Protecting Forests: With and without conservation contracts

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Abstract

To investigate whether there are synergies between NGOs and REDD+ funders, or whether they are substitutes, this thesis investigates the value of reducing monitoring or protection costs with and without donor contracts. I review the optimal contracts for aggregate tropical deforestation presented in Harstad and Mideksas' paper *Conservation Contracts and Political Regimes* from 2017 and expand their *Model of Resource Extraction.* I discuss how the value of reducing protection costs (such as better monitoring, satellites or police) are affected by different parameters in the model, depending on their values, and how these affects an NGOs' motivation to conserve. Moreover, I examine how this value varies from one contract situation to another. I find that the value of reducing costs increases in damages, or when the nr of districts or subsets increase. This implies that the contracts are complementary: We are always better off when a donor offers a conservation contract. And, even better: The rewards are amplified when governments reduce exploitation. In other words: Huge upside potential and low downside risk.

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Contents

1 Introduction

The theme of this thesis is protecting forests and conservation contracts. As a starting point, I chose *The Model of Conservation* by Harstad and Mideksa (2017) from the master course Environmental Economics. My main question to it was: How does its design relate to its drivers? The main factor Bård and I discussed was monitoring. Forests are naturally spread out and hard to monitor, which makes protection costly (Harstad and Mideksa, 2017). However, monitoring is necessary to detect deforestation and ensure successful protection. Therefore, I expand *The Model of Conservation*, which I derive with respect to a reduction in protection costs, with and without conservation contracts. Moreover, I investigate how the value of reducing protecting costs depend on the parameters. The parameters will vary on the political situation and circumstances. I also assess which contract is most alluring. The purpose of this thesis is to *protect forests*, which is a matter of global security, key to our planet's health and *survival of the species*. I invite governments and decision makers to apply these findings.

This first section gives an introduction to primary forests, deforestation and its drivers, monitoring and conservation contracts. Section 2 explains the method and materials. Section 3 presents the *Model of Conservation*, presented by Harstad and Mideksa in *Conservation Contracts and Political Regimes* from 2017. I expand the model by solving it for a cost reduction. The results are analyzed and discussed in Section 4. Section 5 compares how the value of reducing c varies from one contract situation to another, depending on the parameters, and what motivates an NGO to conserve more. Furthermore, I investigate whether there are synergies between NGOs and REDD+ funders, or whether they are substitutes. Then I check how the findings complies with reality, based on the method and materials. Section 6 concludes. Section 7 shows references. Section 8, the Appendix, provides parameter definitions and derivations from section 5.

1.1 Virgin forests

In 2013 the Royal House of Norway reported that King Harald finally had the opportunity to visit the Amazonian rainforest after an invitation from the Rainforest Alliance. According to Harald, it was ”a dream coming true” (The Royal House of Norway, 2013). Our planet's forests vary from blue sea forests in the Arctic to the green lungs of the earth, the tropical rainforests in the Amazon. These virgin forests, also called pristine old-growth forests, play a vital role for global ecosystems, in sustaining wildlife and in mitigating global warming (UN-REDD, 2023). "Forests also contribute to human well-being, food security and nutrition, and to local livelihoods, by providing social, economic and environmental services, such as the regulation of hydrological flows, clean water supply, soil protection and the provision of a wide range of food and raw materials (FAO and UNEP,2020)", according to FAO (2022,1). In addition, virgin forests provide us with shelter and natural life saving medicines (SNL, 2023). In short, a necessity for future generations to thrive and a social economical everlasting equilibrium. These natural resources, are "our common resources", according to professor Karen Helene Ulltveit-Moe (UiO, 2022). "Indeed, forests play a crucial role in climate change, both as sinks and sources of carbon emissions, and the degradation of forests is a significant source of greenhouse gas emissions (IPCC,2019)", according to FAO (2022,1). "However, at the same time, forests contribute to large proportion of the global terrestrial carbon sink (Jia *et al.*,2019), which each year estimated to remove from the atmosphere about one-third of the carbon dioxide emitted by fossil fuel combustion *Friedlingstein et al.*, 2019)", according to FAO (2022,1). Truly, our forests are earth's natural carbon capture and storage.

"The world's forests area covered 3.97 billion hectares (ha) in 2018 - accounting for 30.8 percent of global land area", according to FAO(2022, xii). FAO (2022, 17) writes that "According to the Remote Sensing Survey, most of the world's forests are found in the tropical domain (46 percent), followed by boreal (28 percent), temperate (16 percent) and subtropical domains (10 percent)". "Tropical and boreal are the climate domains with the highest percentage of naturally regenerating forest: 48 and 29 percent respectively", according to FAO (2022, 23). The Amazon rainforest, the focus of this thesis, has the largest forest cover on land and the highest percentage of naturally regenerating forest. Science show we have more to save on conserving these old-growth forests, than subsidizing planting trees, and that conserving tropical rainforests is our best remedy against climate disaster, according to Financial Times (2022). Thus, the Amazon is our most urgent conservation target of our planet's green range of primary forests. Reknown economists like Bård Harstad, Sebastião Salgado and Jens Stoltenberg all address the importance of protecting the Amazon. In addition, environmentalists like Yann Arthus Bertrand, goodwill ambassador for the United Nations Environmental Programme, support these warnings. The solution

Figure 1: The Amazon Basin (FAO, 2022, viii).

is simple: ”It’ not cutting trees” and ”it requires no technology”, according to Harstad and Stoltenberg (Harstad, 2013). It’s effortless and it’s timeless. Fortunately, protecting forests is cheap and cost-effective. According to Harstad, ”Rainforest protection is the most cost-effective thing I know of: It protects nature, the environment, climate, indigenous peoples, and contributes to development – in one and the same way” (UiO, 2023). Moreover, the value of conserving virgin forests is greater than the private economic profitability of cutting them, according to Harstad (DN, 2017). Funfacts, according to UN-REDD+, include: ”Forests are the fastest, cheapest and most immediate climate solution”, ”Forests supply 75 percent of the world’s fresh water”, ”Forests are home to 80 percent of the world’s terrestrial biodiversity” and ”More than 25 percent of medicines originate from tropical forests plants” (2023). Basically, public goods, like virgin forests, satisfy our fundamental needs, both from an economic perspective, but also according to psychology (see Maslows pyramid of needs). In tropical rainforests, like the Amazon, new species are discovered continuously, making it nature’s true innovator. Our jungles have a richness of biodiversity and ecosystem services, a vast genetic material, is hard to imitate, lacks substitutes, is flexible against drought and is resilient to climate change (Nature, 2011). Thus, it’s versatility is unmatched. All of this makes it rare and distinct from monocultures like cattle ranches, palm- and soy plantations, which are the main drivers of deforestation.

1.2 Deforestation

Deforestation, on the other hand, is the clearing or stripping of virgin forests. As a result, our planet just keeps getting hotter and wetter, according to meteorologists. Unfortunately, logging can be illegal or legal (controlled by governments), according to Harstad and Mideksa (2017). Mature tropical rainforests, on the other hand, are climax communities. ”Deforestation is defined as ”the conversion of Forest to other land use independently whether human-induced or not (FAO, 2020a)”, according to FAO (2022, 28). The purpose of deforestation could be to extract timber and produce beef forever on the land (Harstad and Mideksa, 2017). Deforestation is particularly harmful and irreversible, since tropical rainforests are depletable resources and easily exploited (Harstad and Mideksa, 2017; Harstad and Framstad, 2017). This business as usual scenario, or reference point, without governmental or donor intervention (like taxes or subsidies), is our worst possible outcome. The most immediate threat is, for example "Round-up", a chemical produced by Bayer (Monsanto) that kills the tree down to its very roots. EU, for instance, newly renewed the licence for this highly harmful product putting our water supply, and humanity, at risk (Nature, 2023). According to FAO(2022, xii), "The FRA 2020 reveals a slowdown in the trend of global deforestation, together with a slight increase in global annual forest gain". "Annual deforestation declined by around 29 percent during 2010-2018 period, compared with the first decade of 2000 (from 11 million ha per year (Mha/year) to 7.8 Mha/year). Net forest area losses more than halved between the first and second periods studied, decreasing from 6.8 Mha/year in 2000-2010 to 3.1 Mha/year in 2010-2018", according to FAO (2022, xii). "However, the findings confirm that there is no room for complacency, with high deforestation rates recorded in South America, followed by Africa and Asia", according to FAO (2022, xii). "Tropical forests registered the highest rate of deforestation from 2000 to 2018, accounting for 157 Mha of forest losses in the period, which represents more than 90 percent of global deforestation. Most of the tropical forest losses were recorded for tropical rainforests, where the losses accounted for 40 percent of the total forest losses in 2000-2018 (69 Mha deforested)", according to FAO (2022, 32). "On average, 1.6 Mha of forest in the tropical rainforest ecoregion of South America and 1.2 Mha of forest in the tropical rainforest ecoregion of South and Southeast Asia were lost each year (see table 14)", according to FAO (2022, 33). "Forest area expansion is defined as the expansion of forest on land that, until then, was under a different land use, implies a transformation of land use from non-forest to forest (FAO, 2020a)", according to FAO (2022, 28). FAO (2022) writes that "Forest area net change is the difference between forest area expansion and deforestation" (p. 28). "According to the FRA 2020 Remote Sensing Survey, between 2000 and 2018, 173 Mha of forest were deforested worldwide. At the same time, forest area expanded by 80 Mha. As such, this gives a net forest area loss of 93 Mha for the whole period. Annual deforestation decreased by around 29 percent, from 11 Mha per year during the period 2000-2010 to 7.8 Mha per year during the period 2010-2018", see FAO (2022, 28-29). "Within the tropical domain, the greatest net losses occurred in tropical rainforests, at 61 Mha in 2000-2018, representing almost half the net losses of the entire tropical biome. Nevertheless, the trends in this ecological zone marked a slowdown in net forest area losses from 4.1 to 2.4 Mha per year", according to (FAO, 2022, 44).

