉建屋内に流入する地下水・雨水水量、および、地下水ドレンとウェルポイント（海側遮水壁の西側に隣接）からの建屋への移送量の推移を示したものである。作図に用いたデータは、2016年1月～2018年10月の東京電力からの報道配付資料である[18)]。著者は、地下水ドレンとウェルポイントから汲み上げられた地下水は、専用の浄化処理装置によりトリチウム以外の放射性物質が除去された後に港湾内に排水されていると考えていたが、実際は、多い時には800 m^3/dayを越す汲み上げ水が原子炉建屋に移送されていた。



図－8　地下水ドレンとウェルポイントからの原子炉建屋への移送量の推移

これまでこの配布資料を見逃していた理由は、東京電力の廃炉プロジェクトに関するWebサイトにおいて、「地下水が原子炉建屋等に流れ込むことで増加する汚染水の量を減らすため、地下水ドレンを設置して、汚染源を『漏らさない』取り組みを行っています。この取り組みでは、まず、地下水ドレンは護岸の井戸が海側遮水壁でせき止めた地下水をくみ上げます。くみ上げた地下水は、浄化処理を行い、排水基準を満たしていることを確認後に、海洋へ排水することで、原子炉建屋等に近づく地下水の量を減少させます。」と説明しているためである[19)]。

図－8において、地下水・雨水流入量と地下水ドレン・ウェルポイントからの移送量のスパイク状の急増減は、台風による大雨に起因する。2016年1月～9月までは、地下水・雨水流入量は約200 m^3/day前後で変動している。2016年12月初旬の凍土壁陸側部凍結開始後は、これらの流入量は約180 m^3/dayから約120 m^3/dayに低減している。流入量が変動するのは降水が原因である。

地下水ドレンやウェルポイントからの汲み上げ水が建屋へ移送されるようになったのは、2015

年10月に海側遮水壁が完成した後である。この壁により海への流出地下水量が大幅に抑制されたため、T.P.+2.5 m地盤層の地下水位が上昇して地下水ドレンやウェルポイントからの汲み上げ量が急増し、一部をプロセス建屋やHTIに移送して処理する必要が生じた。2016年1月～9月までは、移送量は変動しながら300 m^3/dayから100 m^3/dayへと低減している。低減の原因は、2016年3月に凍土壁海側部の凍結が開始されT.P. +2.5 m地盤層への地下水流出量が減少したためと考えられる。2016年10月以降は、移送量は100 m^3/dayから20 m^3/day弱に低減している。

以下では、図－8の結果を踏まえて、図－7に示されたCs_{137}、およびTの放射線強度とCl^-濃度の挙動について、第230週（2015年11月）以降の動向を中心に考察する。

2）セシウム137とトリチウムの放射線強度の週変化

第160週以降のTの放射性強度の上下動のパターンは、Cs_{137}のそれによく対応している。

前報では、Cs_{137}およびTの放射線強度とCl^-濃度が第250週辺りから第278週まで低減したことにふれ、その原因は不明とした。その理由として、放射性物質の溶出率γが変化したとは考えにくいこと、また、汚染度の低い水が原子炉建屋に継続的に移送された形跡が見当たらないことを挙げた。しかし、図－8から、第230週辺りから第270週(2016年8月中旬)辺りまで、地下水ドレン汲み上げ水とウェルポイント汲み上げ水が、300～100 m^3/dayの規模でプロセス主建屋とHTIに移送されていたことが分かった。この移送水のCs_{137}とTの放射線強度は、前者が100 Bq/L以下、後者が300～800 Bq/Lであるので[20]、移送水は建屋内のたまり水の放射性物質濃度を薄くする効果がある。これが、この期間中Cl^-濃度とCs_{137}とTの放射線強度が下降した理由と考えられる。

第278週辺り（2016年9月中旬）でCs_{137}とTの放射線強度が急降下したのは、台風により放射線汚染の低い大量の地下水・雨水の流入と地下水ドレンとウェルポイント汲み上げ水の移送が生じたためと考えられる。

第279週に入るとCs_{137}とTの強度が跳ね上がり、上昇は第365週（2018年6月中旬）まで続いた。これについては、東京電力より事前に予測されていた。（第1号機T/B復水器内の高濃度滞留汚染水をHTIに移送したためCs_{137}とTの放射線強度が上昇するというもの[21]。）

前報の考察では、Cs_{137}の放射線強度は$(q_bC_b+\gamma)/q_{t1}$に、Tの放射線強度は、$(q_bC_b+\gamma)/(q_{g1}+q_{r1})$に漸近してゆくことになるとした。（ここで、$C_b$：主建屋以外から移送される汚染水の放射性物質の濃度、q_b：主建屋以外から移送される汚染水の量、γ：放射性物質の溶出率、$q_{t1}=(q_{c1}+q_{g1}+q_{r1}+q_b)$、$q_{c1}$：第280週以降の冷却水量、$q_{g1}$：第280週以降の地下水流入量、および、$q_{r1}$：第280週以降の屋根破損部からの降水流入量である。）Cs_{137}とTは第360週辺りまではそれぞれの漸近値に向かっていたと考えられる。

2018年4月中旬から滞留水浄化設備が稼働している。滞留水浄化設備による直接注水量をq_dとすると、この設備の稼働によりCs_{137}の放射線強度の漸近値は$(q_bC_b+\gamma)/(q_{t1}+q_d)$となり、放射線強度の改善（下降）が期待される。しかし、第384週の時点ではあまりそれが明確ではない。

3)　塩素イオン濃度の週変化

第230週以降のCl^-濃度の週変化パターンは基本的にはCs_{137}やTのそれらと同様である。ただし、第278週辺り（2016年9月中旬）でCl^-濃度はCs_{137}とTの放射線強度に比してほとんど急降下して

いない。その理由としては、地下水ドレンやウェルポイントからの移送水のCl^-の濃度が、この時期のプロセス建屋とHTIのCl^-の濃度に近く希釈効果が現れなかったということが考えられる。残念ながら、地下水ドレン汲み上げ水とウェルポイント汲み上げ水のCl^-濃度の測定値が公表されていないので検証は出来ない。

前報では、今後のたまり水のCl^-濃度は、$(q_{g1}C_{g1} + q_bC_b)/q_{t1}$で決まるとした。（ここで、$C_{g1}$：第280週以降の流入地下水の$Cl^-$濃度である。）第360週辺り（2018年6月）ではこの漸近値に向かっていたと考えられる。

滞留水浄化設備の稼働により、Cl^-濃度の漸近値は$(q_{g1}C_{g1} + q_bC_b)/(q_{t1}+q_d)$となり、濃度の改善（下降）が期待されるが、$Cl^-$濃度の場合も第384週の時点ではあまり明確ではない。

5. 汚染水対策にかかる考察

(1) 循環式冷却システムの今後

1）1～4号機たまり水をセシウム除去装置へ直送する配管システム

東京電力は、HTIやプロセス建屋に貯留される高濃度汚染水を冷却水の循環系統から除外するため、1～4号機たまり水を移送ポンプによりSARRYなどへ直送する移送配管設置工事を実施している[21)]。この新移送システムが稼働し始めれば、HTIとプロセス建屋内の貯留水の放射性物質の強度は1～4号機内のたまり水の放射性物質の強度を反映するものではなくなるので、新移送システムの稼働後は、1～4号機たまり水を直接サンプリングしたデータも公示が求められる。

2）1～4号機滞留水浄化設備の設置

東京電力は、2016年10月に冷却水循環システムの稼働条件を変更し、主建屋流入地下水量を120 m^3/day程度に、冷却用淡水注入量を200 m^3/day程度に低減させた[22)]。これにより、一時貯蔵タンクに移送される汚染水量は270 m^3/day程度に減ることになった。しかし、地下水流入量と冷却水量の減少により、主建屋内のたまり水のCs_{137}とTの放射線強度は増大し続け、当初の漸近値より数倍高い新たな漸近値Ce_1に近づくことになってしまった。

このため、東京電力は、滞留水中の放射能濃度を低減させることを目的に、SARRYなどによる処理水の余剰分を直接主建屋に注水するライン（滞留水浄化設備）を設置し、2018年4月中旬から稼働させている。中期目標によれば、2020年度中には$q_b \rightarrow 0$が実現されるので、その段階になれば、Cs_{137}の濃度については新たな漸近値$\gamma/(q_{c2}+ q_{g2} + q_{r2}+q_d)$に漸近していくものと思われ、滞留水浄化設備からの直接注水の効果は期待できる。ここで、q_{c2}：2020年以降の冷却水量、q_{g2}：2020年以降の地下水流入量、および、q_{r2}：2020年以降の屋根破損部からの降水流入量である。

同様に、Cl^-濃度についても新たな漸近値$q_{g2}C_{g2}/(q_{c2}+ q_{g2} + q_{r2}+q_d)$に漸近していくものと思われ、やはり直接注水の効果が期待できる。ここで、C_{g2}：2020年以降の流入地下水のCl-濃度である。

しかし、Tの濃度に関しては、漸近値 は$\gamma/(q_{g2}+q_{r2})$となるので、直接注入による漸近値の低減効果は期待できない。漸近値を下げるためには地下水流入量を増やすなどトリチウム汚染のない水を外部から導入しないかぎり実現できない。

(2) 汚染水浄化装置

周知のようにALPS等をもってしても汚染水からTは除去できない。T汚染水を貯蔵する一時貯蔵タンクは敷地内で増え続けている。

経済産業省資源エネルギー庁内に設置されている汚染水処理対策委員会のもとにトリチウム対策に関するタスクフォース（トリチウム水タスクフォース）が設置された。2013年12月25日に第1回が開催され、2016年5月27日までに計15回の会合が開かれ、2016年6月3日に「トリチウム水タスクフォース報告書」が上申された。報告書には、トリチウム汚染水の地中注入、海洋投棄、水蒸気方式などについて、必要期間と必要経費の試算結果が示されている[23]。

それを受けて、「多核種除去設備等処理水の取扱いに関する小委員会」が設置された。小委員会の目的は、トリチウム汚染水の処理方策について風評被害など社会的な観点等も含めて総合的な検討を行う、とされている[24]。2018年7月13日までに9回の小委員会が開催され、主に風評被害の社会的な観点を中心に議論が進められた。トリチウム汚染水処理方法のベストチョイスについての議論はほとんどなされないまま、2018年8月末に説明・公聴会が開催された[25]。

(3) 凍土壁

地下水のR/BやT/Bへの流入を防ぐため、凍結工法で凍土壁を作り原子炉周辺を取り囲む工事が行われ、2017年11月3日までに全域凍結した[26]。

東京電力は、「凍土壁により地下水の流れが完全に遮断されなくても、サブドレンとの併用により、主建屋周辺の地下水の水位を目的値に十分制御が可能。」としている。2－(2)、(3) で述べたように、東京電力が掲げた凍土壁の構築の目的はほぼ達成されていると考えられる。

(4) 燃料デブリの所在にかかる事柄

4. で検討した内容を総合的に判断すれば、原子炉内の燃料デブリの物理化学的状態は安定しており、現在も当初生成した放射性物質のうち、初期に溶け出さなかった残留分がゆっくりと冷却水中に放出されていると考えられる。

しかし、依然として全ての燃料デブリが格納容器内に収まっているということの確たる論証は得られていない。下部透水層の地下水質の調査データは、全ての燃料デブリが格納容器内に収まっていること確認するための一つの有力な物証なので、わかりやすい形で公表すべきと考える。

6. おわりに

福島第一原発建屋内のたまり水の放射性汚染状況の解析を通じて、前報まで述べた内容に加えて以下のことが明らかになった。

(1) 原子炉冷却に伴う放射性汚染水の処理は順調に進んでいる。現在は、一時貯蔵タンクに貯留される約110万m^3の汚染水の約86％はトリチウムを除く全ての放射性物質が除去されている。しかし、その比率が2018年内に100％になる見込みは薄い。

(2) 第160週(2014年7月)以降のセシウム137とトリチウムの放射性強度の無次元表示による上下変動パターンはよく対応している。両者とも、第240週辺り（2016年2月）から第279

週（2016年10月下旬）までは下降し続けた。今回の検討で、この期間中、プロセス主建屋とHTIに300～100 m^3/dayにも及ぶ水が地下水ドレンとウェルポイントから移送されていたことが判明し、これが両者の放射線強度が下降した原因と推察した。第280週以降の上昇特性については、前報で詳しく検討した。

（3） 第280週以降上昇しているたまり水の放射線強度を低減させるために、2018年度4月から滞留水浄化設備が稼働している。この措置はセシウム137の放射線強度の低減には有効と考えられるが、2018年10月現在、その効果は明確には現れていない。

（4） 塩素イオン濃度については、第230週以降の上下変動は、基本的にはセシウム137やトリチウムの上下変動パターンに同期している。

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Exploring Positive Implications of Eco-labeling Schemes on Sustainable Development Goals

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Abstract

Eco-labeling or environmental certification schemes are voluntary commitments to communicate the environmental attributes of products and services with consumers. Presently, eco-labeling schemes are utilized in various sectors including food, electronics, clothing, mining, and others. The objectives of this article are twofold. The first objective of this article is to introduces eco-labeling as a marketing tool for firms to attract consumers. The second objective is to examine and highlight the potential linkages with Sustainable Development Goals (SDGs) among eco-labeling schemes in the food industry. Recently, there are growing interests and needs among both policymakers and researchers to understand the possible interactions among different SDGs. The results of the study described in this article indicate that several key SDGs are strongly linked to the issues covered by the eco-labeling schemes. The results of the study suggest that the companies in the food industry may be able to enhance their social, economic, and environmental commitments through the use of eco-labeling schemes. It may be also possible to use the eco-labeling schemes as a marketing tool by informing consumers not only about the environmental but also social and economic attributes of the products and services that the consumers would not recognize otherwise.

環境ラベリング制度と持続可能な開発目標(SDGs)の正の関連性の検討

蔡慧穎・鈴木　政史

概要

環境ラベリング制度（環境認証制度）は企業が消費者に対して商品やサービスの環境面での特性を知らせる自主的な取り組みである。現在、環境ラベリング制度は、食品、電気、衣服、採掘などの様々な産業分野で導入されている。本論文の目的は 2 つある。1 つの目の目的は企業が消費者を取り込むためのマーケティングツールとして紹介することである。2 つ目の目的は、食品産業で導入されている環境ラベリング制度のレビューを行い、それぞれの制度と持続可能な開発目標 (SDGs: Sustainable Development Goals) との関連を検討し明らかにすることである。現在、政策立案者及び研究者の間で SDGs の間の関連性を理解しようとする関心とニーズが高まっている。本論文で紹介する研究の結果は、研究対象とした環境ラベリング制度が主要な SDGs との強い関連性を示している。この結果を受けて、本論文の結論は食品産業の企業が環境ラベリング制度の活用を通して、環境面だけなく社会・経済面におけるコミットメントを高めことができる可能性を指摘すると共に、消費者の間で認識されていない環境・社会・経済面の様々な取り組みを消費者に周知するツールとしての環境ラベリング制度の可能性を指摘した。

Exploring Positive Implications of Eco-labeling Schemes on Sustainable Development Goals

1. Introduction

Eco-labeling or environmental certification schemes are voluntary commitments to communicate the environmental attributes of products and services with consumers. They can be useful and effective tools to bridge the gap between production and consumption of products and services by informing the consumers about the environmental attributes of the products and services that consumers would not recognize otherwise. They can be an effective marketing tool to attract "green consumers." In order to obtain an eco-labeling, the target products or services typically need to go through a verification process conducted by a third party. They can be certified with eco-labeling if they meet required environmental criteria. Presently, eco-labeling schemes are utilized in various sectors including food, electronics, clothing, mining, and others.

The objectives of this article are twofold. The first objective of this article is to introduces eco-labeling as a marketing tool to attract consumers. The first part of the article describes the main drivers for producers and retailers to obtain eco-labeling and illustrates possible marketing implications for them. The second objective is to examine and highlight, if there are any, the potential linkages with Sustainable Development Goals (SDGs). Eco-labeling schemes in the food industry are the focus of this study. While the scope of many eco-labeling schemes typically limited to the environmental issues, the schemes may have positive implications on economic and social issues covered under SDGs. Recently, there are growing interests and needs among both policymakers and researchers to understand the possible interactions among different SDGs (Nilsson, 2017). While SDGs are well-recognized both in the public and private sectors, the understanding of the inter-linkages among various goals is lagging behind.

2. Introducing eco-labeling as a marketing tool of products and services

2.1 What is ecological or green marketing?

Various articles indicate that there are "green consumers" who seek to purchase "green" food products. In order to meet their demand, many food and retail companies produce and promote food as eco-products, sustainable products, bio-products and green products in the market. According to a European Union (EU) Council Regulation, many of these products are categorized as organic food by the government at first (Council Regulation No 834/2007, 2007). However, the term "organic" is simply referred as product itself rather than the whole production process. In the case of the EU, the EU Council defines organic process as "combines best environmental practices, a high level of biodiversity, the preservation of natural resources, and the application of high animal welfare standards" (Council Regulation No 834/2007, 2007).

And yet, consumers still hold the confusion towards the meaning of "green" or "organic." In this circumstances, the green marketing has emerged as an approach to create an opportunity for both companies and consumers to have a better understanding of greenness (Charter, 2017). Some literatures have regarded green marketing as an approach for firms to verify themselves as environmentally-friendly organizations by combining their market environment (such as consumers and competitiveness) and non-market environment (such as regulators and citizens) together (Teisl & Roe, 2005).

As indicated above, various terms are being used to identify the relationship between business marketing and environment such as environmental marketing (Iyer, Coddington, & Ottman, 1994), ecological marketing (Dyllick, 1989), and sustainable marketing (van Dam & Apeldoorn, 1996). These green strategies sometimes can be regarded as part of their efforts for information disclosure (Prakash, 2002) to help consumers to compare various environmentally sound products and services. In this context, eco-labeling schemes are often being introduced as a useful and effective tool for the producers to disclose information and for consumers in the choice of the products and services.

2.2 What are the main drivers for producers and retailers to obtain eco-labeling?

Some literatures illustrate that the main motivation for firms to obtain eco-labeling is to respond to external market pressure from various stakeholders such as "green consumers" and improve their market competitiveness (Iraldo & Barberio, 2017). In other words, the market factors such as adding the values of current products and expanding a new market could be the main drivers for firms to apply for eco-labeling. More specifically, many firms attempt to send the environmental information, through eco-labeling, that affects consumers' decisions on choosing products. In many cases, eco-labeling is an intermediate to build a bridge between producers and consumers with environmental sound products (D'Souza, Taghian, Lamb, & Peretiatkos, 2006). Some literatures point out another drive for firms to obtain eco-labeling. They indicate that obtaining eco-labeling could be an opportunity to improve their product image or reputation by going through a third-party certification process and proving the superior ecological performance of products or services (D'Souza, 2004).

While scholars suggest that eco-labeling schemes are beneficial for green consumers who wish to identify environmental products, various research have questioned whether premium on environmental sound products and services can increase the sales (D'Souza, 2004) as the cost of eco-labeling (due to the fee paid to consultants, funding, and licenses) may increase the prices of such products and services. When "green" recognitions are lacking by a majority of consumers, the relatively higher cost of the products and services can become a main barrier to promote eco-labeling. Nevertheless, as stated above, eco-labeling is often recognized as a useful tool to help consumers looking for some criteria to justify their purchases (D'Souza, 2004) based on positive contributions to the global environment. It is reasonable to state, therefore, that eco-labeling can be unique approach to link environmental concerns and environmentally responsible

purchasing to marketing strategies.

3. Research design

This study examines and highlights, if there are any, potential linkages with several different Sustainable Development Goals (SDGs). While the scope of many eco-labeling schemes typically limited to environmental issues, the schemes may have positive implications on economic and social issues covered under SDGs. Indeed, there are growing interests and needs among both policymakers and researchers to understand the possible interactions among different SDGs (Nilsson, 2017). While SDGs are well-recognized both in the public and private sectors, the understanding of the inter-linkages among various goals is lagging behind. Some scholars indicate that there are both positive and negative interactions among different SDGs. While there may be synergies among various SDGs (positive interactions), trade-off or cancelation of each effort among different goals (negative interactions) is also conceivable.

This study focuses upon the positive interactions between eco-labeling schemes and various SDGs in the food industry. It attempts to identify SDGs in selected food eco-labeling schemes and provide cross-sectional information on the food eco-labeling schemes. As stated above, many firms attempt to integrate environmental considerations into business or marketing strategies through eco-labeling in order to meet consumers' demand for the products and services with clear indications of environmental superior attributes. This is also the case with the food industry. For consumers, when they go to a retail store to purchase food, reading an eco-labeling is the starting point to explore how the products are positioned in an environmentally sound fashion.

While many of the existing food eco-labeling schemes tend to emphasize the single dimension of environment-related issues such as the use of organic component (e.g. EU organic labels) or animal rights (e.g. Animal Welfare Approval), the single dimension only reveals the limited information about the products (Ridoutt, Sanguansri, & Harper, 2011). Therefore, this study copes with 11 general food eco-labeling schemes that are not focusing on a single dimension of environmental issues.

Figure 1 classifies those 11 eco-labeling schemes into four groups based on their main scopes and aims. Group I (UTZ Certified, Demeter, LEAF and Food Alliance Certified) focuses mainly on creating sustainable management in the farming practices, while eco-labeling schemes in Group II (AENOR Certification, Global GAP and Milieukeur) place priority on sustainable outcomes such as sustainable products and services in the food industry. Fair Trade Organization Mark, one of the most widely recognized ethical labeling schemes, is classified into Group III, as it is the only scheme with the main focus placed upon the social issues for the farmers and workers in the food production chain. This labeling scheme is an exception in this study as the main scope of the labeling scheme is not environmental issues. Lastly, Group IV including Marine Stewardship Council, DeLaval and LODI RULES emphasizes one specific food product such as fish, dairy

products as well as wines.

Figure 1 illustrates the possible interactions between selected eco-labeling schemes and SDGs. As preliminary research has indicated that several SDGs including 1, 4, 9, 10, 11 and 16 are not strongly related to eco-labeling schemes, Figure 1 does not indicate the relationships between the labeling schemes and those goals.

4. Review results

As seen in Figure 1, SDG 12 (Sustainable Production and Consumption) is relevant to all eco-labeling schemes in the food industry reviewed in this study. This is because SDG 12 attempts to build the connections between production and consumption. Indeed, the use of eco-labeling scheme is encouraged under this goal as follows:

"There also needs to be significant focus on operating on supply chain, involving everyone from producer to final consumer. This includes educating consumers on sustainable consumption and lifestyles, providing them with adequate information through standards and labels and engaging in sustainable public procurement, among others." (UN Environment)

SDG 12 aims to improve the quality of life without increasing environmental deterioration and foster the emergence of eco-labels (Horne, 2009). As indicated above, the food-related eco-labeling schemes can be a useful instrument to communicate the environmental performance of products or services from the supply side (Thøgersen, Haugaard, & Olesen, 2010). They can connect the production side and the consumption side and are likely to help to improve the quality of life of consumers.

Apart from SDG 12, SDG 2 on sustainable agriculture is also a fundamental goal there are related to all 11 food eco-labeling schemes. SDG 2 integrates food security, nutrition and sustainable agriculture which are essential parts in food industry and being emphasized in every food eco-labeling scheme reviewed in this study. It is reasonable to recognize that the most targets set under SDG 2 support the progress of SDG 12 and vice versa. For example, sustainable agriculture, which is the core target of SDG 2, aims to increasing productivity and efficiency in the farming practices, and directly contributes to all parts of SDG 12 (Mollier, Seyler, Chotte, & Ringler, 2015). Similarly, the sustainable natural resources and the increase in productivity encouraged under SDG 2 directly support SDG 12 with respect to the management of chemicals and efficient use of water and resources.