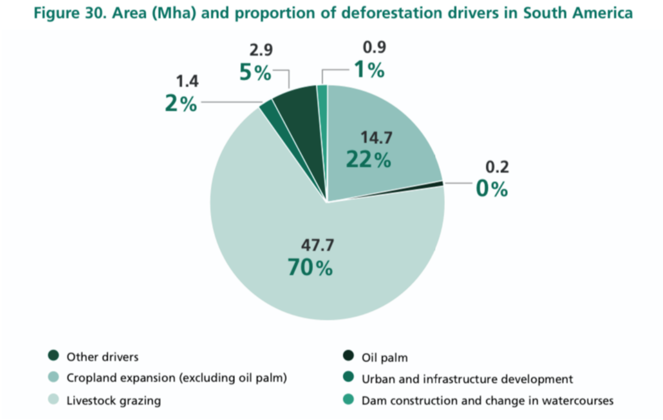

Figure 2: Proportion of direct drivers of deforestation in 2000-2018 (FAO, 2022, 47).

1.3 Drivers

Deforestation is a complex issue and hard to comprehend, with multiple drivers globally. The scope of this thesis is to draw attention on the stripping of *tropical rainforests* and shed light on the main drivers. Considering this, I expand *the Model of Conservation* with respect to a reduction in protection costs, like better satellites. Harstad and Mideksa (2017) are the pioneers behind the model. Safeguarding forests is mostly determined by governmental policies, according to Harstad. Lack of governance, like low enforcement and monitoring, undermines an economy. From Harstad and Mideksa (2017), we know that the timber and beef markets are integrated and characterized by oligopolistic competition by large multinational global companies (Harstad and Mideksa, 2017). One example is Monsanto. FAO (2022) writes that "In South America, expansion for livestock grazing was a major driver, causing 70 percent of total deforestation. This is due to the ongoing expansion of cattle ranching in forested areas, particularly the Amazon basin, Gran Chaco region and the Cerrado" (p. 50). Wesley et. al (2023) reports that the Amazon basin is subject to systematic exploitation from land grabbers and cattle ranch expansions. The situation is critical, urgent and calls for defence. Cattle ranching as main driver, or beef as direct and predominant cause, is consistent with Harstads finding in his recently updated article "Trade and Trees" (Harstad, 2023). With cattle ranching comes new roads and agricultural expansions, according to Financial Times (2022). The wildfire phenomena, destruction around roads, is further driving the rate of deforestation, according to Financial Times (2022). The fires generally appear around roads cleared for grazing land and drive species on flight (Financial Times, 2022). Patrolling is dangerous, due to high level of organized crime, drug-trafficking (like cocaine) and money laundering. Reuters (2023) reports that "'Narco-deforestation' is focus at the upcoming summit of Amazon nations" and "represents a new target for law enforcement". It requires international cooperation on investigation, training of police and lab technology, to analyze the location of the source, according to Reuters (2023). UN (2023) writes that "Narco-deforestation" – the laundering of drug trafficking profits into land speculation, the agricultural sector, cattle ranching and related infrastructure – is posing a growing danger to the world's largest rainforest". Furthermore, Mongobay (2023) reports that "drug trafficking groups find unique ways to cover up their operations. Cattle ranching, one of the main drivers of Amazon deforestation and climate change, is useful for hiding airstrips and facilities, but also happens to be a convenient form of money laundering". Marta Machado, the national secretary for drug affairs in Brazil, says that "the problem in the Amazon is clearly a consequence of ... the deliberate omission of the previous government and [its] almost [encouragement of] environmental crime in the Amazon" and that "weakening the monitoring and surveillance mechanisms for organized environmental crime has opened up this space that was occupied by the drug cartels", see the Guardian (2023). Thus, better governmental policies across the globe, like strengthened monitoring and surveillance, is necessary to protect the forest and combat organized crime. We know from Harstad and Mideksa (2017) that "deforestation are mostly determined by governmental policies", and whether governments, or districts, favor exploitation or conservation, according to Harstad (The Conservation Multiplier, 2023). Lack of governance and agricultural lobby influences are key drivers, according to Harstad (The Conservation Multiplier, 2023). Satellites, on the other hand, can reduce tension, shooting and "knife-edging" combats between indigenous people, cattle ranchers and the police (Harstad and Mideksa, 2017). Arguably, governments must promote transparency and lobby registers in the fight against organized crime. Norway, for instance, is presently missing lobby registers, according to Harstad (DN, 2023). Lack of transparency is counterproductive in economic terms, because it weakens democracy and national right of countries disposal. Lobby registers are important to ensure enforcement compliance and keep record of whether governments buys from companies that destroy the Amazon. Mongobay (2019) refers to Monsanto (Bayer), one of the major soy producers and seller to the global meat and fish farming industry, as a major driver behind land grabbing and deforestation. The company is global and has operations in donor countries, like Norway.

1.4 Monitoring

"It's costly for countries to protect their resources and prevent extraction", according to Harstad and Mideksa (2017, 1709). This thesis suggests that improved monitoring, such as better satellites, police or drones, can help detect and reduce the loss of tropical rainforest. Investigating this is important, because it can reduce violence, make us *better off* and improve *overall welfare*. I apply Harstad and Mideksas (2017) tractable workhorse model and adjust it for monitoring. Monitoring is especially suitable since it is a matter of global security and plays an important role in safeguarding tropical forests, which are mandatory public goods and our global safety net. Additionally, "monitoring the world's forest resources through period assessments has been a core activity for the Food and Agricultural Organization of the United Nations, ever since its foundation", according to FAO (2022, xii). Fortunately, the access to satellite data is increasing, according to Harstad and Mideksa (2017). As we know, satellites makes it possible to approach the forest from a higher altitude. However, satellites does have a problem monitoring forests when it's foggy, it's vapour, it rains or when it burns. In addition, fast technology development makes it hard for governments to keep up. Hijackers of satellites are also a threat. I encourage governments to add more to this framework. For instance, what the development in the latest technology says. Nevertheless, it's extraction, which is the main problem, not monitoring. "To protect a parcel of the forest, the government must monitor so much that the expected penalty is larger than the profit from illegal logging", according to Harstad and Mideksa (2017, 1710). "The total enforcement cost is thus larger when there is a large profit of harvesting (timber and agricultural products), as will be the case when there is little logging elsewhere", according to Harstad and Mideksa (2017, 1710). The reason is leakage. Souza Cunha et al. (2016) show that "Brazil, the country with the largest forest cover, has in the recent years spent more than 100 million dollars (USD) on monitoring and controlling for illegal forest activities", according to Harstad and Mideksa (2017, 1709). Harstad claims that "the party in power might be able to raise the net benefit from conservation by investing in enforcement and monitoring technology, like satellites. If the cost of conservation declines and the net conservation benefit increases, future parties will be induced to conserve more." (The Conservation multiplier, 1755). "While is evidence that the forest monitoring capacity in countries has increased significantly during the past decade, many countries, especially in Africa, Asia and Oceania, still lack consistent national times series data for some of the key forest attributes", according to FAO (2022, ix). "To fill this gap and support countries' efforts to use remote sensing and modern digital tools for forest monitoring, FAO Forestry Division conducted a global remote sensing survey as a part of the Global Forestry Resource Assessment (FRA) 2020 programme", according to FAO (2022, ix). "Underpinned by a standard methodology, the process was driven by a network of more than 800 photo interpreters from 126 countries", writes FAO (2022, xii). "FRA interprets the status and trends of forest from a land-use perspective (that is, the activities by which human use land)", according to FAO (2022, 3). "A network of more than 800 photo interpreters from 126 countries was trained in satellite imagery interpretation and collected data from more than 400 000 sample sites world wide through visual assessment of cloud-free satellite images using Collect Earth Online (Saah *et al.*,2019)", see FAO (2022,4). "Since 2005, FRAs have been based on data provided by a well-established network of national corespondents appointed by country governments (FAO,2018b). As with any country-driven process, the quality of FRA depends on the capacity of countries to provide reliable estimates of their forest resources. However, while there have been significant advances in forest resource assessment, some countries still lack the capacity to conduct periodic assessments and provide reliable data for FRA, which can result in varying levels of data timeliness and accuracy across countries", according to FAO (2022, 3-4)