In addition to SDG 2 and SDG 12, there are other goals that are interacting with eco-labeling schemes. The four eco-labeling schemes in Group I aim to improve the sustainable management practices in farming. These schemes support to improve the working conditions, achieve equality (SDG 8) and protect life on

Figure 1: Possible interactions between selected eco-labeling schemes and SDGs

Group	Name	Brief	SDG 2 Zero Hunger and Sustainable Agriculture	SDG 3 Good Health and Well-being	SDG 5 Gender Quality	SDG 6 Clean Water	SDG 7 Affordable and Clean Energy	SDG 8 Decent Work and Economic Growth	SDG12 Responsible Consumption and Production	SDG13 Climate Change	SDG14 Life Below Water	SDG15 Life on Land	SDG17 Partnership for the Goals
I	UTZ Certified	Certification and labelling scheme to work together with existing brands, and show that consumers that products have been sourced, from farm to ship shelf in a sustainable manner.	○	○	○	○		○	○	○		○	○
I	Demeter	Demeter is the largest certification organization for biodynamic agriculture.	○				○	○	○			○	○
I	Linking	LEAF (Linking Environment	○				○	○	○			○	
I	Food Alliance Certified	Certification and labelling scheme that certifies farms, ranches, and food processors and distributors for sustainable agricultural and facility management practices.	○			○		○	○			○	○
II	AENOR Certification	Ecolabel system aimed at recognizing	○			○	○	○	○	○		○	○
II	Global Good Agricultural Practice (Global GAP)	Global G.A.P. is a private sector body that sets voluntary standards for the certification of agricultural products around the globe. The aim is to establish one standard for Good Agricultural Practice with different product applications capable of fitting to the whole of global agriculture	○	○		○	○	○	○			○	
II	Milieukeur	The Dutch environmental quality label for products and services. The	○			○	○		○	○		○	○
III	Fair Trade Organization Mark	This label connects disadvantaged farmers and workers with consumers, promotes fairer trading conditions and empowers farmers and workers to combat poverty, strengthen their position and take more control over their lives.	○		○			○	○	○			○
IV	Marine Stewardship Council	The MSC is an independent, not for profit, international body based in the UK. It was initiated by the	○					○	○		○		○
IV	DeLaval	DeLaval	○		○		○		○	○			○
IV	LODI Rules	LODI RULES for Sustainable Winegrowing is California's original sustainable viticulture program. This program truly began from the ground up, with grape growers deciding it was important for the future of the Lodi region. Our certification process is rigorous, based in science, voluntary, and third-party accredited and audited.	○			○	○		○			○	○

land (SDG 15). The food industry is expected to provide livelihood for the poor and vulnerable people and improve the poor economic development. By improving the working conditions and creating equal job opportunities for both women and men which is the main part of SDG 8, the eco-labeling schemes can help to promote sustainable economic growth. With respect to SDG 15, the goal supports sustainable agricultural production and genetic diversity in order to protect, restore and promote sustainable use of terrestrial ecosystems. Those four eco-labeling schemes in Group I may help to promote sustainable agricultural production and therefore they are likely to be linked to the goal as well.

It is also noted that some eco-labeling schemes reviewed in this study have direct interactions with specific goals. The focus of the UTZ and Food Alliance Certified is sustainable management of water (SDG 5), while the other two in Group I (Demeter and LEAF) is directly linked sustainable use of energy (SDG 7). In the case of the UTZ, the impacts of food upon mental, emotional and physical health are also considered in the certification process, as the quality food and nutrition status are a fundamental driver for health and well-being. As such, the linkage between the eco-labeling scheme and SDG 3 on good health and well-being is observable. On the other hand, SDG 5 indicates that empowering women in agriculture through increasing their decision-making over agricultural production and incomes has been shown to improve both family health and nutrition outcomes. From this perspective, the eco-labeling schemes such as the UTZ have the direct and indirect interactions with SDG 3 and SDG 5.

While the labeling schemes in Group II pay more attentions to sustainable outcomes such as productions and services rather than the process or management of practices, the goals related to environmental issues including SDG 6, SDG 7 and SDG 15 are linked to those schemes in Group II. In the case of AENOR and Milieukeur, they are specifically related to SDG 13 that requires the reduction of GHG emissions in agriculture. Group IV contains labeling schemes that have strong focus business areas such as fishery, dairy farming and wines. Each eco-labeling scheme in this group is directly and/or indirectly linked to different SDGs. While the main focus of the MSC is the life in the sea (SDG 14), DeLaval and LODI cope with the improvement of energy efficiency in business operations (SDG 7).

5. Conclusion

This study illustrated the positive interactions between eco-labeling schemes and SDGs. The study analyzed 11 schemes in the food industry. The results of the study indicated that SDG 2 and the SDG 12 have the strong connections with them. It turns out, however, that they are also strongly linked to other environmentally-related goals such as SDG 6, SDG 7, SDG 13 and SDG 15. In addition, the goals in the social and economic dimensions such as SDG 3, SDG 8 as well as SDG 17 are also associated with the labeling schemes in the food industry sector. The results of the study suggest that the companies in the food industry may be able to enhance their social, economic, and environmental commitments through the use of eco-labeling schemes. It may be also possible to use the eco-labeling schemes as a marketing tool by informing

consumers not only about the environmental but also social and economic attributes of the products and services that the consumers would not recognize otherwise.

Note: The brief introductions of each labeling schemes in Figure 1 are taken from various sources on internet. The research was supported by the Environmental Research and Technology Development Fund (S16-4) of the Environmental Restoration and Conservation Agency of Japan.

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Families and SDGs Goal 5: Parental Leave Policies and Gender Equality

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Abstract

This paper explores how family policies can positively enhance gender equality that SDG Goal 5 aims to achieve. In recognition to the global attention given to gender equality vis-à-vis work-and-family conflict, this paper gives special attention to the impact of family leave policies on women's career outcome and men's participation in unpaid work. Literature from 1990s was reviewed among which evaluative studies that adopt experimental design were selected for further examination. The major findings are two-fold. First, longer and generous parental leave policies do not necessarily promote gender equality in the labour market. They encourage mothers to delay their return and thus jeopardize long-term advancement of their career, resulting in perpetuating gender gap in economic rewards. Second, parental leave reserved for fathers, as a benefit non-transferable to mothers (daddy quota), is a promising scheme to encourage fathers to take leave from work, especially when this benefit is provided as bonus period of 'take-it-or-lose-it'. Gender equality in the public sphere can never be achieved unless unpaid domestic work and care work is shared more equally in the private sphere. Future family policies should give more attention to the contradicting demand that they are trying to fill. They must ensure well-being of children while making sure that equality between genders is promoted.

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持続可能な開発目標と家族政策
―育児休業制度の効果―

平尾　桂子

概要

ジェンダーの平等（持続可能な開発目標　Goal5）の達成に対する育児休業制度の効果を検証する。子どもを養育する労働者を対象とする休業制度は、パプアニューギニアを除く全ての国と地域で制定・施行されており、世界的に休業期間、補償内容ともに拡大される傾向にある。本論では、1）女性の労働供給および賃金格差、2）男性の育児休業取得および実際の育児参加に注目し、その政策変化の効果を文献研究により検証した。レビューに用いた文献は、1）政策変化の事前・事後における、2）縦断的ミクロデータを用いた（疑似）実験法（quasi-experimental design）により因果関係を明らかにする研究に限定した。その結果、1）育児休業の長期化は総じて女性の労働供給を低下させ、労働市場におけるジェンダー平等には必ずしも効果的ではないこと、2）男性の育児取得率の向上には父親しか利用できないパパ・クォーターが有効だが、実際の育児参加に対する影響は限定的であることが判明した。家族は、その形こそ多様化したが、依然として社会の結合力や生産性の源泉であり、文化を次世代に伝える中心的制度の一つであることに変わりはない。持続可能な開発目標の達成に向けて家族政策の視点の重要性が示唆される。

Families and SDGs Goal 5: Parental Leave Policies and Gender Equality*

Introduction

The past four decades witnessed a substantial progress toward equality of gender. When the United Nations General Assembly adopted the Convention on the Elimination of All Forms of Discrimination against Women (CEDAW) in 1979, a majority of girls living in the world did not have a chance to grow up imagining what they might be able to do in the future, except for getting married and being mothers. There have been substantial advances since then in women's legal rights, educational opportunities, health status, employment, and decision-making power. Much of the progress has been credited to the voices of women and advocacy agents that promoted international conventions, treaties, resolutions and following legislative changes in member nations that pledged to be bound by the international agreements.

The progress toward gender equality, however, is still far from complete. We still observe persistent gender segregation horizontally and vertically; women are overrepresented in the informal economy, part-time jobs with little job security, and in low-paying occupations, such as domestic service and care work. Vertical gender segregation is still prevalent, and the women's share of top management in large corporations is still unacceptably low. It is expected to take more than 70 years before it is completely closed (ILO, 2016b). Gender inequality remains an assiduous challenge for the international community as a significant obstacle to sustainable development. The Goal Number 5 of the 2030 Sustainable Development Goals (SDGs), therefore, aims to continue the progress that the international society has made for gender equality.

This paper seeks to contribute our knowledge of how family policies can positively enhance gender equality that SDG Goal 5 aims to achieve. Specifically, this paper tries to answer the following two questions:

1. What is the impact of parental leave on women's labor force behavior and their income?
2. Which designs of parental leave policies are most likely to encourage men's take-up rate and increase their participation in unpaid work?

This paper pays particular attention to the effect of policies that address work and family conflict because of the following two reasons. First, the interplay within family profoundly affects the power relationship between men and women through the allocation of roles and responsibilities for domestic work and upbringing of their children. Gender inequality in the public sphere is both the cause and the result of the disparity in the private area. How men and women spend their time within their family mirrors and reproduce the differences in their access to resources outside the home, namely income and political power.

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Second, reconciling work and family conflict is one of the most challenging conundrums facing humanity. As a society, reasonable economic growth must be maintained, and at the same time, sound care must be provided for upbringing the next generation to keep a society sustainable. The competing demands for production and reproduction are particularly acute in developed countries where fertility has long fallen below replacement levels.

This paper consists of four sections. After a brief description of SDGs Goal 5, part three gives the general overview of parental leave policies around the globe and then presents the global evidence on how they affect the women's career outcome and men's contribution to domestic work.

Gender Equality in Sustainable Development Goals

Goal 5 of the SDGs aims to achieve gender equality not only as a fundamental human right but also as a necessary condition for attaining peaceful, inclusive, and sustainable development. Although gender equality is enshrined as a stand-alone Goal of its own, it is a cross-cutting issue and is deeply interlinked with many of the other SDGs such as poverty (Goal 1), food security (Goal 2), health (Goal 3), and education (Goal 4). For example, women still make up a high proportion of people living in income poverty (e.g., Chant, 2006), and gender equality is expected to contribute to the reduction of poverty through improvement in women's income, health, education, and access to and control over land and other resources.

Sustainable Development Goal 5 consists of six outcome targets and three sub-targets. These targets show the practical starting points and translate that gender equality refers to ending discrimination (5-1), violence (5-2), and harmful practice against women and girls (5-3). Equality between the sexes also means equal rights in the public sphere that include: access to economic resources and land ownership (5-A), equal opportunities for leadership in political, economic and public life (5-5), which are supported by sound policies enforceable legislation that promotes gender equality and empowerment of women and girls. In tandem with women's empowerment in the public spheres, Goal 5 also calls for recognition of unpaid care and domestic work. Through a provision of public services and infrastructure as well as the promotion of shared responsibility within the household and the family, the target 5-4 aims to enhance acknowledgment of care work and domestic work that are unpaid.

This paper identifies target 5-1 (ending discrimination) and targets 5-4 (recognition of unpaid work) as the focusses that are most pertinent to family perspective. It also defines gender equality as equal access to monetary rewards and an equitable distribution of unpaid work between men and women as measured by gender wage gap and the time used in unpaid work. As noted earlier, this paper focuses on policies aiming at balancing work and family responsibilities as the critical elements for gender equality. The following sections will give the general overview of parental leave policies and then presents the global evidence on how they affect women's career outcome and men's contribution in domestic work.

Parental Leave Policies and Gender Equality: Review of Literature

Parental leave policies are almost universal today, but at the onset, they started as policies to protect

maternity. It goes back to the first International Labour Conference in 1919 when the Convention on maternity protection was adopted (Convention No. 3). It was initially designed to promote the health of a mother and her newborn baby by providing a mother time to physically recover from the childbirth and also to build psychological attachment to her newborn child. It was later developed as a statutory provision of the right to return to the previous employment so that the female workers would not be discriminated against for the maternity reasons.

As of this writing, all countries except Papua New Guinea have laws mandating some form of parental leave (ILO, 2014). There are significant variations in the duration and level of compensations of the provisions among countries. The job-protected leave available to either parent varies from 12 weeks in the United States to 156 weeks in France, Germany, Poland, and some other countries in East Europe. A majority of countries (98 out of 185 countries as of 2013) provide at least 14 weeks of maternity leave among which 42 countries meet or exceed the 18 weeks of leave proposed in the Recommendation No. 191 (ILO, 2014). Among the OECD countries alone, maximum job-protected leave for mothers varies from 12 weeks in the United States to 166 weeks in Spain. The amount of cash benefit and its source also differ widely. The average payment rate for mothers as measured by the percentage of the national earnings of 2014 vary from no payment in the United States to 100 percent coverage in Spain and Netherland. (Olivetti & Petrongolo, 2017)

The recent trend is toward expansion in the leave coverage. Canada, for example, increased paid family leave about 25 weeks to 50 weeks in 2000. In 2004, the state of California strengthened maternity rights, allowing for up to 6 months of maternity leave. Other countries that have recently extended the parental benefit include the United Kingdom, 2003, 2007, Denmark 2002, and in Germany 1979, 1986, 1992, and 1993 (Schonberg & Ludsteck, 2014). Sweden was the first country to introduce gender-inclusive leave policy in 1974 that enabled mothers and fathers to share six months of parental leave. Other developed countries began to supplement "maternal leave" for mothers around the time of childbirth with "parental leave" to care for the children in their early years (OECD, 2017).