1.5 Conservation Contracts

Conservation contracts are favored by economists "who view them as a the natural Coasian solution", according to Alston and Andersson (2011), see Harstad and Mideksa (2017, 1711). When property rights are well-defined and there are no transactions costs, bargaining among parties lead to an efficient outcome, according to Coase (1960) (Harstad and Mideksa, 2017). Economic markets works well if prices reflect true marginal costs: When the two are equal, we are in equilibrium. "Without a conservation contract" is the "absence of an agreement" or "the default option of no agreement", similar to business as usual, according to Harstad (International climate action, 2023). In the presence of negative externalities, like deforestation, equilibrium prices are incorrect. Then the social cost is higher than the private cost. Fortunately, the price of reducing the dead weight loss from deforestation, is smaller the cost from these negative externalities. Thus, conservation is cost-effective (Harstad and Mideksa, 2017). Third parties, like NGOs, are therefore interested in paying for conservation (Harstad and Mideksa, 2017). According to theory, donors are willing to pay for conservation and negotiate until the marginal benefit equals the marginal cost. The donor commits to pay a district an amount linear in the district's choice of x_i. A donor will offer payments, consisting of a pair (t_i, x_i), in exchange for reduced level of extraction (Harstad and Mideksa, 2017). Many forces work to safeguard the Amazon rainforest. Examples range from the Rainforest Alliance, Survive International, WWF, environmental organizations to private funders. In addition, donor countries (in particular Norway, Germany and Japan) and organizations such as the World Bank and the United Nations, offers conservation contracts (REDD+ and PES agreements) to reduce deforestation "in a number of countries", according to Harstad and Mideksa (2017, 1711). This thesis is an example of how these conservation contracts are designed, such as the United Nations program "Reduced Emission from Deforestation and Forest Degradation" (REDD+). REDD+, for instance, "is the largest single climate policy measure implemented by Norway", according to Hermansen (Ursin, 2018). The Norwegian government writes that "Norway's most important international climate initiative is to help preserve the rainforest and other tropical forests" and have "promised to give up to three billion kroner annually to tropical forest lands to reduce deforestation, through the climate and forest investment. Internationally, the initiative is known as Norway's International Climate and Forest Initiative (NICFI)", see Regjeringen (2022). In other words, safeguarding the forest is on the top agenda and conservation is required if it's going to hold it's promises. Unfortunately, Reuters writes that "in 2019, the governments of Brazil and Norway disagreed on how much discretion the Brazilian government should have and, as a result, the funding was suspended", according to Harstad (The Conservation Multiplier, 2023, 1738). Thus, exploitation continues to expand and the Amazon lacks adequate protection. "The linear contract is particularly simple as it is similar to a Pigou subsidy", according to Harstad and Mideksa (2017, 1720). A conservation contract, or agreement, is enforceable by international law. By economic theory, the Pigou subsidy is equal to the "value of lost forest" or the negative externality on third parties, corrects for the market failure and bring the economy back to equilibrium, an efficient state with higher level of social welfare. A Pareto improvement, in economic terms. Hoel (1999) argued that an equilibrium policy is implemented by a tax on production, such as fossil fuels or deforestation, or a subsidy for not extracting the resource. The subsidy rate must be designed such that the recipient should be indifferent between accepting or rejecting the contract. In addition, it must be designed so it reflects the "value of lost forest or nature", according to Harstad. I highlight that there exists several debates within the field of economics beyond traditional cost-benefit analysis. For example "non-priced impacts" and "green taxation", in addition to those mentioned in Harstad and Mideksa(2017). Additionally, other displines also arise questions about the appreciation of nature. For instance, they relate to ethics, moral, law, philosophy, spirituality, culture, region, habits, time-inconsistency and self-respect. Equador, for example, has it's own unique constitution recognizing Nature has it's own rights: *A subject rather than an object*. Indigenous people don't use money, what they care about is land, according to Survive International. Adam Smith, the father of modern economics, also reflected on moral. He wrote "Man is an animal that makes bargains: no other animal does this - no dog exchanges bones with another" (The Wealth of Nations, 1776). For some the forest is cheap, for others its priceless. The economics in this thesis is only to show how much forest we can protect from a mathematical perspective. In addition, Harstad and Framstad (2016) argue that conservation is more efficient in protecting forests than traditional boycotts or directives.

2 Methods and Materials

The method of this thesis is theoretical. The foundation is (1) *Conservation Contracts and Political Regimes* by Harstad and Mideksa (2017), hereafter CC, and (2) *FRA 2020 Remote Sensing Survey* by FAO (2022). This thesis reunites the two. Additionally, I've added perspectives from other sources when needed. FRA (2) is used since it's the "most comprehensive and authoritative source of information on global forest resources" according to (FAO,2022, ix) and because Harstad recommended it. It's the latest survey published by The Food and Agriculture Organization of the United Nations. It's used as the main information source for our worlds forests. "It relies on national capacities to monitor and report on forests", accoring to FAO (2022, ix). "FRAs are based on national statistics compiled by a global network of officially nominated National Correspondents", according to FRA (2022, ix). The starting point of the mathematical analysis is the first material (1). CC includes a flexible model of resource extraction, fixed to tropical deforestation. The model is applicable to many exhaustible resources (such as land or fossil fuels) and is easy to maneuver in relation to parameters (Harstad and Mideksa, 2017). So it opens up to many variations. This thesis is an extension of (1), *The Model of Conservation*, in the paper. I derive the optimal conservation contracts after a cost change. *I expand the model by looking at what is the value of a reduction in protection costs c with and without donor contracts.* Protection costs c could be the costs of changing to better satellites, police or drones, according to Harstad. There are three reasons why I've chosen to keep the idea fixed to *tropical* deforestation: Firstly, 90 percent of worldwide deforestation is tropical deforestation, according to the World Forest Survey (FAO, 2022). Secondly, tropical rainforests contain a vast extension of genetic material, is irreplaceable for maintaining tropical biodiversity and lack substitutes. When it's cut, the genetic material of the primary forests is lost forever, according to Nature (2011). Thirdly, South America is the region where it is possible to save most on C02 emissions according to FAO (2022). Thus, the Amazon plays a key role in mitigating climate change.

3 Mathematical Analysis

I expand the model by looking at *what is the value of a reduction in protection costs c with and without donor contracts*. This could be changing to better satellites, police or drones, which help protect the forest. Total timber extraction, or deforestation level, is explained by aggregate x. I focus on deriving x wrt c, which is the marginal benefit, or value, from reducing c on x. Mathematically, it is dx/dc, which is like d(-x)/d(-c). An NGO have a benefit function equivalent to -dx, meaning it benefits from less deforestation and more conservation. If it's costly to reduce c, this marginal benefit would be set equal to the cost of reducing c, according to Harstad. I derive x wrt to c for four cases: 3.1) Without donor contracts, 3.2) Donor contracts with single central government, 3.3) Donor contracts with all districts independently, and 3.4) Donor contracts with a subset (m) of the districts. We let (X) measure total stock of forest, (x) deforestation level or aggregate timber extraction, (b) benefit of timber extraction, (c) cost of protecting the forest, (p-hat) demand, (v) value of conserving the forest, (d) donors' marginal damage from deforestation, (n) nr of districts, (m) nr of subsets or coalition size, (a) marginal value of beef from extraction of total stock of forest (X) (Harstad, Lecture 2022). See the appendix for further parameter definitions. For simplicity, we assume there are two districts (n=2). Districts (n) could be municipalities, subsets (m) could be coalitions. The gain from reducing c depends on the derivatives I've found. These are, in their turn, dependent on several parameters (such as X, but also a and b). I discuss how these parameters affect an NGOs' motivation for reducing protection costs. For each term, I discuss how much a donor, for example an NGO, wants to reduce c. This is costly, according to Harstad. In the calculation I have used the quotient rule and summarized the effect of X in both equations to conclude what the effect is. Let's get started. By the quotient rule,

$$f(x) = \frac{u(x)}{v(x)}$$

$$f'(x) = \frac{u'(x)v(x) - u(x)v'(x)}{v(x)^2}$$

3.1 Without donor

From Proposition 1, equation (4) p. 1716 in CC, equilibrium conservation is:

$$x^0 = \frac{nb\overline{p} - v}{ab(n+1)} + c\frac{nv + abX}{ab(b+c)(n+1)} \qquad (3.1.1)$$

Inserting for n = 2 yields:

$$x^0 = \frac{2b\overline{p} - v}{3ab} + c\frac{2v + abX}{3ab(b+c)}$$

The first order condition writes:

$$\frac{\partial x^0}{\partial c} = \frac{(2v + abX)(3ab(b+c)) - c((2v + abX)3ab)}{(3ab(b+c))^2}$$

Rewriting:

$$\frac{\partial x^0}{\partial c} = \frac{(2v + abX)(3ab(b+c))}{(3ab(b+c))(3ab(b+c))} - c\frac{(2v + abX)3ab}{(3ab(b+c))(3ab(b+c))}$$

Canceling:

$$\frac{\partial x^0}{\partial c} = \frac{2v + abX}{3ab(b+c)} - c\frac{2v + abX}{3ab(b+c)^2}$$

Collecting like terms:

$$\frac{\partial x^0}{\partial c} = \frac{2v}{3ab(b+c)}(1 - \frac{c}{b+c}) + \frac{abX}{3ab(b+c)}(1 - \frac{c}{b+c})$$

This gives:

$$\frac{\partial x^0}{\partial c} = \frac{2v}{3ab(b+c)}(\frac{b}{b+c}) + \frac{abX}{3ab(b+c)}(\frac{b}{b+c})$$

Finally:

$$\frac{\partial x^0}{\partial c} = \frac{2v}{3a(b+c)^2} + \frac{bX}{3(b+c)^2} \qquad (3.1.2)$$

3.2 Donor contracts with single central government

From Proposition 3 (i) p. 1720 in CC, the equilibrium contract leads to the first best:

$$x^* = \frac{(b+c)\overline{p} + caX - v - d}{2a(b+c)} \qquad (3.2.1)$$

The first order condition writes:

$$\frac{\partial x^*}{\partial c} = \frac{(\overline{p} + aX)(2a(b+c)) - (b\overline{p} + c\overline{p} + caX - v - d)2a}{(2a(b+c))^2}$$

Rewriting:

$$\frac{\partial x^*}{\partial c} = \frac{(\overline{p} + aX)(2a(b+c))}{(2a(b+c))(2a(b+c))} - \frac{(b\overline{p} + c\overline{p} + caX - v - d)2a}{(2a(b+c))(2a(b+c)}$$

Canceling:

$$\frac{\partial x^*}{\partial c} = \frac{\overline{p} + aX}{2a(b+c)} - \frac{(b\overline{p} + c\overline{p} + caX - v - d)}{2a(b+c)^2}$$

Collecting like terms:

$$\frac{\partial x^*}{\partial c} = \frac{\overline{p}}{2a(b+c)}(1 - \frac{b+c}{b+c}) + \frac{X}{2(b+c)}(1 - \frac{c}{b+c}) + \frac{v+d}{2a(b+c)^2}$$

Finally:

$$\frac{\partial x^*}{\partial c} = \frac{bX}{2(b+c)^2} + \frac{v+d}{2a(b+c)^2} \qquad (3.2.2)$$

3.3 Donor contracts with districts independently

From Proposition 4 (i) p.1721 in CC, the contract can be written as:

$$x^* = \frac{n(b+c)\overline{p} + caX - nv}{a(b+c)(n+1)} - \frac{2nd}{a(b+c)(n+1)^2} \qquad (3.3.1)$$

Inserting for n = 2 yields:

$$x^* = \frac{2(b+c)\overline{p} + caX - 2v}{3a(b+c)} - \frac{4d}{9a(b+c)}$$

Intermediate calculation - Derivative of 2nd term:

$$\frac{4d9a}{(9a(b+c))^2} = \frac{4d9a}{(9a)^2(b+c)^2} = \frac{4d}{9a(b+c)^2}$$

The first order condition writes:

$$\frac{\partial x^*}{\partial c} = \frac{(2\overline{p} + aX)(3a(b+c)) - (2(b+c)\overline{p} + caX - 2v)3a}{(3a(b+c))^2} + \frac{4d}{9a(b+c)^2}$$