The literature that examines the effect of family policies on gender equality can be roughly categorized into two groups: 1) cross-country approach and 2) within-country approach. The cross-country approach tries to capture the impact of policies using comparative aggregate data compiled by international organizations. The variables employed, however, are inevitable coarse and leave many of the unobserved heterogeneities unspecified, which makes identification of causal impact impossible. Moreover, family policy is very complex and does not stand-alone by itself. It has to be studied in conjunction with many other legislation that affects families, such as tax and pension system, employment regulations, pay equity between part-time and full-time work, availability of subsidized daycare and early childhood education, school hours, demand for parental involvement for school children, and so on.

Because of these limitations in cross-country research, this paper focuses on within-country approach that examines the impact of specific policy interventions. By using longitudinal microdata (on pre- and post- policy reform) this approach enables a natural experimental design of policy assessment. This method is by far more robust in specifying the causal impact of a particular policy. A drawback of this approach is that it can consider only one policy intervention at a time. The challenge, therefore, is the generalizability

on how a particular program in a specific time and place can be applied to a different cultural and social setting. With these limitations in mind, the following section will present the results of the literature review.

Literature Search

The literature search was undertaken in February-March and June-August 2017, using Web of Science (WOS) and a combination of EndNote search engine connected to EBSCO and PubMed. The first round of search used the topic word such as "family policy," "gender equality," (WOS, 68 hits, with oldest published in 1996), "parental leave" and "gender equality" (WOS, 107 hits with oldest published in 1990). EndNote directly connected to Thomson Reuter WOS Core Collection with the keyword search "gender equality" and "family policy" found 401 articles with oldest published in 1994, "gender equality and "parental leave" hit 135 articles from 1990. A further search was conducted to identify the source references in relevant articles that reviewed the literature.

Once the list of literature was built, they were selected by conceptual coherency, methodological and scientific validity. Papers that met all three standards were included in the study. Table 1 and 2 in the Appendix provide the list of the articles accepted for the review in this paper.

Parental Leave Policies on Women's Career Outcome

Thirty years of research on gender-impact assessment of parental leave policies have found mixed and somewhat enigmatic evidence. While some scholars claim that generous leave policies have some favorable effect on female labor market outcome (Gornick, Meyers, & Ross, 1998), there have been serious concerns raised about the unintended adverse effect on gender equality. It is argued that developed welfare states facilitate women's access to the labor force, while at the same time, such policies are negatively associated with women's prospect of reaching a higher position in the labor market compared with men (Mandel & Semyonov, 2006). That is, nations characterized by progressive and "family friendly" policies tend to have a high level of gender segregation that disfavors women. (Charles & Grusky, 2004; Mandel, 2012; Mandel & Semyonov, 2006). The negative association between the generosity of parental leave entitlement and women's labor outcome, as known as "welfare state paradox" has been a focus of debate for some time.

Theoretically, the impact of parental leave on gender equality is ambiguous. It may foster employment by allowing mothers who would have withdrawn from the labor market and also by encouraging women who were not previously employed to work for pay because leave benefit makes employment more plausible. Conversely, parental leave mandate increases the labor cost and may prompt employers to engage in statistical discrimination.

The changes in parental leave policies in many countries have enabled the quasi-experimental design to assess the impact of policies on women's labor outcome. In the United States, when Family and Medical Leave Act (FMLA) was enacted at the federal level in 1993, 12 states and the District of Colombia had already stipulated similar leave provision (Waldfogel, 1998). This staggered introduction of legislation enabled Baum

(2003) to assess the effect of parental leave policies. Using National Longitudinal Survey of Youth (NLSY) and difference-in-difference estimator he did not find a significant impact of legislation on the wages of women.

Likewise, Hofferth and Curtin (2003) assessed the effect of FMLA using the 1984-1997 wave of Panel Study of Income Dynamics (PSID) and its 1997 Child Development Supplement. The findings suggest that only in states that had not passed leave statute, women who gave birth after the passage of the FMLA in 1993 were more likely to return to the same job. That is, although it was not as powerful a job retention policy as paid leave, unpaid leave can help workers retain their jobs. On the other hand, the passage of FMLA was not associated with an increase in wage in the two years after birth (Hotterth and Curtin 2003).

Using a similar approach, Waldfogel (1998) examined the effect of childbirth and parental leave policies on women's earning in the United States and Britain. The data used were NLSY for the U.S. and National Child Development Study (NCDS) for Britain. She found heavy motherhood penalty in both countries; about 40-50 percent of the wage gap explained by the parental status that women are penalized for having children, and another 30-40 percent by the family status, that mothers taking more time out of the labor market. The result also showed that women who had parental leave and returned to work after childbirth received a wage premium that offset the adverse wage effects of children. This positive effect is partly explained by the employer characteristics (in the United States) and previous wages (in Britain), but after controlling these factors, the premium of leave entitlement remained significant (Walfogel 1958).

In Austria, Lalive and Zweimueller (2009) and Lalive et al. (2014) examined the effect of sequential changes in leave benefit in 1990, 1996, and 2000. The 1990 reform extended the job protection and cash benefit from one year to two years; the 1996 change kept the job protection period unchanged but decreased the cash benefit period from two years to 18 months; the 2000 reform increased the cash benefit to 30 years while keeping the job protection at two years. Using the Austrian Social Security Database, they compared mothers' career outcomes for those who had childbirth before and after these policy changes. The analysis found that longer leave durations significantly delay mothers' return-to-work. Nevertheless, despite the significant delays of labor force reentry of mothers exposed to the more generous leave regimes, no evidence was found that the delay had any detrimental effect on their labor market outcome in the medium-run (Lalive et al., 2014; Lalive & Zweimueller, 2009).

In Germany, sequential reforms that expanded maternity leave coverage took place in the late 1970s to 2007. Schonberg and Ludsteck (2014) examined the effect of these policy changes by constructing complete work histories of men and women covered by the Social Security Records. The results show that each expansion in leave coverage reduced mothers' post-birth employment rates. In the long run (2-6 years after childbirth), there was no improvement in mothers' labor market participation (Schonberg & Ludsteck, 2014).

Using a similar scheme, Gangel and Ziefle (2015) examined the effect of the extension of parental leave entitlement in Germany. They used the German Socio-Economic Panel (1990–2004 waves) and found that

increasing generosity of leave right leads to a decline in mothers' work commitment in both East and West Germany. They conclude that policy-induced shifts in mothers' preferences contributed to hindering women's labor force participation.

Similar policy impact of shaping employment behavior was confirmed in Australia when paid leave became available in 2011. The policy provided entitled mothers up to 18 weeks of paid leave with the Australian minimum wage. Using Household, Income and Labor Dynamics in Australia, Hondralis (2017) found that women who gave birth after the reform did postpone their return to work until the end of the entitlement period. Women with higher education react strongly to the available policy and markedly adjust their employment behavior.

Baker and Milligan (2008) examined the impact of policy change in Canada where job-protected leave provisions are under provincial rather than federal. Using the panel sample and between-province time series data created from the Labor Force Survey from 1976 to 2002, they find that modest leave entitlements of 17-18 weeks do not change the length of time mothers spend away from work. However, longer leaves do have a substantive impact on behavior, leading to more time spent at home.

Parental Leave Policies and Fathers' Take-up and Participation in Unpaid Work

Gender equality cannot be achieved unless men take a more active role in parenting. The European Union Parental Leave Directive 2010/18 recommended that non-transferable parental leave for fathers be introduced. Today, leave entitlement for fathers is granted in 79 countries out of 167 for which data are available (ILO, 2014). Among the OECD countries, 26 states provide at least a few days of paid leave that can be used only by fathers (OECD, 2016).

The duration varies widely from only one day in Tunisia to one year in Japan. In spite of the prevalence of legal entitlement, the take-up rate of fathers has been meager. Less than 1 percent of leave recipients are fathers in the Czech Republic; 2 percent in Finland and Poland, and 3 percent in Austria (INLPR, 2012). However, in countries where leave entitlement for father is non-transferrable and is well paid, fathers are more likely to take the leaves. This trend is most prevalent in Nordic countries (INLPR, 2012).

Sweden was the first country to introduce gender-inclusive leave policy in 1974 that enabled either mothers or fathers to share the period of parental leave. The actual men's take-up rate, however, did not change until 1995 when the Swedish government decided to create what is called "daddy month," a month of parental leave exclusively reserved for fathers. In 2002, a second daddy month was added (Ekberg, Eriksson, & Friebel, 2013).

Norway is another head runner that introduced four weeks of fathers' quota in 1993, two years before such policy was adopted in Sweden. The fathers' quota in Norway has been extended to 14 weeks through progressive reforms and then decreased to 10 weeks in 2014 (NAV, 2014). Iceland provides fathers the largest non-transferable share of parental leave; three months reserved for the father, three months to the mother, and three additional months that can be allocated between parents (Steingrimsdottiry & Vardardottirz, 2015). Likewise, Quebec in Canada established a "daddy quota" in 2006. It is operated through the Quebec

Parental Insurance Plan (Patnaik, 2016). In Germany, too, non-transferable paid paternity leave is established in 2007 (Kluve & Tamm, 2013).

The existing literature suggests three critical findings. First, as a direct effect, non-transferable "daddy-quota" increased the take-up rate of parental leave by fathers. In Norway, the introduction of "daddy-quota" in 1993 increased the take-up rate of fathers from 3 percent before 1993 to 60 percent in 1995 (Rege & Solli, 2013). Iceland introduced a reform in 2001 that give parents an option to add one month of parental leave in addition to the allotted six months on the condition that the father uses the additional month. The reform created substantial incentives for fathers to be more involved in caring for their children during their first months of life, and the take-up rate in the first year was 82.4 percent (Steingrimsdottiry & Vardardottirz, 2015). In Sweden, the incentive provided by the "daddy month" encouraged men to take approximately 15 days longer parental leave which accounts for about 50 percent increase from the pre-reform average (Ekberg, Eriksson, & Friebel, 2013). A similar effect was confirmed in Germany (Kluve & Tamm, 2013) and in Canada (Patnaik, 2016) where fathers' take-up rate of parental leave increased after the introduction of non-transferable paternal leave. This evidence shows that parental leave period that is non-transferable to mothers ("use-it-or-lose-it" quota) is a powerful instrument to increase men's participation in parental leave.

Second, findings on the effect of policy reform on fathers' involvement in childcare and domestic work are mixed. In a cross-section cross-time research daddy quota is found to be associated with men taking more time within the family and child care. This association, however, is observed only among highly educated fathers, and no effect was identified for fathers with lower levels of education (Boll, Leppin, & Reich, 2014).

Ekberg et al. (2013) operationalized involvement in childcare as whether or not parents use the leave to care for sick children. Their result indicates that Swedish fathers in the treatment group are no more likely to take time off from work to take care of sick children than the control group who did not have a choice for the "daddy quota." In Germany, Kluve and Tam (2013) find that fathers are not more involved in childcare beyond the period of leave allocated for them.

On the other hand, in Canada where "daddy-quota" was introduced, Patnaik (2016) finds that introduction of "daddy quota" in Quebec province was effective in changing gender dynamics within the household not only for short-run but also for 1 to 3 years after the reform. Using the time diary data from Canada's General Social Survey (GSS), Patnaik found that fathers spent 37 minutes longer in non-market work per day while mothers reduced their time spent in housework by 18 minutes.

Third, there is some evidence that the "daddy quota" lead to fewer conflict regarding the division of household chores. Kotsadam (2011) find that daddy quota introduced in Norway reduced the level of conflicts over household work within couples, but this does not necessarily mean that men are doing more of the housework. Rønsen and Kitterød (2015) report that after the introduction of the reform in Norway, especially in the mid-2000s, women returned to work significantly faster. However, they failed to disaggregate the effect of policy reform and the expansion of subsidized daycare services that was initiated at the same time. In Iceland, the introduction of the "daddy quota" is credited for more marital stability. After the reform, the fathers entitled to paternity leave were less likely to divorce during the first years of children's life

(Steingrimsdottiry & Vardardottirz, 2015).