Rewriting:

$$\frac{\partial x^*}{\partial c} = \frac{(2\overline{p} + aX)(3a(b+c))}{(3a(b+c))(3a(b+c))} - \frac{(2(b+c)\overline{p} + caX - 2v)3a}{(3a(b+c))(3a(b+c))} + \frac{4d}{9a(b+c)^2}$$

Canceling:

$$\frac{\partial x^*}{\partial c} = \frac{(2\overline{p} + aX)}{3a(b+c)} - \frac{(2(b+c)\overline{p} + caX - 2v)}{3a(b+c)^2} + \frac{4d}{9a(b+c)^2}$$

Collecting like terms:

$$\frac{\partial x^*}{\partial c} = \frac{2\overline{p}}{3a(b+c)}(1 - \frac{b+c}{b+c}) + \frac{X}{3(b+c)}(1 - \frac{c}{b+c}) + \frac{2v}{3a(b+c)^2} + \frac{4d}{9a(b+c)^2}$$

This gives:

$$\frac{\partial x^*}{\partial c} = \frac{X}{3(b+c)}(\frac{b}{b+c}) + \frac{2v}{3a(b+c)^2} + \frac{4d}{9a(b+c)^2}$$

Finally:

$$\frac{\partial x^*}{\partial c} = \frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2} + \frac{4d}{9a(b+c)^2} \qquad (3.3.2)$$

3.4 Donor contracts with a subset of the districts

From Proposition 5 (i) p. 1724 in CC, the contract can be written as:

$$x^* = \frac{n(b+c)\overline{p} + caX - nv}{a(b+c)(n+1)} - \frac{2md}{a(b+c)(n+1)^2} \qquad (3.4.1)$$

Inserting for n=2 yields:

$$x^* = \frac{2(b+c)\overline{p} + caX - 2v}{3a(b+c)} - \frac{2md}{9a(b+c)}$$

The first order condition writes:

$$\frac{\partial x^*}{\partial c} = \frac{(2\overline{p} + aX)(3a(b+c)) - (2(b+c)\overline{p} + caX - 2v)3a}{(3a(b+c))^2} + \frac{2md9a}{(9a(b+c))^2}$$

Rewriting:

$$\frac{\partial x^*}{\partial c} = \frac{(2\overline{p} + aX)(3a(b+c))}{(3a(b+c))^2} - \frac{(2(b+c)\overline{p} + caX - 2v)3a}{(3a(b+c))(3a(b+c))} + \frac{2md9a}{9a(b+c)9a(b+c)}$$

Canceling:

$$\frac{\partial x^*}{\partial c} = \frac{2\overline{p} + aX}{3a(b+c)} - \frac{(2a(b+c)\overline{p} + caX - 2v)}{3a(b+c)^2} + \frac{2md}{9a(b+c)^2}$$

Collecting like terms:

$$\frac{\partial x^*}{\partial c} = \frac{2\overline{p}}{3a(b+c)}(1 - \frac{b+c}{b+c}) + \frac{X}{3(b+c)}(1 - \frac{c}{b+c}) + \frac{2v}{3a(b+c)^2} + \frac{2md}{9a(b+c)^2}$$

This gives:

$$\frac{\partial x^*}{\partial c} = \frac{X}{3(b+c)}(\frac{b}{b+c}) + \frac{2v}{3a(b+c)^2} + \frac{2md}{9a(b+c)^2}$$

Finally:

$$\frac{\partial x^*}{\partial c} = \frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2} + \frac{2md}{9a(b+c)^2} \qquad (3.4.2)$$

4 Results

This section interprets and discusses the main results from the mathematical analysis. For each expression, with and without contracts, I discuss how much an actor, like an NGO, wants to reduce c. If it's costly to reduce c, the marginal benefit of reducing c will equal the marginal cost of reducing c. Moreover, I show how an NGOs' motivation to reduce c are affected by the parameters. The value of reducing c depends on the derivatives I've found in each case. These are, in their turn, dependent on several parameters, for instance the size of the forest (X), value of conservation (v), coalition size (m), the marginal value of beef (a) and the marginal benefit of timber extraction (b).

4.1 Without donor

According to Proposition 3.1.1, equation (4) p.1716 in CC, the equilibrium conservation without donor was:

$$x^0 = \frac{nb\overline{p} - v}{ab(n+1)} + c\frac{nv + abX}{ab(b+c)(n+1)} \qquad (3.1.1)$$

Intuition: *If c or X_i* increases, or v decreases, then x_i increases, x increases, and p decreases. Furthermore, x_j decreases in X_i, j $\neq i$.

(Harstad and Mideksa, 2017, 1716).

According to Proposition 3.1.2, the new equilibrium conservation without donor, is:

$$\frac{\partial x^0}{\partial c} = \frac{2v}{3a(b+c)^2} + \frac{bX}{3(b+c)^2} \qquad (3.1.2)$$

Intuition: ***The marginal benefit of reduced c increases in the value of conservation (v) and large forest stock (X), and decreases in the marginal benefit of beef (a). The effect of (b) is ambiguous; in the numerator it increases the marginal benefit, in the denominator it decreases it. Generally, a high (b) is harmful for an NGO (e.g. when governments place higher weight on profit from timber extraction)***

Naturally, the value of reducing c is bigger, with a larger size of the forest (X), like the Amazon. When *(X)* is large, enforcement is costly and the marginal gain from reducing c is big. This gives an NGO incentives to reduce costs. The value of reducing c also increases in the value of conservation (v) of each unit of forest that is conserved and kept intact. The marginal benefit of beef (a), on the other hand, reduces the value from a lower c. An NGO benefits when the beef industry become unprofitable or worthless, that's when (a) is low. For example when land speculation fever drops or flops. When (a) decreases, total timber extraction (ax) decreases (ax is the demand function in CC). This increases the value from reducing c. As a result, donors costs decrease and the NGO will have to pay less. This is in line with Coasian bargaining (1960). The effect of (b) is ambiguous: The marginal benefit is reduced by (b) in the denominators, but increases in the numerator in the 2nd term. In general, a high (b) harms the donor. When b is large and c is small (property rights are strong), the situation is similar to a sales-driven Cournot game, for example high oligopoly power, where most of the deforestation is legal. In this case, governments place high weight on profit from timber extraction (b) and enforcement costs, or monitoring costs (c), are low. In contrast, if b is small and c big (weak property rights and illegal logging), like in Brazil, enforcement is expensive and districts are less likely to capture revenues from extraction. In this case, the value of reducing c is bigger.

4.2 Donor contracts with single central government

According to Proposition 3 (i) p. 1720 in CC, the equilibrium contract leading to the first best, was:

$$x^* = \frac{(b+c)\overline{p} + caX - v - d}{2a(b+c)} \qquad (3.2.1)$$

Intuition: *Naturally, x* decreases in d, while the transfer must increase. The linear contract is particularly simple as it is similar to a Pigou subsidy.* (Harstad and Mideksa, 2017, 1720).

According to Proposition 3.2.2, the new donor contract with the central government is:

$$\frac{\partial x^*}{\partial c} = \frac{bX}{2(b+c)^2} + \frac{v+d}{2a(b+c)^2} \qquad (3.2.2)$$

Intuition: ***Again, the value of reducing c increases in large stock of forest (X), value of conservation (v) and damages (d). The marginal benefit of reduced c decreases in (a) and partly (b). The effect of (b) is ambiguous: In the first term, (b) in the numerator increases the marginal benefit of a cost reduction, while (b) in the denominators reduce it. But generally, a large (b) harms the donor.***

Naturally, if the forest stock (X) is large like the Amazon, the value from reducing c is particularly big, since protection is expensive. This motivates an NGO to enhance monitoring and reduce costs. A donors' marginal benefit from a cost reduction also increases in (d), the marginal damage from deforestation. If the damages from deforestation are high, it's particularly important and valuable for an NGO to reduce the harm. Increased marginal value of beef (a) harms and crowds out an NGOs efforts, and reduces the value from reducing c. For instance rising demand from China and Germany for Brazilian beef. From the denominator in the second term, we see that the marginal value of beef (a) reduces the fraction and again the value from reduced c. The effect of the marginal benefit on profit from timber extraction *(b)*, or the weight districts place on this profit, is ambiguous: In the first term the marginal benefit increases in (b) in the nominator, but it decreases in (b) in the denominator in both terms. But generally, a high *(b)* harms the donor, since more is extracted rather than conserved. Thus, a reduction in b increases the value from a reduction in protection costs. If b is large and c is small (strong property rights), similarly to sales-driven extraction in a Cournot model, monitoring is cheap (or doesn't exist, e.g. c=0) and the central government benefits from extraction. So a high (b) generally harms the donor, as timber extraction increases when the government finds exploitation profitable. Thus, the donor is less likely to benefit when (b) is large, since it reduces the value from reduced c. Therefore, when the government prefers profits from timber extraction, the harder it becomes to persuade the government. Reasons could be high corruption, control from lobbyists or profit maximizing behavior while in power (Harstad and Mideksa, 2017; Harstad, The Conservation Multiplier, 2023). In this case, the government benefits when other countries extract less, since the timber price increases and logging becomes more profitable. In contrast, if b is small and c is large (weak property rights and illegal logging), like in Brazil, the government is less likely to benefit from timber extraction, since most of the revenues goes to illegal cutters, or a large multinational company, and the districts are more likely to capture a larger fraction of the revenues, according to Harstad and Mideksa (2017). This makes it easier for an NGO to tie the central government to a conservation contract, since it already has low profit from timber extraction. We know that under a contract with a central government, the government reduces extraction strategically so it can benefit from a higher price. This increases the profit for everyone.

4.3 Donor contracts with districts independently

According to Proposition 4 (i) p.1721 in CC, the written contract was:

$$x^* = \frac{n(b+c)\overline{p} + caX - nv}{a(b+c)(n+1)} - \frac{2nd}{a(b+c)(n+1)^2} \qquad (3.3.1)$$

Intuition: *The proposition shows that a larger d reduces the extraction levels. However, the reduction is small and approaches zero as n grows. The reason is leakage: when one district extract less, the other districts prefer to extract more. Thus, when the donor pays one district to extract less, it also has to pay more to all the n-1 districts for any given extraction vector. This reduces the donors' willingness to pay when n is large.*

(Harstad and Mideksa, 2017, 1722)

According to Proposition 3.3.2, the new contract is:

$$\frac{\partial x^*}{\partial c} = \frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2} + \frac{4d}{9a(b+c)^2} \qquad (3.3.2)$$

Intuition: ***Again, the value of reducing c for an NGO increases in large stock of forest (X), value of conservation (v) and marginal damages (d). It decreases in the marginal value of beef (a), while the effect of (b) is ambiguous, like before. But generally, an increase in (b) hurts the donor.***

Again, the value of reducing c increases in damages (d) and the value of the forest (v). In other words: The more we suffer, or the more we value clean fresh water and natural food, the more motivated we are to conserve forests. Or, the more we value the richness of tropical rainforests (v), such as survival of the species, pristine habitats and biodiversity, the more likely it is we appreciate safeguarding it and protect the forest from intruders. A larger stock of forest (X) also increases the value of reducing c. This motivates an NGO to conserve more and enhance monitoring. A reduction in the marginal benefit of beef (a) improves the value from reducing c. If one district extract less, (x) is reduced and more is conserved. However, when the supply declines, the timber prices and profits from extraction increases, and other districts prefer to extract more. This is because the districts are strategic substitutes. This leakage makes the other districts better off. As a result, an NGO will have to pay all other (n-1) districts for not exploiting. This is costly and crowds out donors efforts (Harstad and Mideksa, 2017). From previous, we know an NGOs' motivation is decreasing when (n) is large, since leakage offsets some of its efforts. If (n) is small, on the other hand, an NGO prefers decentralized contracts with the districts, if and only if the property rights are weak, like in Brazil (when b is small and c large). Here most of the deforestation is illegal, *above 50 percent*, according to Harstad and Mideksa (2017, 1709). If b is small and c is large, the districts are unable to capture a significant share of the revenues and this makes it easier for the parties to agree on conservation and more beneficial for the districts to contract with the donor. This reduces extraction. In contrast, when b is large and c is small (property rights are strong), it's harder for an NGO to persuade the districts, since the profit from timber extraction is big. Districts have incentives to merge if the externality is positive, otherwise not. If the externality is positive, districts ought to increase conservation because they have an incentive to strategically keep the price high by extracting less. In contrast, if the externality is negative, districts ought to extract more to reduce the price, the high protection costs and the pressure from illegal loggers. When protection costs are high, it's important for the districts to reduce monitoring costs. The districts know if they let a fraction of the forest go unmonitored, it reduces the price and the costs of protecting the remaining part of the forest. The downside is that the part of the forest which is not protected eventually will be logged (Harstad and Mideksa, 2017). The upside is that it increases the probability of protecting the remaining part more effectively. If there is a large set of districts, meaning (n) is large, persuading all districts is costly for an NGO (Harstad and Mideksa, 2017). This reduces an NGOs motivation to contract with all. In addition, deviating becomes more tempting for the districts since the price is high when extraction is low. In this case, an NGO prefers a centralized contract with merged districts to reduce the chance of defecting (Harstad and Mideksa, 2017). As mentioned, deforestation is mostly affected by governmental policies, according to Harstad and Mideksa (2017). This implies that how concerned governments are about deforestation and distribution of resources to monitoring forests depend on whether governments or districts prefer profits from timber extraction (b) and beef produce (a), or whether they value forests (v) more.

4.4 Donor contracts with a subset of the districts

According to Proposition 5 (i) p. 1724 in CC, the contract could be written as:

$$x^* = \frac{n(b+c)\overline{p} + caX - nv}{a(b+c)(n+1)} - \frac{2md}{a(b+c)(n+1)^2} \qquad (3.4.1)$$

Intuition: *The proposition generalize the similar parts of Proposition 4. Naturally, the total extraction level is smaller if m is large. A larger m can reduce the sum of payoffs. In other words, the donor's contracts with the districts may be harmful for the efficiency. The explanation for this is the possibly negative contractual externality. When property rights are weak, one district is harmed when the other districts extract less, as when they are offered conservation contracts by the donor. This negative externality may outweigh the donor's benefit from the contracts, particularly when the donor's marginal damage is relatively small. Another interpretation of the result is that the contracts may worsen an already existing collective action problem between the districts: when property rights are weak, districts are protecting too much, because they do not internalize the larger enforcement cost on the others. Conservation contracts will reduce the extraction even further, and thus they also reduce the sum of payoffs.* (Harstad and Mideksa, 2017, 1725)

According to Proposition 3.4.2, the new donor contract with a subset of the districts, is:

$$\frac{\partial x^*}{\partial c} = \frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2} + \frac{2md}{9a(b+c)^2} \qquad (3.4.2)$$

Intuition: ***The value of reducing c increases in large stock of forest (X), value of conservation (v), nr of subsets (m) and damages (d). The value of reducing c decreases in the marginal benefit of beef (a).***

Again, the value of reducing c is greater when the size of forest (X) is large. For example the Amazon, which is the largest tropical rainforest. In addition, we see that the value of reducing c increases in the nr of subsets (m) and damages from deforestation (d). This motivates an NGO to expand the coalition (m) and conserve (v) more forest, since the value of reducing c increases in (m). An NGO prefers (m) to be high, since a larger (m) reduces timber extraction, protects more forest and increases the value of reducing c. So an NGO prefers (m) to be as high as possible, even if it reduces the sum of payoffs and districts utilities (Harstad and Mideksa, 2017). When damages (d) are high, it's particularly important for an NGO to reduce costs. When damages are small, it's less valuable to reduce costs, since we know from Harstad and Mideksa (2017) that some of donors' benefits from conservation contracts are offset when property rights are weak due to negative contractual externalities. The reason is that districts are harmed when other districts extracted less, since the price increases and enforcement becomes more costly. Thus, from the result, we see that the value of reducing c is increasing in (d). The gain also increases when the districts' value on conservation (v) increases, since it reduces donors' need to transfer subsidies. We know from the payoff function that the donors' utility is a function of less extraction (-dx) and more conservation. So a donor benefits when damages (d) and timber extraction (b) are reduced. We know that when the nr of subsets (m) increases, extraction (x) decreases, damages (d) are reduced and donors utility (-dx) increases. A lower value of beef (a) also increases the value from reducing c. On the other hand, if the value of beef increases, the more likely it is cattle ranching expands, continuing to drive deforestation and harm third parties. Therefore, a donor prefers a low (a) and a low (b). Thus, the value of reducing c increases when (b) and (a) decreases. Harstad and Mideksa (2017) claim that in the case of contracts with a subset (m) of the districts, contracting with all might lead to too little extraction, and more tempting to deviate, since the price is high when extraction is low. This is the main argument for why it's best contracting with a subset of the districts. In contrast, the case without contracts, leads to too high extraction (x) (Harstad and Mideksa, 2017). Therefore, the donor prefers to contract with a subset (m) of the districts rather than all. We know that when b is low and c is high (property rights are weak), conservation in one district, increases enforcement costs for the other districts. Thus, each district benefits from contracting with a donor when offered a contract, but all are better off refusing since the price is high (Harstad and Mideksa, 2017).

This is similar to a prisoner dilemma game, like the Cournot-Nash oligopoly model, which is applied in this thesis. However, the lesson from the *Prisoner dilemma game* by John Nash is that if the subsets manages to collude, all parties benefit.

5 Comparison

This section compares how the value of reducing c varies from one contract situation to another, which is the most interesting part of the analysis. To examine the question, the key similarities and differences between the contracts are highlighted. The focus of the discussion is how the value, or effect, of each contract depends on the parameters. In addition, I discuss whether there are synergies between NGOs and REDD+ funders, or whether they are substitutes. Moreover, I reflect on how this coincides with reality, based on the method. First, let's review the results:

(1) Without donor

$$\frac{\partial x^0}{\partial c} = \frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2} \qquad (3.1.2)$$

(2) With donor - Contract with the central government

$$\frac{\partial x^*}{\partial c} = \frac{bX}{2(b+c)^2} + \frac{v+d}{2a(b+c)^2} \qquad (3.2.2)$$

(3) With donor - Contract with the districts

$$\frac{\partial x^*}{\partial c} = \frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2} + \frac{4d}{9a(b+c)^2} \qquad (3.3.2)$$

(4) With donor - Contract with a subset of the districts

$$\frac{\partial x^*}{\partial c} = \frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2} + \frac{2md}{9a(b+c)^2} \qquad (3.4.2)$$

From the equations, we see that the value of reducing c increases in *(X)* and *(v)* inn all equations. It also increases when *(a)* declines. The effect of *(b)* is ambiguous, but generally a reduction in *(b)* increases the value of reducing c. It's only donor contracts that increases in *(d)* and only a donor contract with a subsets of the districts which increases in *(m)*. We see that if d=1 and m=2, (dx/dc) is like for (3) and (4). However, the derivative of (4) is bigger than the derivative of (3) when (m) is larger than 2, which is special for this type of agreement. Below I use different values on the parameters to illustrate how the value varies depending on the parameters. Calculation is simple, it's just plugging in suitable parameters.

Example 1. If all parameters are set to 1, except d=0, the third term in (3) and (4) vanish, and (1), (3) and (4) are like. From the results, note that the two first terms in (1), (3) and (4) are like. Inserting the parameters, the marginal benefits of reducing c are (1) 1/4 (2) 1/4, (3) 1/4 and (4) 1/4. In this case, we are indifferent between not having a donor contract and having a donor contract. All options are identical. Thus, without damages, conservation contracts are unnecessary since all outcomes are like. This result coincides with Harstads' lesson about the "Rainforest paradox": "Forest protects when it expects to be compensated, but compensation is unnecessary when the forests protect anyway" (The market for conservation and other hostages, 2016; DN, 2016). It's only once the destruction intensifies, that the Pigou subsidy is triggered. When the harm is high, it's particularly important to reduce damages (d), according to Harstad and Mideksa (2017).