In sum, providing father-specific leave seem to increase men's participation in parental leave, at least when they are well-paid. The countries mentioned above have the compensation of 80 to 100 percent of pay during the paternal leave. We cannot overemphasize the importance of monetary benefit because the leave decision can be driven by simple financial logic. Regardless of the policy design, there is a strong incentive for a couple to allocate their time for paid and unpaid work according to the comparative advantage (Becker, 1985, 1991). Given the persistence of the gender wage gap, it is more likely that fathers would continue working unless otherwise compelled. In this respect, merely providing fathers with an exclusive entitlement for leave is not enough; it must be not only well-paid but also be offered as an extension as "use-it-or-lose-it" option for fathers.

Conclusion and Discussion

This paper examined how family policies can contribute to gender equality that SDG 5 aims to achieve. The outcome indicators used in this study are women's career outcome (represented in wage gap) and time men and women spend on unpaid work.

As reviewed in this paper, countries characterized by "family friendly" policies with more extended and more generous leave provisions tend to have a higher level of gender segregation that disfavors women. Maternity leave policies are expected to promote and achieve gender equality at workplace by securing the right to return to the previous employment position. However, the research finding suggests that the opposite is true. The studies that use micro-level analysis with natural-experimental design generally find that the provision of longer parental leaves for childbirth discourages female labor force participation. Although the job protection of leave entitlement enables more women to stay in the labor force, extension in the duration of leave entitlement or increased wage compensation rate worked as incentives for mothers to spend a longer time at home after the child birth.

More time at home for parents after the childbirth is the direction that most developed nations are heading. This trend means, in reality, more time at home for mothers and little if any more for fathers. As noted above, mothers are more likely to delay their return to work as much as the entitlement and compensation allow them, while fathers do not respond to the leave entitlements. This would increase the amount of child care and housework done by the mother, and the share of such work and reinforce the gendered division of housework. The underlining frame of work-and-family conflict continues to be a "women's affair." Concerns about the negative consequences of more extended parental leave are most prominent for higher-skilled, higher-earning professional workers. It is because these workers are hard to replace, and employers would be reluctant to place women in such jobs that substitution of one worker for another is difficult. Consequently, an introduction of generous and more extended parental leave, in general, is found to have an adverse effect on gender equality in the labor market.

On the other hand, fathers' response to changes in leave policies is minimal. Only when the leave entitlement is made non-transferable to mothers and provided as bonus period of "take-it-or-lose-it," fathers

are more likely to take the leave. Even in an exceptional case where paternity leave is made mandatory (Portugal since 2009), the take-up rate of fathers remains around 50 percent (Wall & Leitaro, 2016, p. 283). In other words, fathers need to be strongly incentivized or even urged, to take leave from work when they become parents.

Whether a policy is viewed as effective or not depends on the desired outcome. Parents spending more time at home means children are receiving more time of parental care at home. From the perspective of child development, this is a desirable outcome (Waters & Cummings, 2000 ; England & Hiester, 1995). literature on the importance of the early childcare scheme, however, rarely frame their argument concerning gender equality.

Family policies are often about competition among competing values and embodiment thereof, more so than other fields of systems. The reproduction of the next generation is the necessary condition of the sustainable future. As family policies are directly related to the nexus of production and reproduction, they inevitably have to face the question of what is suitable for children as well as what enhances equality between gender. As Hertz (1999) notes, the extent to which the idea of balancing work and family may be a euphemism for competing ideals about childrearing, such as professional/commodified services vs. parental (or maternal) care.

The problem between the demands for economic productivity and reproductive capacities of the post-modern societies cannot be solved by achieving gender equality alone. Instead, it is deeply related to our believed values of gender, generation, and class, that are interrelated but often in conflict with each other. Future family policies should give more attention to the contradicting demand that they are trying to meet. They must ensure the well-being of children while making sure that equality between genders is promoted.

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Appendix

Table 1. List of articles on the effect of parental leave policies on women' (quasi-experimental designs)

Article	Family intervention description	Country/ region	Policy Target	Level	Data & Meihods	results
Kluve Tamm (2013)	Added generousity in parental leave (*Eltenge*) from January 1 of 2007. It offers earning-related benefit of 67% replacement rate for either father or mother for up to 12 months. If father and mother participate, they receive 2 extra months, resulting 14 months of leave in total	Germany, East & West	Parents	National	Survey data from parents with children born in the first quarter of 2007 and parents with children born in the last quarter of 2006. before- and after the reform, natural experiment	Found a significant decrease in mothers' employment probability during the 12 months after giving birth and an increase in mothers' employment probability after the transfer expires. The implementation of two daddy months is currently not reflected in significant changes in fathers' time devoted to childcare
Gangl & Ziefle (2015)	Extension of leave period in 1991 (from12 to 18 weeks), in 1992 (from 18 to 36 months) and in 2001 (additional flexibility enabling parents to take three-year leave between a child's second and eighth birthday.	Germany, East & West	Parents	Germany, East and West National	German Socio-Economic Panel and difference-in-differences, triple difference, and instrumental variables estimators for panel data	Increasing generosity of leave entitlements led to a decline in mothers' work commitment in both East and West Germany. Policy-induced shifts in mothers' preferences contributed to retarding women's labor force participation.
Hofferth & Curtin (2003)	Family and Medical Leave Act, Unpaid job-protected leave	U.S. Federal	Parents	Federal	1984-1997 waves of the Panel Study of Income Dynamics and its 1997 Child Development Supplement	Women who return to work are more likely to return to the same job after the passage of the FMLA, but this is true only in states that had not passed a medical leave statute before the FMLA. FMLA and leave are not associated with increased wages in the two years after birth.
Schoenberg & Ludsteck (2014)	five major expansions in maternity leave coverage in Germany	Germany, East & West	Mothers	National	Data: Social Security records from Institute for Labor Market Research. Complete work histories including the leave period. difference-in-difference design	Each expansion in leave coverage reduced mothers' postbirth employment rates in the short run. The longer-run effects of the expansions on mothers' postbirth labor market outcomes are, small. 1986 reform, extended paid maternity leave beyond the period for job security.

Lalive et al. (2014)	1990 Austrian reform, extending job protection and cash benefit from one year to two years, 1996 two year job protection but shorter cash benefit period to 18months, 2000 reform; job protection two years, cash benefit increased to 30 months	Austria	Parents	National	Data: Austrian Social Security Database, Comparing mothers' career outcomes for those who had labor before and after the policy changes in 1990, 1996 and 2000 for a length of cash benefits and job protection	Longer leave durations significantly delay return-to-work. Despite the significant delays in return-to-work among mothers exposed to the more generous leave regimes,No detrimental effects on their labor market outcomes in the medium-run
Lalive & Zweimueller (2009)	Austria, reform increasing the duration of parental leave from one year to two years for any child born on or after July 1, 1990, AND reduction of parental leave duration in 1996, reducing from 24 months to 18months.	Austria	Parents	National	Data: Austrian Social Security Database (ASSD), individual history of employment, earning and parental leave take-ups.	More extended parental leave increases fertility (mothers who gave birth their first child after the reform have more second children than control group) and extended parental leave significantly reduces the return to work. The reversal reform in 1996 increased employment and earning, but compressing the time between births.
Waldfogel (1998)	U.S. 1993 Family and Medical Leave Act, U.S. 12 weeks of unpaid parental leave and Leave Policies / Britain Trade Union Reform and Employment Rights Act, July 1993, and European Directive of Council of Ministers, implemented March 1994	U.S and Britain	Parents	Firm/ union before FMLA (1992) in U.S. National in Britain	Data: NLSY (National Longitudinal Survey of Youth) for the US and National Child Development Study (NCDS) for Britain. NCDS followed babies born in 1958 when they reached 7, 11, 16, 23, and 33. NLSY (since 1976) selected British equivalent age groups. OLS to access the effect of children to differences in wages (fixed effect model)	Women who had leave compensation and returned to work after childbirth received a wage premium that offset the adverse wage effects of children.
Baum (2003)	1993 Family and Medical Leave Act, U.S. 12 weeks of unpaid parental leave	The U.S.	Parents	Federal	Data: NLSY, difference-in-difference -in difference estimator taking advantage of variations in state-level maternity leave legislation and FMLS	Maternity leave legislation did not have significant effects on employment and wages of women. The result holds true for women who work for employers that are covered by the FMLA
Baker & Milligan (2008)	Canada, reforms in parental leave by provinces. Modest expansion (from 17 to 18 weeks) in the 1970s, more substantial expansion (to34, 29, 52) in the 1990s, and	Canadian provinces	Parents	Provinces	Data: Labor Force Survey from 1976 to 2002. Two samples, panel and time series of cross-section	Job protected leave can increase the time mothers spend with their newborns and increase the likelihood of a return to the pre-birth employer. Job continuity associated with an expansion of leave entitlement, but they come from two sources: one from those who continued their jobs rather than leaving totally, and two from those who changed to a part-time job.

Hondralis (2017)	2011 up to 18 weeks of paid leave, receiving the Australian minimum wage (approximately A$673 per week before tax).	Canada	Parents	National	Data: Household, Income and Labor Dynamics in Australia (HILDA) 2008-2013/ 2008-2010 pre-reform birth vs. 2011-2-13 post-reform birth/ propensity score matching and assessed the probability of working in a specific week after a childbirth	Women do postpone the return to work until the end of the entitlement period. Highly educated women react strongly to the available policy and markedly adjust their employment behavior. Systems have substantial power in shaping employment behavior.
Rønsen & Kitterød (2015)	introduction of "daddy quota" and its extension from 4 weeks in 1993, to 14 weeks in 2013 (but reduced to 10 weeks in 2014) research was administered before the reduction.	Norway	Parents	National	Panel from Norwegian Labor Force Survey (NLFS).1996-2010	Women in Norway returned to work significantly faster after the policy change. However, public or subsidized daycare was greatly expanded at the same time, so Rønsen & Kitterød did not find that the "daddy quota" was solely responsible for the timing of work entry
Schonberg & Ludstook (2014)	Expansion of job protection period: 1979 (from 2 to 6 months)/ 1986 (from 6 to 10), 1988 (from 10 to 12 months) / 1992 (from 12 to 18 months) / 1993 (18 months to 36 months). Maternity benefit expansion: 1986, 1992, 1993.	Germany	Parents	National	Data: Social Security records, provided by the InstituteFor Labor Market Research. Difference-in-difference design that compares labor market outcomes of mothers who give birth shortly before and shortly after a change in maternity leave legislation in years of policy changes and years when no changes have taken place.	Each expansion in leave coverage reduced mothers' postbirth employment rates in the short run. The longer-run effects of the expansions on mothers' postbirth labor market outcomes are, however, small.

Table 2 Table 1. List of articles on the effect of parental leave policies on fathers' involvement in childcare. (quasi-experimental designs)

Article	Family intervention description	Country/ Region	Plicy Target	Level	Data & Methods	What are the results?
Kotsadam & Finseraas (2011)	Daddy quota in Norway (1993), four weeks of leave reserved exclusively for fathers which are nontransferable to mothers.	Norway Govemment	fathers	Norway, National	Data: 2007/2008 Life course, Generation and Gender study (LOGG). Control group parents with the last child born between April 1, 1991, and March 30, 1993, vs. experiment group of parents who had their last child born between April 1, 1993, and March 30, 1995. Quasi-experimental	Respondents who had their last born child just after the reform report an 11% lower level of conflicts over a household division of labor and that they are 50% more likely to equally divide the task of washing clothes than respondents who had their last child just before the reform. (but this does not necessarily mean that men are doing more of the housework.)
Ekberg, Eriksson & Friebel (2013)	1995 'daddy month' reform. This package reserved one month of the parental leave to the father.	Government Sweden	Fathers	Sweden, National	Data: Swedish registry and employment data. Assessed involvement in childcare of fathers as measured whether or not fathers use the leave to care for sick children. Comparison: fathers who had children before the reform and those who had children after the change.	Find strong short-term effects of the incentives on male parental leave, but no behavioral effects in the household. Fathers in the treatment group do not take larger shares of the leave period to take care of sick children, which is their measure for household work. They also investigate a second data set on fathers' and mothers' long-term wages and employment, without finding evidence for substantial effects of the reform.
Patnaik (2017)	Quebec Parental Insurance Program in 2006, that improved compensation and reserved five weeks of leave for fathers or the "daddy quota" reserved exclusively for fathers.	Quebec	fathers	Provinces	Benefit claims from the 2002-2010 rounds of the Employment Insurance Coverage Survey / for long-run effect, time diary data from Canada's General Social Survey (GSS)	Leave reserved for fathers did increase fathers' take-up; Fathers not only responded to higher benefit but also the daddy-only label associated with quota. (Majority of families did not exhaust leave benefit before the reform. Long-term effect was observed in the time-use pattern that showed an increase in the hours men spend in unpaid work.
Rege & Solli (2013)	Introduction of a paternity-leave quota in 1993, reserving four weeks of the total of 42 weeks of paid parental leave exclusively for the father.	Norway	Fathers	National	Data: Norwegian registers, a difference-in-differences model that exploits differences in fathers' exposure to the paternity-leave.	Increased fathers' take-up rate from 3 % in 1993 to 60 % in 1995. Fathers who took paternity leave experience decline in earning.
Steingrimsdottiry & Vardardottirz (2015)	2001 take-it-or-lose-it paternity-leave quota given to fathers as an option to add one month of parental leave to the allotted six months but only if the additional month was used by the father.	Iceland	Fathers	National	Register-based panel dataset comprising a sample of 600 Icelandic families who had children in the three months before and the three months after the first change to the parental leave system. Difference-in-difference model estimating the risk of divorce.	Created substantial economic incentives for fathers to be more involved in caring for their children during their first months of life and the take-up rate in the first year was 82.4%. Parents who are entitled to paternity leave are less likely to divorce during the first ten years of their child's life,

並列均衡と交換経済

鷲田豊明

概要

一般均衡（General Equilibrium）は、今日の市場経済の本質的な機能を、価格による財・サービスの交換過程として表現する。また、このような過程が、パレート最適状態をもたらすという、規範的な意味も示している。さらに、ゲーム論との関係のなかで、この一般均衡が、コアに含まれるという意味での頑健性、安定性を持っている蓋然性も示されている。

本論文では、市場経済を理解するためのツールとして、一般均衡とは少し異なる並列均衡（Parallel Equilibrium）という概念を提起する。並列均衡とは、市場に参加する全ての主体が二者に分解され、その二者の間で並列的に進行する交換手続きを通して実現する均衡であり、均衡は全ての参加者にとってそれよりは望ましいものであり、規範的にはパレート最適性のみが約束される均衡である。この並列性のために、価格が機能していない。したがって、この均衡がコアに属することも約束されていない。並列均衡の中には一般均衡も含まれ、それに近い状態となることはあり得るが約束されるものではない。

Parallel Equilibrium and Exchange Economy

Toyoaki Washida

Abstract

General Equilibrium expresses essential functions of our market economies as processes of exchanges of goods and services. It also has the robustness and stability in the meanings that it is included in core defined by game theory. Moreover, it shows us the normative meanings that it brings Pareto optimal states.

The paper proposes Parallel Equilibrium which is slightly different concept from the General Equilibrium. The Parallel Equilibrium is realized by processes of all participants divided into two subjects pair who exchange each other. The equilibrium state is preferred to the initial states for all participants and the state is Pareto optimum. The price is not unique so that the processes go on in parallel. Then it is not necessarily included in a core though it possibly includes a General Equilibrium states.

並列均衡と交換経済

鷲田豊明

1　はじめに

均衡は、経済学の中心概念の一つで、複雑でダイナミックな経済を変化する契機がない状態として把握し、分析し、認識する手段である。経済学はそのために、多様な均衡概念を用いるが、一般均衡（General Equilibrium）はその中でも最も重要な概念である。一般均衡は、今日の市場経済の本質的な機能を価格による財・サービスの交換過程として表現する。また、このような過程が、パレート最適状態をもたらすという、規範的な意味も示している。さらに、ゲーム論との関係のなかで、この一般均衡が、コアに含まれるという意味での頑健性、安定性を持っている蓋然性も示されている。

一般均衡が、市場経済の本質的側面をとらえていることは否定しがたい。が、それだけで市場経済の本質の全てが語られるものでないことも明らかである。丸山徹氏は一般均衡の前提となる「全ての主体にとって共通な市場が存在するという想定を外すとどうなるか？」と提起し、取引条件が一部の売り手と一部の買い手との間の交渉になり、その条件が相手が変わるごとに変わってしまい、「こうした、いわばバラバラに分解された経済では、市場の競争人の示す価格にあわせて、全主体が受動的に需給計画を決定すると言うがごとき、一種交響楽的なハーモニーは到底期待されそうにない。分断された経済の分析には、別の手法が開発されなければならない」（丸山、2013）と述べている。

本論文では、市場経済を理解するためのツールとして、一般均衡とは少し異なる並列均衡（Parallel Equilibrium）という概念を提起する。並列均衡とは、市場に参加する全ての主体が二者に分解され、その二者の間で並列的に進行する交換手続きを通して実現する均衡であり、均衡は全ての参加者にとってそれよりは望ましいものであり、規範的にはパレート最適性のみが約束される均衡である。この並列性のために、価格が機能していない。したがって、この均衡がコアに属することも約束されていない。並列均衡の中には一般均衡も含まれ、それに近い状態となることはあり得るが約束されるものではない。

本論文は、このような並列均衡のワーキングの解明、および一般均衡が見落としてしまうような市場の機能を明らかにすることを目的としている。並列均衡そのものは一般性のある概念だが、ここでは一つの分析例として、並列均衡によって、市場の恩恵を受けるものと受けないもの、相対的に多くを手に入れる者とそうでない者との差の発生を分析する。一般均衡においては、交換の前後で、どの主体にとっても価値は保存されているが、並列均衡は、その原始的性質から、また、価格という概念を持たないので、このような保存性が失われている。逆に、それによって、われわれの交換経済の本質に迫ることも可能になるのである。

2　並列均衡の定義とアルゴリズム

並列均衡は、その実現手続きとともに定義される。そのまえに、まず、交換から確認しておこう。

定義 1：交換とは、それに参加する主体が、他の主体との財・サービスの授受によって自らを望ましい状態に変更しようとする行為である。

したがって、各主体は、自らの状態が改善していない限り交換に同意しないことを前提とする。

定義 2：並列均衡は、全ての主体を無作為に選択した二者の交換の繰り返しによって実現する均衡である。

二者の交換の繰り返しが、均衡にいたいるのか、すなわちそれ以上の状態の変更が、全ての主体にとって受け入れられなくなるような状態に至るのか、その状態は、パレート最適性を実現するのか、これを理論的に明らかにすることは困難である。交換過程にさまざまな想定を組み込まない限り、理論分析の対称とはなり得ない。ここでは、アルゴリズムを定義し、それによるシミュレーションによって均衡の可能性と特性を把握する。

まず、二者の交換の交換手続きをエッジワースのボックス図で示そう（図 1）。

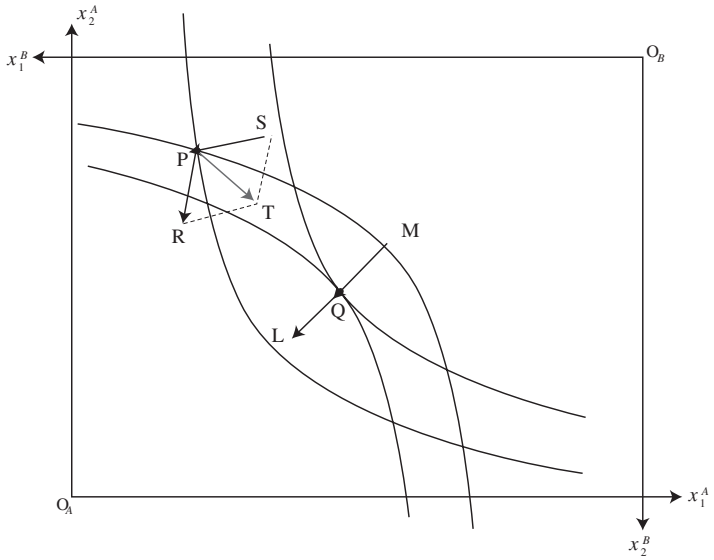

図 1: Gradient and Exchange

二人を A と B で表そう。交換前の状態が P であったとしよう。P は A からみれば (x_1^A, x_2^A) であり、B からみれば (x_1^B, x_2^B) であるとする。このとき、P 点において、効用を増加させる方向への gradient ベクトル $\overrightarrow{PS}$ と $\overrightarrow{PR}$ は、それぞれの効用関数を U^A および U^B として、

$$\overrightarrow{PS} = \left(\frac{\partial U^A}{\partial x_1^A}, \frac{\partial U^A}{\partial x_2^A} \right)$$

および、

$$\overrightarrow{PR} = \left(\frac{\partial U^B}{\partial x_1^B}, \frac{\partial U^B}{\partial x_2^B} \right)$$

となる。

交換は、その結果として両者が望ましい状態にならなければならない。それは、この場合、P から、無差別曲線で囲まれたレンズの内側への移動によって実現する。無数の選択肢はあるが、ここ

$$\overrightarrow{PT} = \overrightarrow{PS} - \overrightarrow{PR} = \left(\frac{\partial U^A}{\partial x_1^A} - \frac{\partial U^B}{\partial x_1^B}, \frac{\partial U^A}{\partial x_2^A} - \frac{\partial U^B}{\partial x_2^B} \right)$$

となり、B からみると、

$$\overrightarrow{PT} = \overrightarrow{PR} - \overrightarrow{PS} = \left(\frac{\partial U^B}{\partial x_1^B} - \frac{\partial U^A}{\partial x_1^A}, \frac{\partial U^B}{\partial x_2^B} - \frac{\partial U^A}{\partial x_2^A} \right)$$

交換の方向性、すなわち交換比率は上記の $\overrightarrow{PT}$ で与えるとして、実際どれだけの規模で交換するかは別に定義されるべきである。この規模を決定するパラメータは、共通に β として与えることにしよう。この β は、ある程度小さくなければならない。なぜなら、大きすぎると、パレート最適点を外してしまうからである。

また、$\overrightarrow{PS}$ および $\overrightarrow{PR}$ の長さ（絶対値）に注目すべきである。二人の状態がともに改善することは、それぞれの長さが不適切だと実現できない。両者の長さが等しいと、その和のベクトル $\overrightarrow{PT}$ は、両者の効用を厳密に改善する方向となる。すなわち、

$$|\overrightarrow{PS}| = |\overrightarrow{PR}|$$

であることが必要となる[1]。

したがって、一回の交換によって実現する A の新たな所持量 P_{new} は、

$$\overrightarrow{O_A P_{new}} = \overrightarrow{O^A P} + \beta(\overrightarrow{PS} - \overrightarrow{PR})$$

同じく、B の所持量は

$$\overrightarrow{O_B P_{new}} = \overrightarrow{O^B P} + \beta(\overrightarrow{PR} - \overrightarrow{PS})$$

となる。

いまもし、交換前の状態が図の Q 点のように表されると、実質的な交換は行なわれない。$\overrightarrow{PR} - \overrightarrow{PS} = 0$（零ベクトル）となってしまっているからである。この状態はまた、限界代替率が等しい状態である。

われわれのアルゴリズムはすべての参加者の間で、すべての財に関して限界代替率等しくなっているときに、手続きは止まるようになっていなければならない。実際の計算では、この $\overrightarrow{PR} - \overrightarrow{PS}$ の絶対値（ノルム）がある正の十分小さな値以下になっている状態で計算を止めるように設計されるべきである。

アルゴリズムは、図 2 に表している。

したがって、このすべての限界代替率が等しくなっている状態は、また、パレート最適でもある。並列計算アルゴリズムは、正常に収束する場合には、パレート最適点に収束していることになる。また、それが初期状態（アルゴリズム開始の時点）より望ましい状態であることは、十分確かに推定される。

3　並列均衡のシミュレーション

この並列均衡アルゴリズムが実際にパレート最適点に収束することを、いくつかのシミュレーションで示しておこう。純粋交換経済を考える。主体の数を N とし、財の数を M とする。効用関数を U^i とし、次のように特定化する

[1]ただし、本論文における実際のシミュレーションでは、収束を高速化させるために、これにこだわらずにベクトルを定める。結果的に、並列均衡においては、両者の効用が改善されることと、パレート最適性が実現されれば良いからである。