Example 2. If all parameters are set to 1, including m=1 and d=1, the values are: (1) 1/4, (2) 1.5/4, (3) 1.44/4 and (4) 1.22/4. In this case, the derivative of (2) is largest. If m=1, the derivative of (3) is also larger than the derivative of (4). This example shows we are better off with donor contracts when (d) is bigger than 0. (1) is unaffected and remains the same. Thus, when (d) increases, or is bigger than 0, the value, or effect, of reducing c is larger when a donor offers a contract. This means that the contracts are complementary: *We are always better off with a donor contract*, according to Harstad. We will appreciate that a donor offers a contract, since the value of reducing c is higher and protects more forest. This *"complementarity"* also holds when the nr of districts or subsets (m) increase (see example 4). At first glance, this seems like a beautiful outcome, since it seems like those who pay, NGOs and those who reduce c, complements each other. If this corresponds with reality, I discuss after the examples.

Example 3. If all parameters are set to 1, except m=2, the values are: (1) 1/4, (2) 1.5/4, (3) 1.44/4 and (4) 1.44/4. We see the derivative of (2) is largerst, while (3) and (4) are like (or equally good alternatives/substitutes).

Option (1), without donor, is worst. Thus, when d increases (or, the nr of districts or m increases), the contracts are "complementary". When m=2, the value of reducing c is like for (3) and (4). From the equations, we see the value increases when the third terms are added to (3) and (4) (when d and m are positive and increases).

Example 4. If all parameters are set to 1, except m=3 (nr of subsets increases), the values are: (1) 1/4, (2) 1.5/4, (3) 1.44/4, (4) 1.67/4. In contrast to Example 2, when m=1, we see here that when *(m)* is larger than 2, the derivative of (4) is larger than the derivative of (3). The reason is that the marginal benefit of (4) surpasses (3). Thus, when *(m)* is larger than 2, the rewards are big from reducing c. This makes it less tempting for participants to freeride and more attractive to protect the forest (like, for example, by investing in satellites). Note that in this example I've used b=1, assuming the government finds timber extraction profitable. This shows that the value of reducing c increases in the number of subsets (m). In contrast, if m=0, (4) is similar to (1), which is (1/4), the situation without a donor. Then (4) is no longer complementary. But (2) and (3) are complementary and welfare-improving. In this case, without members, the derivative of (2) is larger than (3). From this, we see that an NGOs motivation increases in the nr of subsets (m), since this increases the value of reducing c. This makes it less tempting to defect and more stimulating to cooperate. An increase in m, will only affect (4), which is special for this type of agreement.

Example 5. So how does the level of b affect an increase in m? I continue with Example 4, where all parameters are set to 1, except m=3. Let's now assume b=0 instead of b=1. The new values are: (1) 2/3, (2) 3/3, (3) 3.33/3 and (4) 4/3. From previous, we know the effect of (b) on the equations was ambiguous. But we also know that a high (b) generally harms the donor. A low b and high c is similar to a state capacity with weak property rights and illegal logging, like in Brazil. Comparing these values with the previous findings, the derivatives are now much greater when b declines. Thus, there are big rewards from enhancing monitoring (or the value of reducing c improves substantially) when (b) declines. Thus, a reduction in (b) is very motivating for a donor, or give increased incentives to offer conservation contracts to a nr of subsets (m). The reason, or neat detail, is that the value of reducing c is amplified. Thus, the size of the effect is specially high. Intuitively, from the equations, it also seem that the sum of the fractions, and again the marginal benefit of a reduction in costs, increases when (b) declines. This is because the effect from (b) in the denominators is reduced when (b) declines.

In which situation is a reduction in c most valuable?

This part analyzes in which situation reducing c is most valuable. I.e. when dx/dc is greater in one case, compared to another case. The contracts have different styles and characteristics. To compare them, we take the first payoff, minus, the second. See the appendix for derivations. Again, (1) is no contract, (2) is contract with the central government, (3) is contract with the districts, and (4) is contract with the subsets. It's possible to do many comparisons, so I've decided to focus on two cases for the Amazon. In the first case I compare when the derivative from contracting with subsets (4) is greater than contracting with the districts(3). In the second case I compare in which situation the value of contracting with the subsets (4) is larger than with the central government (2). The reason is that presently, Norway only makes agreements with central governments (2). However, negotiations have come to a fault. Since the damages are large, we are *better off* with a contract.

Case 1. Comparing (4) and (3):

$$m \geq 2$$

Intuition: *The derivative of (4) is bigger than the derivative of (3) when (m) is greater than 2. Thus, the value of reducing c can be larger for (4) if the coalition increases and more parties invest in monitoring (e.g. satellites). This decreases the temptation to free ride, increases synergies from collaborating and increases the likelihood of future successful cooperation. From example 4 we see that the value of reducing c increases when (m) increases from 2 to 3. We know from subsection 4.4 that the value of reducing c increases in the nr of subsets (m). Additionally, it reduces timber extraction in the Amazon. Since the damages are large and the value of reducing c is increasing in (d), it's particularly important to increase (m) to reduce high protection costs.*

Case 2. Comparing (4) and (2):

$$3v + 4md \geq 3abX + 9d$$

$$3v + d(4m - 9) \geq 3abX$$

Intuition: *The derivative of (4) is bigger than the derivative of (2) if RHS is greater than LHS. This is more likely if v and m increases. Thus, if the conservation value (3v) and damages times coalition (d(4m-9)) is greater than the marginal benefit from oligopoly timber- and agricultural extraction from the forest stock (3abX). Intuitively, we know the conservation value of the Amazon rainforest is enormous - it's irreplaceable. In addition, if the coalition size increases and damages are large, the derivative of (4) is larger. The derivative of (4) is even larger than (2) if b and a declines. We know that when property rights are weak (b is low and c is large), like in Brazil, a donor has incentives to contract with subsets rather than the central government. Then it's particularly valuable and important to reduce protection costs.*

Findings

Previous examples show that the value of reducing c is larger if D contracts with districts (or, if m is large, or d is large). That means the donor contracts are complementary, meaning we are always *better off when a donor offers a contract*, according to Harstad. In addition, the rewards are amplified when b declines. These are the key findings. This coincides with the evidence in Harstad and Mideksa (2017), where an increase in the nr of subsets *(m)* reduce deforestation and, again, protects more forest. But the contracts are *not* "perfect" complements. The reason is that the value of reducing c will not increase by the same amount for each contract. The effect of c on x will always be positive, but how big the effect is, and which contract is best, depends on the size of the parameters (m, d, b, X, a and v). The real effect also depends on governments giving accurate data estimates. In reality, this is a scientific challenge. This, and what is possible to achieve in practice, depend on the political situation and governmental policies, according to Harstad and Mideksa (2017).

Utilities

From the results, we know the derivative of x wrt -c is bigger if (m) is bigger. But is also the utility level wrt -c bigger, if *(m)* is bigger? According to Harstad, the utility function depends on who it belongs to. In the article, it belongs to either the district or the donor. The total welfare is the sum of these. Let's review the utility functions:

According to equation (2) (Harstad and Mideksa, 2017, 1714),*"district i's payoff* is: $u_i(x_i, x_{-}i) = bp(x)x_i + (v - c(x))(X_i - x_i)$". Intuitively, when protection costs *c* decline, the utility level of a district increases. Thus, it's also the utility level wrt -*c* which is bigger if *(m)* is bigger.

According to equation (7) (Harstad and Mideksa, 2017, 1719), *"donor's, D's, payoff* is: $U_D = u_D(x) - \tau$." Or equivalently, donor's payoff is a function of the remaining forest stock (*X*-*x*) (Harstad and Mideksa, 2017, 1719). Thus, the donor prefers a big forest and benefits from more protected forest. $\tau \geq 0$ measures the transfer, and $u_D(x) = -dx$, where *(d)* bigger than 0 measures "donor's marginal damage from aggregate extraction", according to Harstad and Mideksa (2017, 1719).

Let's now suggest NGO's utility function, or *NGOs' payoff*, is: $U_{NGO} = Gx - Cp(X - x)$, according to Harstad. *(G)* measures the extraction benefit to the party in power, *(x)* the timber extraction level, *(C)* monitoring costs (for example consumption of satellites), *(p)* the timber price (p's value of a dollar is normalized to 1) and *(X-x)* the remaining intact forest. I've used the same explanation for *p*, *G* and *X*-*x* as Harstad in his recent article *The Conservation Multiplier* from 2023. Intuitively, an NGOs utility is a product of *timber extraction benefit to the party in power* minus *enforcement costs*price*remaining virgin forest.* I.e. if C=c, an NGO internalizes the entire monitoring costs. From the function, we see that if C increases, NGOs' utility decreases. Thus, an NGO has incentives to reduce c. If C=0, we are back to the simplest case, when an NGO doesn't monitor (e.g. *b* is high and *c* is low). If it doesn't extract, enforcement costs increase since prices increase and more forest must be protected. An NGO can, as well as the donor, primarily be concerned about reducing c, according to Harstad. However, if C=0, governments doesn't monitor or enforcement is very cheap (for example if previous parties have invested in satellites and the next party benefits from the investment). If C=0, the second term cancels and the NGOs utility equals $U_{NGO} = Gx$. Thus, an NGO has a utility from extraction, or consumption *Gx*, so it has incentive to extract while in power. *Gx* is a product of extraction benefit to the party in power times timber extraction. Allowing for C different from c makes the model more general, according to Harstad (2023). Harstad and Mideksa (2017) also points out that there is a limit to how much governments can collect, due to limited liability (people don't have deep pockets). However, in reality, it's not certain that all revenues from penalties are collected either, due to bribes for instance or lack of knowledge of true costs and benefits. For example, much of theory is estimates. In addition, X-x represents the remaining forest, which is a generalization. It requires that satellite interpreters can confirm whether the forest is intact, or whether there has been activity and the forest is of diminished quality. In reality, this is difficult. A lower quality of the forest will, as we know, reduce the value of the forest (v) and is beneficial to the agricultural lobby, since they are more likely to conserve less, according to Harstad (The Conservation Multiplier, 2023). Fires, rain and fog also makes photo-interpretation challenging. For instance, satellite pictures have problem distinguishing between virgin forest and planted trees like cacao or coffee. Similarly, in reality, timber markets does experience problems, or costs, of distinguishing what timer comes from legal or illegal deforestation, even if there exists an international tropical timber agreement. Thus, it's overall deforestation that must be reduced, when the supply is too large, according to Harstad (DN, 2019). If an NGO reduces Gx, it builds trust to a coalition that they are willing to reduce extraction and increases the attractiveness of a climate agreement. If we consider the donor to be "an NGO or a single country offering REDD contracts, such as Norway", see Harstad and Mideksa (2017, 1719) and "exclude that the donor is a benevolent planner and the possibility that the donor values consumer surplus" (Harstad and Mideksa, 2017, 1719). Thus, if the nr of subsets *(m)* increase, and cooperation is successful, there is a synergy since (C) is reduced.