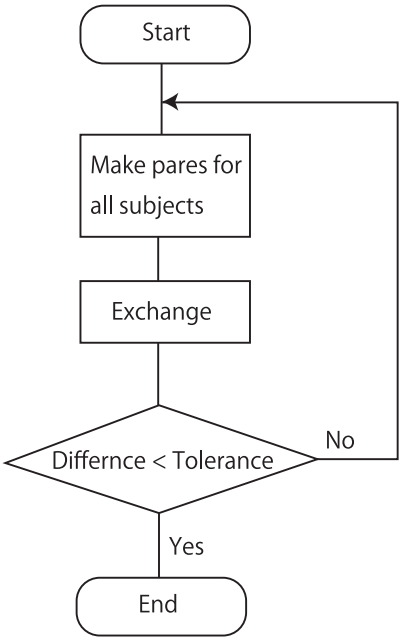

図 2: Parallel Equilibrium Algorism

$$U^i = \sum_{j=1}^{M} \alpha_j^i \ln(x_j^i + \beta i)$$

ここで α_j^i が特定化され、また、x_j^i の初期状態があれば、このアルゴリズムを実際にシミュレーションすることができる。

今回は、表 1 のような設定で行った。収束基準を 5.0e-8 にしているが、1.0e-9 程度でも十分収束する。

表 1: Parameters and Initial Endowments

α_j^i range	α_j^i base	$\overline{x}_j^i$ range	$\overline{x}_j^i$ base	β_i	tolerance
0.5	0.2	10.0	1.0	0.01	2.0e-8 ∼ 1.0e-9

α は、各主体 i、各財 j に関して、まず、base となる値を与え、range の範囲内の無作為に実数を加えて設定した。同じく、初期賦存量 $\overline{x}_j^i$ についても、base を与えた上で、range の範囲内の実数を無作為に加えて設定した。ただし、初期分配の所得は、すべての財の価格を 1 と想定した上で、すべての人について財数と同じになるように調整する。すなわち、各主体が一つの財を平均 1 ずつ持つように設定している。したがって、各自の初期賦存量の財の割合は、総保持量（総所得）がすべての人にわたって等しくなるような形で、無作為にばらついた値となっているのである。

交換主体と財の数を、(1) 10 人 10 財、(2) 100 人 100 財、(3) 1,000 人 1,024 財、(4) 10,000 人 1,024 財、(5) 300,000 人 1,024 財の 5 パターンで行なった。計算には、並列計算アルゴリズムと並列計算コンピュータを用いたが、そのスレッド数の制約から、財の数は 1,024 財が上限となり、メ

モリ制約から最大主体数が 300,000 人となっている[2]。

シミュレーションの結果を表 2 にまとめた。

表 2: Simulation Results

persons	goods	iteration	time (sec.)	final diffs	mrs diff max	mrs diff min	mrs diff ave
10	10	5,796	1	5.08e-10	2.03e-6	2.43e-9	3.00e-7
100	100	28,219	3	1.82e-8	1.62e-6	0.0e-12	1.11e-8
1,000	1,024	9,104	4	9.73e-10	2.64e-9	0.0e-12	0.3e-11
10,000	1,024	9,317	40	9.83e-10	2.40e-9	0.0e-12	0.1e-11
300,000	1,024	9,472	2,364	9.88e-10	3.17e-9	0.0e-12	0.0e-12

まず、シミュレーションでは、並列計算アルゴリズムとマルチコアのハードウェア[3]を用いているので、計算速度はきわめて速い[4]。30 万人が 1,024 個の財を交換する状況でも、最適解を約 40 分で解いている[5]。

final diffs は、最終的な各財の gradient の差の最大値であり、それが tolerance 以下になっていることを示している。ほぼゼロである。mrs は第 0 材に対する限界代替率を表し、すべての人、すべての財にわたって計算し、対応する限界代替率の差の割合の最大値、最小値、平均値を表している。比較的、人と財の数が少ない場合に、大きな値となっている。たとえば、10 人 10 財の場合、最大の限界代替率の差は 0.0002%であり、それでもほとんどさがないと言ってよい。他の場合は、ほぼ限界代替率に差はないことを表す値となっている。すなわち、すべての人の間で、二つの財の限界代替率は等しくなっているのである。すなわち、シミュレーションの結果において、すべての並列均衡は、パレート最適である。

また、すべてのシミュレーションにおいて、すべての主体が、初期状態からみて効用を厳密に増加させていることも確認している。

4 並列均衡の意味

並列均衡が、すべての参加者によって初期状態よりも望ましくまたパレート最適であるという規範性を持ちうることを示したので、改めて並列均衡の意味を考えてみよう。

並列均衡は、パレート最適であるために、パレート基準で、一般均衡よりも劣った均衡であるとは言えない。ただし、コアには含まれていない可能性があるので、ゲーム論的な意味での、安定性の点では、粗野な均衡であることは否めない。

一般均衡と本質的に異なるのは、価格が機能していないことである。純粋交換の一般均衡においても、最終状態において限界代替率はすべて等しくなっているが、それは同時に価格比でもある。しかも、その価格で計ると、最終状態の財全体の価値は、初期状態の総価値に一致している（自由財がなければ)。並列均衡においても、一般均衡と同様に限界代替率はすべての主体にとって等しいので、それを価格と見なすことはできるが、その価格で計った初期状態の価値は、必ずしも最終

[2]並列計算アルゴリズムと、ハードウェアの詳細は別に述べる。

[3]Tesla K20, 2,496 cores.

[4]たとえば、500 人 100 財の純粋交換均衡の場合、非線形連立方程式解を求める GAMS を用いると 10 時間以上かかった。

[5]この計算時間のかなりの割合が、無作為に 2 者の組み合わせを決めているプロセスで費やされていることを指摘しておこう。実際に、並列的な交換プロセスの計算は、半分以下の時間しかかかっていないと思われる。

状態の価値に一致しない。すなわち、最終状態における財の総価値からみれば、初期状態から豊かになった人も貧しくなった人もいるのである。しかし、価格がないので、そのような結果は明示的には見えてこない。

並列均衡において、価格が役割を果たしていないという事実は、この均衡の完全な非現実性を表していると言えるだろうか？ 市場経済において、価格の成立していない市場はないように見える。並列均衡においては、交換が完全に分解されてしまっているので、分解された個々の交換において、交換比率は発生するが、その交換比率は、交換が現実に行なわれているプロセスでは、他の場で行なわれている同じ財の交換比率とは異なってしまっている可能性がある。すなわち、「一物一価の法則」は全く成立しない。

確かに、同じ市場の同じ場所にある特定の財に二つの価格がつくことは理論的にも現実的にもあり得ないだろう。しかし、財やサービスが、そのおかれた条件の違い以上に、異なった価格をつけているように見える事態は、それほどまれではない。市場で、主体の交渉力などによって価格がかわってくることは日常的にあり得る。価格よりも、交換が優先されることは現実に発生する事態なのである。その交渉力の対象になっているものが同じ財ではないと言えるかもしれない。たとえば、A さんの持っている G という財と B さんの持っている同じ G という財は、財だけみれば同じだけれども、市場では異なった財と見なすということは、漕艇場はあり得るかもしれない。あるいは、賃金は労働につけられた価格であるが、それは同じ労働時間でも、無数に近いバリエーションを持っている。経済学は、このような財やサービスにつけられる多様な価格を単に捨象しているのにすぎない。

すなわち、現実の経済に均衡があるとしたら、それは並列均衡と一般均衡という二つの性質を持っていると考えた方がよいということである。あるいは、現実の経済の均衡は、並列均衡と一般均衡の中間にあると言ってもよい。

また、財の流通ということを考えてみてもよい。ある主体から、別の主体に、財が次から次へと持ち手を帰ることによって流通は成り立っている。このようなプロセスとその結果は、並列均衡のアルゴリズムそのものに似ている。

5　並列均衡から見える市場

並列均衡は、一般均衡とは異なった視点からわれわれの市場経済を分析するツールとなる。

ここでは、一つの例を示そう。先に述べたように、一般均衡においては、初期値の総価値と交換後の総価値は基本的に等しい。これは、ある与えられた価格のもとで全体一斉に交換が行なわれることを前提にしているからである。しかし、並列均衡においてはこのようなことが成立しない。すべての主体は初期状態よりも満足しているのだが、交換の結果には完全に平等ではない状況が現れる。交換前は、先に述べたように、すべての財の価値を 1 として、財の数だけの共通の所得で財が配分されている。財の配分そのものはランダムだが、その合計はすべての主体で等しくなっているのである。交換後の状態は、すべての財の価格を 1 としても、あるいは、限界代替率を用いても計ることはできる。いま、すでに示したシミュレーション結果でこれがどのようになっているのかを示すと、図 3 のようになる。

この図は、縦軸がその所得の人数であり、横軸が所得である。所得 1 単位ごとのヒストグラムになっている。ただし、価格がすべて 1 として、最終状態の所得の分布を示したものである。価格を最終的な限界代替率に変えても、分布はほとんど重なるので、そちらは示していない。この場合、初期の所得は、1,024 に統一しているので、きわめて公平な状態から出発して、図のような分布が

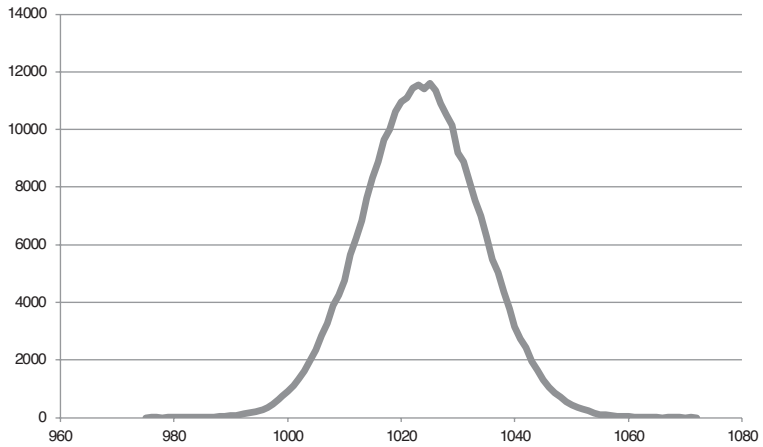

図 3: Income Distribution 30,0000 subjects

発生したことになる。最大所得は、1,071 で、最小は 976 である。これを大きいとみるか、小さいとみるかはこれだけでは判断しがたいが、完全に等しくなる一般均衡との差は歴然としている。

このように所得の分布が発生することは、単に、並列均衡の粗野な性質からくるものと考えるべきではない。先にも述べたように、並列均衡は現実の一部を反映しているのであり、したがって、このような所得の分布もまた、交換経済の帰結と考えるべきである。遺産などの外的なものをのぞけば、われわれはただ、自分の持っている物を交換しているだけである。しかし、実際に貧富の差は発生する。労働は単一のサービスではなく、多様な質を持った多様なサービスと考えるべきである。それらの交換の結果としてあるものは豊かになり、貧しくなると言える。

この所得分布では、全てが 1 である初期の価値と最終的な限界代替率で測った価値で評価した所得分布がほとんど重なっていたが、少し違った場合も示しておこう。図 4 は、主体が 300,000 人、財が 1024 の場合における、その両者の分布を 1 単位ごとのヒストグラムで示している。ここでは、初期の分配パラメータ α の base 値を最初の第 1 財から最後の第 1024 財まで、0.02 ずつ増加させている[6]。したがって、財の需要に偏りが発生することになる。

シミュレーションは、117,021 回で収束し、8 時間 5 分 14 秒かかっている。そうしない場合よりも、格段に必要繰り返し回数、および時間が増えている。全ての主体が最終的に初期状態より厚生水準を厳密に増加させ、最終誤差は 9.35e-10 で、最終限界代替率の違いの最大値は 2.82e-9 で、最小値、平均値はそれぞれほぼ 0 である。したがって、最終状態がパレート最適であることはほぼ確実である。

図 4 をみると、この場合は、初期の単位価値で最終所得を評価すると、分布は、ほぼ初期配分の 1,024 の近くに固まってしまっているが、限界代替率で評価した所得は、このような偏りを入れていない場合と同様な分布を見せている。