What about the reality? Does it exist synergies between NGOs and REDD+ funders, or are they substitutes?

On the quest for answers, I've focused on highlighting the most prominent findings from the material, provided in FAO (2022) and Harstad and Mideksa (2017). The answers I've searched for are mostly based on the method I chose. However, from curiosity, I've added extra insights. Firstly, Harstad and Mideksa (2017) show that Norway only makes agreements with central governments (Harstad and Mideksa, 2017). My findings show there are big rewards from contracting with subsets when *(m)* increase and *(b)* decrease. We know b is low and c is high in Brazil. In this case, this restraint is inefficient, and thus contradicts Harstad and Mideksa's (2017) and my findings. In Brazils case, we know most of the deforestation, "above 50 percent", is illegal (weak property rights with low b and high c), according to Harstad and Mideksa (2017, 1709). When b declines and the nr of subsets *(m)* is bigger than 2, the derivative of contracting with subsets is larger than with the central government. The reason is that the value of reducing c is amplified when m increases. The novel insight is that this is similar to economies of scale (and increasing returns to scale). It means there is *strength in numbers* or *power in scales*, from expanding the nr of subsets *(m)* and invest in monitoring. Thus, contracting with subsets is a *Pareto improvement*, improve efficiency and protects more forest. From this, I suggest that the contract form should vary depending on the situation rather than being harmonised, as Harstad questioned in Aftenposten (2013). Secondly, we know that when d increases (or when the nr of districts or subsets m increase), the value of reducing c is always *bigger* when a donor offers a contract. We know there are immense deforestation damages in the Amazon. Additionally, the forest is on a tipping point of not recovering. Since our foreign relations, and negotiations, have come to a fault, there exists a market failure we have an opportunity to improve upon. Thirdly, the question is whether there exist synergies between NGOs, those who pay and those who reduce c. Intuitively, both NGOs and those who pay, benefits from lower monitoring costs and free global satellite access. However, it's only the donor who pays. This represents a fundamental asymmetry, according to Harstad (The Conservation Multiplier, 2023). In addition, in reality, NGOs have incentives to reduce c, not monitor and only extract. This is not in the interest of the forest or third parties. Governments also have more information than donors about monitoring and investments. Monitoring is good if it's in our common interest for safeguarding the forest, otherwise not. We know the Amazon is in danger, negotiations have become to a fault, and that important policies, enforcement and convictions are lacking. We also know monitoring quality varies between countries. Thus, FAO (2022), being an independent survey, was produced. This implies that NGOs alone are not enough to protect our forests. Additionally, "it's only the donor who gives money", according to Harstad. It's also only the donor who benefits from less extraction (-dx), see Harstad and Mideksa (2017). Thus, it's the donor who ultimately pays the price of reducing the harm if an NGO avoids internalizing costs (C=0). Thus, the donor and the NGO are not substitutes, the NGO does not replace the donor. If we didn't have donors like REDD, or forest protectors, extraction dx would be higher. The NGO can, in reality, prefer extraction, as when the party in power benefits from extraction, which depend on the political circumstances and lobbyism. Protection is costly, making an NGOs less inclined to protect the forest. The donor, on the other hand, benefits from less extraction (*-dx*) and more forest (when *X-x*, the remaining virgin forest, is larger). Arguably, if all NGOs internalized the costs, why is the Amazon at danger? And why have NGOs who are supposed to "protect" the Amazon been producing and importing products that cause deforestation? Another explanation can be green corruption. Økokrim writes that *internationally, green corruption is a kind of corruption that facilitates environmental crime or makes environmental crime lucrative* (Økokrim, 2022). It covers corruption in all forms, weak governance and money laundering, according to (Økokrim, 2022). Økokrim (2023) writes that illegal deforestation, is a result of environmental criminality, green corruption, lack of supervision and punishments. In addition, *owners offers bribes to law enforcement in order to stop the investigation*, according to Økokrim (2023). Økokrim writes that environmental crime generally is linked to weak governance, financial intermediaries, low penalties, driven by demand in rich countries (2022). In addition, *the entire enforcement chain is riddled with corruption risks that are not being properly addressed*, according to Økokrim (2022).

What about those who reduce c?

Protection is costly, so both parties have synergies from better monitoring and reduced c. As mentioned, NGOs can, as well as the donor, be concerned about reducing c. However, the distribution of costs between the parties, depends on whether the NGO internalizes the monitoring costs or not. Lack of monitoring, or enforcement, from a NGO inflicts a cost for the donor, in terms of transfers (a pigou subsidy). As we know, "it's only the donor who gives money", according to Harstad. Thus, I assume the NGO doesn't internalize monitoring costs (C=0). From the utility function, we see that if NGOs internalized the monitoring costs (C=c), NGOs utility decrease since total enforcement costs increase. When the remaining part of the forest *(X-x)* is large, and timber supply is low, timber prices and enforcement costs increase, so total enforcement costs are high. Thus, the chance is higher that an NGO will extract rather than conserve. However, the upside is, if NGOs collude, costs are reduced. FAO (2022) showed that global satellite monitoring have made it possible to collaborate and enhance forest protection on a global scale and that overall deforestation has declined. Nevertheless, we know the Amazon is in danger and need reinforcements. If the NGOs collude effectively and the nr of subsets increase, there are big efficiency gains from reducing c. In addition, third parties are less likely to suffer from the harm. Harstad and Mideksa (2017) list several reasons that prevent the first best from being achieved. For example, a high level of corruption makes the value of timber extraction *(b)* increase. In reality, government officials have profited from agricultural expansion *(a)* from lobby groups. This "trade" drives up their commissions, speculate up agricultural land value and increase deforestation. Again, this give lobbies further incentives to expand, according to Harstad (The Conservation multiplier, 2023). In addition, timber extraction (x) becomes more sensitive, according to Harstad (The Conservation Multiplier, 2023). Even if the virgin forests are resilient, logging, or stripping, reduces the value *(v)* of the forest. Main challenges are lack of governance, scientific challenges related to accurate data monitoring, low enforcement, punishments and land grabbing. Adequate protection, on the other hand, makes our forests and planet thrive.

It's not certain that an NGO should put so much emphasis on the profit or the cost of protecting, but it should be a cost associated with reducing c?

Mostly, the gain from reducing c depends on the design of the contracts. Intuitively, as long as the value of reducing c is bigger than the marginal costs from reducing c, there are gains from reducing c, and we will scale up protection, until we reach the equilibrium level of protection. Since the marginal benefit is positive, there is an opportunity to increase protection. On the other hand, if the value of reducing c is negative, the marginal costs of reducing c is bigger than the marginal benefit. Then the costs are larger than the benefits, investing is superfluous and it's necessary to downscale. From the analysis, we know that if d increase, or districts or subsets m increase, we are better off when a donor offers conservation contrasts, meaning the contracts are *complementary*. Then it's optimal to offer donor contracts and much to gain, since the value of reducing c is high. If it wasn't, it's a waste of resources.

6 Conclusion

Weaving the pieces together: Overall deforestation has gone down, but there are still high deforestation rates in the Amazon. It's on the verge of not recovering. Deforestation is an inefficiency, according to Harstad (Kane, 2023).

It's a burden of expenses on third parties and a distortion of perfect markets. In the Amazon the predominant cause is cattle ranching expansion from large oligopolies, like Monsanto. Deforestation is mostly due to lack of governance and enforcement, corruption and organized crime. Monitoring is costly and challenging. Conservation contracts, on the other hand, are cost-effective; assuming that damages *(d)*, the nr of districts or subsets (m) increase. The optimal design of conservation contracts depend on the political situation, like weak governance and levels of organized crime. Thus, conservation contrasts need to be flexible, and adjusted accordingly, to ensure efficiency. Nevertheless, the main findings are promising: The value of reducing monitoring costs increases in damages, or when the nr of districts or subsets increase. This implies that the contracts are *complementary*: *We are always better off when a donor offers a conservation contract.* And, even better: *The rewards are amplified when governments reduce exploitation.* This implies there is *strength in numbers* or *power in scales.* This should be enough to entice enforcement, further investigation, cooperation and the application of the most ideal conservation contracts. In addition, it can stimulate donor's motivation, support donor's efforts and *keep land grabbers back.* Enclosing the case, the paper demonstrates we need to keep up our good foreign relations with Brazil by protecting the Amazon rainforest rather than exploiting it. At the end of the thread, the key lessons and recommendations are: Strengthened global cooperation, valuing our virgin forests more, and reduce logging and agricultural expansion. As Harstad says "Redd REDD" (Aftenposten, 2013). Enforcement depends on good governance, healthy power dynamics and governments unwillingness to abide from lobby corruption. To finish off, key takeaways are: *Protecting the Amazon rainforest is a matter of global security, is urgent and calls for global action.* To ensure our economy, and our planet, is evergreen - like Nature's perfect symphony of species. We have a dream. Flaws and shortcomings of this thesis are my responsibility. Future research must take care to "calculate" precisely, to avoid *"the risk of our species going extinct"*, according to Harstad (DN, 2023).