[6]実際さらに、総和が、そうしない場合と同じ時なるように正規化しているが、理論的にはこれはしてもしなくても結果は同じになる。

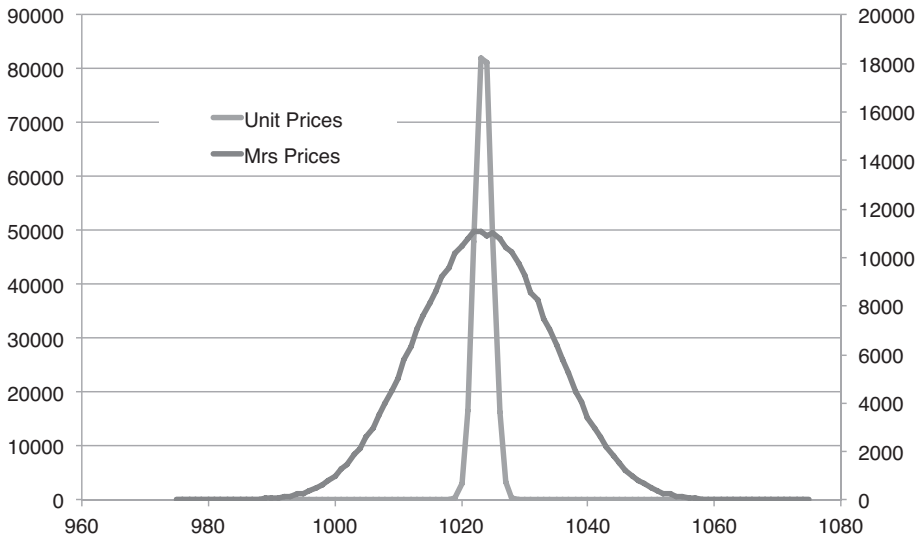

図 4: Income Distribution 30,0000 subjects with MRS

6 生産を含む並列均衡

6.1 生産と交換

これまでのモデルの中には、消費者だけが存在した。消費者はそれぞれ、初期に財のバスケットを保有していて、交換をすることによってそのバスケとの財の組み合わせをより望ましいものに変更する。この交換の繰り返しによって、すべての主体がそれ以上の交換を望めない状態、それが並列均衡となった。ここで、生産をモデルの中に組み込もう。生産とは、通常は、生産要素を投入し、何らかの財を新たに生み出すアクティビティと経済学では考えられてきた。そこには、生産を、新たな財が創造されるプロセスに注目していた訳である。このプロセスを担っているのは一般に企業と呼ばれるが、この企業も、対外的には単に交換を行っているだけであり、交換によって状態を変えようとしているという点では、消費者と同じである。ここでは、まず、こうした生産の担い手である企業を、交換主体として定義する必要がある。

また、並列均衡においては、価格というものを明示的に表さない。通常、企業の利潤最大化行動なり、費用最小化行動は価格を用いなければ定義できない。この問題も同時に解決しなければならない。

いま、最も単純な形で、生産を含む均衡を考えよう。二人の消費者と企業が一つあったとする。財は、2 種類のみで、一つの企業がこの二つの財を結合生産している。既に生産要素は企業に与えられていて、企業はただ、この二つの財の生産フロンティア上で二つの財の生産量の組み合わせだけを技術的に調整できるだけだとしよう。図 5 にこの状況が描かれている。消費者二人の状況は、初期分配をのぞけば図 1 に描かれたものと基本的に同じである。企業は、原点 O_A からみて、曲線 F で表される生産フロンティアを持っている。いま、このフロンティア上の一点 O_B が企業によって選択されたとする。そして、この企業の所有権を A および B が $O_AM : O_BM$ の割合で持っていて、その割合に応じて二つの生産物が二人の消費者に分配されたとすると、二人の消費者の初期

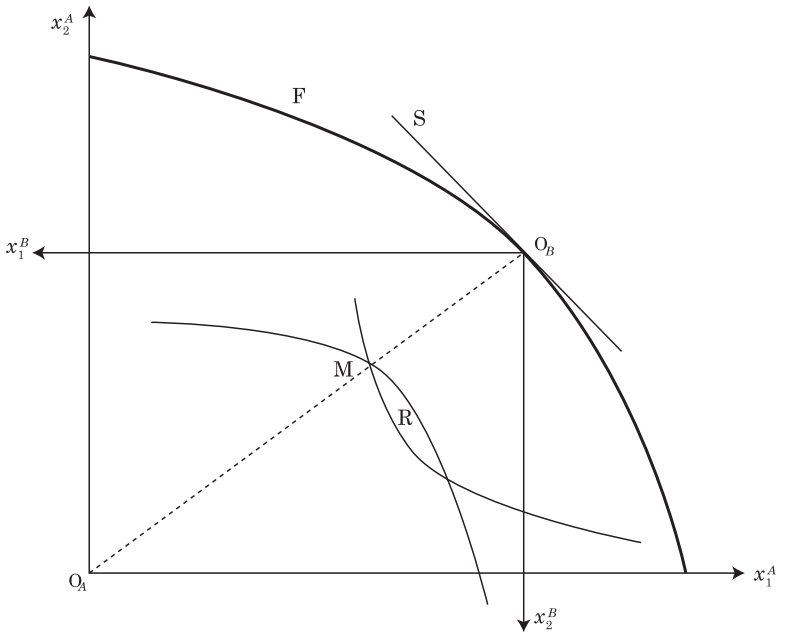

図 5: Parallel Equilibrium and Production

保有量は M 点となる。

この M 点は、なによりも二人の消費者の間の限界代替率が等しくないので、二人の間で交換が行われ、最終的に領域 R の中のある一点で、限界代替率が等しくなるようなところが選ばれる。しかし、もし、この最終的な限界代替率が、もともとの生産フロンティア上の限界変形率と等しくない場合は、もともとの生産フロンティア上の点を別な点に変更することによって、パレート優位な最終結果を得ることができる。たとえば、いま、両消費者の間で等しい限界代替率を $\triangle x_2/\triangle x_1$ であり、限界変形率が $\triangle x_2'/\triangle x_1'$ であったとしよう。そして、さらに、

$$\frac{\triangle x_2}{\triangle x_1} < \frac{\triangle x_2'}{\triangle x_1'}$$

となっているとしよう。このとき、消費者にとっては、第 1 財を微小に 1 単位だけ減じ第 2 財を $\triangle x_2/\triangle x_1$ 単位増加させても、両者の効用水準は変わらない。一方、第 1 財の生産を 1 単位減じると、第 2 財の生産を $\triangle x_2'/\triangle x_1'$ だけ増やすことができる。そうすると、$\triangle x_2'/\triangle x_1' - \triangle x_2/\triangle x_1 > 0$ だけ、両消費者の満足度を維持したまま、余剰を発生させることができる。これを両方、あるいは、どちらかの消費者に配分すれば、誰の満足度を下げることなく、いずれか一方、あるいは両方の満足度を増加させることができることになり、そのような状態はパレート最適ではないことを意味する。したがって、パレート最適であるためには、限界代替率と限界変形率のすべてが等しくなっていなければならないのである。

このような状況の中に、生産を含む並列均衡の基本的な形が描かれている。価格が明示的な役割を果たす必要がなく、消費者も生産者も相互の分離された交換と、限界代替率ないしは限界変形率だけが問題になる状況となっている。

6.2　生産の概念

ここで、改めて並列均衡と整合性を確保できるような生産概念を考えてみよう。企業は消費者との間で財と貨幣を交換する。貨幣は価値基準財にすぎないとすれば、これは消費者と企業の間での財の交換と解釈できる。また、消費者は労働の提供者であるとすれば、労働と財の交換だといえる。

7　並列均衡のアルゴリズム

ここでは、通常の直接的計算と対比させる形で、並列均衡計算のアルゴリズムのコアの部分を示しておこう。交換主体が 20,000 人、財が 1,024 種類あるとする。

まず、従来の直列的計算法を示す。計算用のコア（CPU）が一個であるとする。先に示したアルゴリズムを通常の計算手続きで実現すると、図 6 のように基本的にループ計算を用いる。まず、無作為に 2 人のペアが 10,000 ペア作成される。次に、ペアの一つを取り上げて、1,024 個の財について、1 個ずつ、gradient（一種の相対価値）を計算し、ペアの両者の差から、その財についての交換量を計算する。これが一番内側のループ Loop 1 である。次に、これをすべての人について、一人ずつ 10,000 回行なう。Loop 2 である。ここだけで一つの CPU を利用して 1,024 万回の計算が行なわれる訳である。

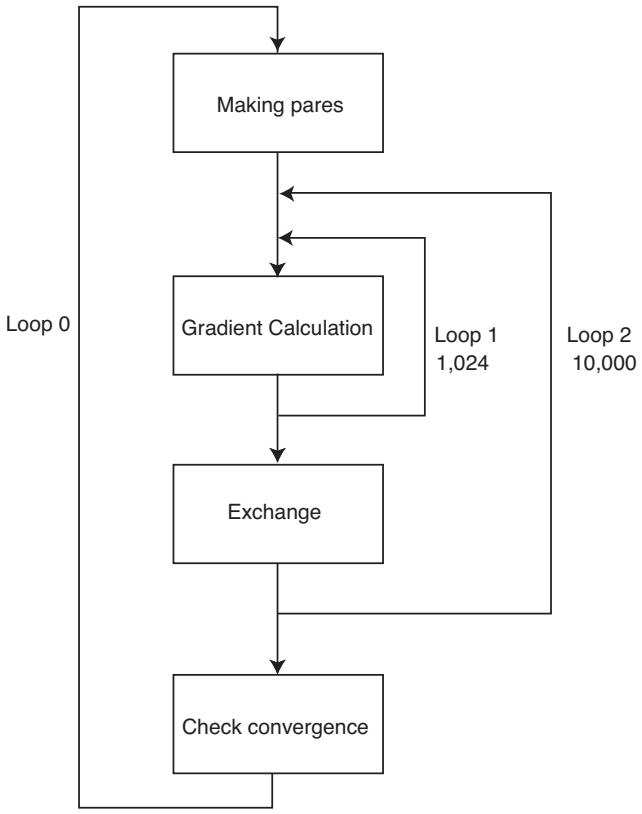

図 6: Series Calculation

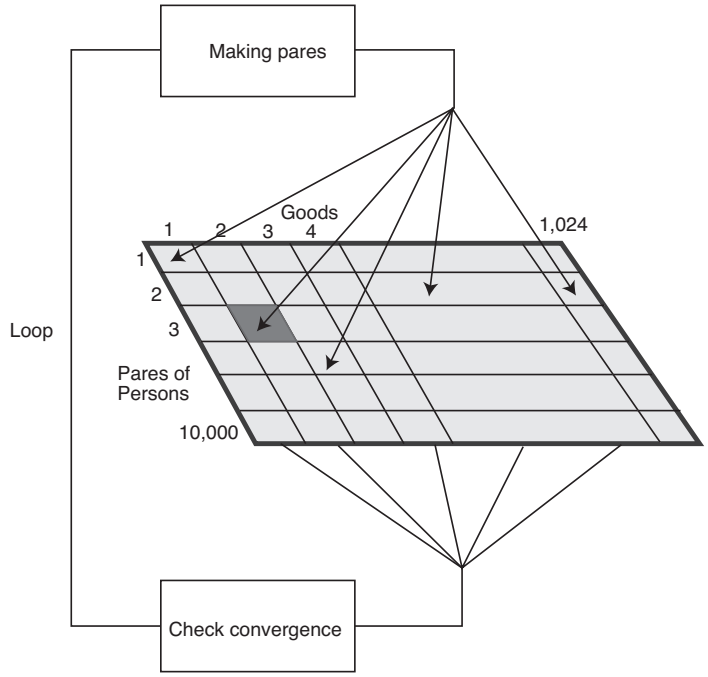

図 7: Parallel Calculation

この課程の最大交換量を誤差として、収束を判定する。交換量が十分少なくなっていれば、それがパレート最適状態である。誤差がまだ大きいと、一番外側の Loop 0 がおこなわれる。

以上が、従来の直列的計算のアルゴリズムである。

これに対して、並列計算は、多数のコアを利用して、並列的に計算を行なう。図 7 に計算のアルゴリズムを示す。直列の場合の、Loop 1 および Loop 2 は存在しない。まず、ペアが 10,000 個造られる。これは同じである。このペアと、財をマトリクスのように指定されたセルについて、一つのスレッドが割り当てられる。たとえば、図の色の濃いセルは、第 3 番目のペアの、第 2 番目の財について割り当てられたスレッドである。ここで、gradient の計算、およびその財についての交換の計算が行なわれてしまう。すなわち、1,024 万個のスレッドが作成され、システムによって多数のコアに自動的に割り当てられるのである。ここでの計算の場合は、2,496 個のコアに 1,024 万個スレッドが割り当てられる訳である。

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上智地球環境学会

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持続可能な地球社会システムを形成するために、社会科学、人文科学そして自然科学の成果を総合した地球環境学の創成と発展の必要性が今日誰の目にも明らかになってきています。上智地球環境学会は、これに貢献するために研究者の知的コミュニケーションと人的ネットワークの形成およびそれを基礎にした、研究と人材育成のダイナミックな展開を目的として発足しました。自由でオープンな議論、自立的な研究の相互依存、琢磨によって新しい文明創造的な場を広く提供していきます。

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