In the spirit of Torleif Skogstad.

7 Appendix

7.1 Parameters

(*a*): The marginal (present discounted) agricultural value of beef. Constant of the demand function.

(*b*): The marginal benefit of timber extraction. It represents the weight a central government or districts place on the profit from timber extraction or the probability of the state capturing the cutter's revenue in the region not highly protected. When b is large and c is small (strong property rights), in a sales-driven Cournot model, the government places high value on profit from extraction and enforcement is cheap. When b is small and c is large (weak property rights), the government is unable to capture a significant share of the revenues and enforcement is costly. The simplest model of illegal extraction is when b=0. A higher b means more legal extraction. (Harstad; Mideksa, 2017).

(*c*): The marginal cost of protecting the forest. E.g. by satellites, drones or police. It measures the marginal cost of increasing protection costs (or protecting another unit) enough to raise expected penalty, theta, by one. It also measures the cost of ensuring local public agencies are not corrupt (Harstad and Mideksa, 2017). For protection to be effective, the expected penalty must be at least as large as the profit from logging, otherwise it's inefficient to monitor and more profitable to cut trees. Total enforcement costs, theta, is larger when the profits from timber extraction (b) and/or agricultural products are large (a). (Harstad and Mideksa, 2017).

(*d*): Donors' marginal damage from aggregate timber extraction (*x*). Marginal means when a unit, or parcel, of the forest is logged. Aggregate means the sum, or total size, of the forest.

(*m*): The number of subsets.

(*n*): Number of districts or countries.

(*p-hat*): The price. A decreasing function of aggregate timber extraction (x). It also represents the market size (equilibrium price equal equilibrium quantity). Intuitively, when the price is high, districts have incentive to extract more since extraction its profitable and enforcement is expensive.

***(v)*: The value of each unit of forest, X, that is conserved.** When (v) is big, we conserve more. When (v) is small, we extract more.

***(X)*: Forest size**. The aggregate resource stock in a district.

(x): **Deforestation level**. The amount of timber and/or agricultural extraction.

7.2 Derivations from Section 5

Case 1. Comparing (4) and (3):

$$\frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2} + \frac{2md}{9a(b+c)^2} \geq \frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2} + \frac{4d}{9a(b+c)^2}$$

$$\frac{2md}{9a(b+c)^2} \geq \frac{4d}{9a(b+c)^2}$$

$$m \geq 2$$

Case 2. Comparing (4) and (2):

$$\frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2} + \frac{2md}{9a(b+c)^2} \geq \frac{bX}{2(b+c)^2} + \frac{v+d}{2a(b+c)^2}$$

$$\frac{bX}{3} + \frac{2v}{3a} + \frac{2md}{9a} \geq \frac{bX}{2} + \frac{v+d}{2a}$$

$$\frac{6bX}{18} + \frac{12v}{18a} + \frac{4md}{18a} \geq \frac{9bX}{18} + \frac{9v}{18a} + \frac{9d}{18a}$$

$$\frac{3v}{18a} + \frac{4md}{18a} \geq \frac{3abX}{18a} + \frac{9d}{18a}$$

$$3v + 4md \geq 3abX + 9d$$

$$3v + d(4m-9) - 3abX \geq 0$$

Case 3. Comparing (4) and (1):

$$\frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2} + \frac{2md}{9a(b+c)^2} \geq \frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2}$$

$$2md \geq 0$$

Case 4. Comparing (3) and (4):

$$\frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2} + \frac{4d}{9a(b+c)^2} \geq \frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2} + \frac{2md}{9a(b+c)^2}$$

$$\frac{4d}{9a(b+c)^2} \geq \frac{2md}{9a(b+c)^2}$$

$$2 \geq m$$

Case 4. Comparing (3) and (4):

$$2 \geq m$$

Case 5. Comparing (3) and (2):

$$\frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2} + \frac{4d}{9a(b+c)^2} \geq \frac{bX}{2(b+c)^2} + \frac{v+d}{2a(b+c)^2}$$

$$\frac{bX}{3} + \frac{2v}{3a} + \frac{4d}{9a} \geq \frac{bX}{2} + \frac{v+d}{2a}$$

$$\frac{6abX}{18a} + \frac{12v}{18a} + \frac{8d}{18a} \geq \frac{9abX}{18a} + \frac{9v}{18a} + \frac{9d}{18a}$$

$$6abX + 12v + 8d \geq 9abX + 9v + 9d$$

$$3v \geq 3abX + d$$

Case 6. Comparing (3) and (1):

$$\frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2} + \frac{4d}{9a(b+c)^2} \geq \frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2}$$

$$4d \geq 0$$

Case 7. Comparing (2) and (4):

$$\frac{bX}{2(b+c)^2} + \frac{v+d}{2a(b+c)^2} \geq \frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2} + \frac{2md}{9a(b+c)^2}$$

$$\frac{9abX}{18a} + \frac{9(v+d)}{18a} \geq \frac{6abX}{18a} + \frac{12v}{18a} + \frac{4md}{18a}$$

$$9abX + 9v + 9d \geq 6abX + 12v + 4md$$

$$3abX + 9d \geq 3v + 4md$$

$$3abX + d(9-4m) \geq 3v$$

Case 8. Comparing (2) and (3):

$$\frac{bX}{2(b+c)^2} + \frac{v+d}{2a(b+c)^2} \geq \frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2} + \frac{4d}{9a(b+c)^2}$$

$$\frac{9abX}{18a} + \frac{9(v+d)}{18a} \geq \frac{6abX}{18a} + \frac{12v}{18a} + \frac{8d}{18a}$$

$$9abX + 9(v+d) \geq 6abX + 12v + 8d$$

$$3abX + d \geq 3v$$

$$abX + \frac{1}{3}d \geq v$$

Case 9. Comparing (2) and (1):

$$\frac{bX}{2(b+c)^2} + \frac{v+d}{2a(b+c)^2} \geq \frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2}$$

$$\frac{3abX}{6a} + \frac{3(v+d)}{6a} \geq \frac{2abX}{6a} + \frac{4v}{6a}$$

$$3abX + 3(v+d) \geq 2abX + 4v$$

$$abX + 3d \geq v$$

Case 10. Comparing (1) and (4):

$$\frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2} \geq \frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2} + \frac{2md}{9a(b+c)^2}$$

$$\frac{3abX}{9a(b+c)^2} + \frac{6v}{9a(b+c)^2} \geq \frac{3abX}{9a(b+c)^2} + \frac{6v}{9a(b+c)^2} + \frac{2md}{9a(b+c)^2}$$

$$0 \geq 2md$$

Case 11. Comparing (1) and (3):

$$\frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2} \geq \frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2} + \frac{4d}{9a(b+c)^2}$$

$$3abX + 6v \geq 3abX + 6v + 4d$$

$$0 \geq 4d$$

Case 12. Comparing (1) and (2):

$$\frac{bX}{3(b+c)^2} + \frac{2v}{3a(b+c)^2} \geq \frac{bX}{2(b+c)^2} + \frac{v+d}{2a(b+c)^2}$$

$$2abX + 4v \geq 3abX + 3v + 3d$$

$$v \geq abX + 3d$$

8 References

Hodgson, Camilla and Campbell, Chris (2022): "Climate Graphic of the week: Amazon rainforest loss fuelled by destruction around roads." *Financial Times.* Published: May 7, 2022. Assessed: May 12, 2022. https://www.ft.com/content/d57eeb32-258f-4b7c-896f-1c99ffe5e48f

FAO. 2022. "FRA 2020 Remote Sensing Survey." FAO Forestry Paper No. 186. Rome.

Harstad, Bård and Mideksa, Torben K. (2017): "Conservation Contracts and Political Regimes." *The Review of Economic Studies*, 84(4 (301)), 1708–1734. https://www.jstor.org/stable/26543870.

Harstad, Bård (2023): "The Conservation Multiplier." *Journal of Political Economy* July 2023 Vol. 131 Issue 7 Pages 1731–1771.

Harstad, Bård (2016): "The market for conservation and other hostages." *Journal of Economic Theory*. 2016, 166, 124-151, DOI: https://doi.org/10.1016/j.jet.2016.07.003

Harstad, Bård (2023): "Trade and Trees." June 2023. Working Paper No. 4127. https://www.gsb.stanford.edu/faculty-research/working-papers/trade-trees

Framstad, Nils C. and Harstad, Bård (2019): "Conservation Contracts for Exhaustible Resources." *University of Oslo*. https://www.sv.uio.no/econ/personer/vit/bardh/dokumenter/cct.pdf

Gibson, L., Lee, T., Koh, L. *et al. (2011): "*Primary forests are irreplaceable for sustaining tropical biodiversity. *Nature* **478**, 378-381 (2011)". https://doi.org/10.1038/nature10425

The Royal House of Norway (2023): "Kong Harald i Amazonas." *The Royal House of Norway.* Published: May 4, 2013. Assessed: Nov 6, 2023. https://www.kongehuset.no/nyhet.html?tid=115092&sek=26939

Pileberg, Silje (2020): "Når gode, faglege resonnement ikkje er nok." *University of Oslo.* Published: Oct 12, 2020. Assessed: Nov 9, 2023. https://www.sv.uio.no/forskning/kunnskap-i-bruk/eksempler/nar-faglige-rad-ikke-er-nok-.html

Phillips, Tom and Ionova, Ana (2023): "Amazon facing 'urgent' crime crisis after gutting of protections, says drugs tsar." *The Guardian.* Published: Jun 28, 2023. Assessed: Oct 20, 2023. https://www.theguardian.com/world/2023/jun/28/organized-crime-drives-environmental-amazon-devastation

Sunding, Per (2023): "Skog." *Store Norske Leksikon.* Last updated: Sept 11, 2023. Assessed: Nov 9, 2023. https://snl.no/skog

UN-REDD(2023): "Save forest now." *UN-REDD Programme.* Assessed: Nov 9, 2023. https://www.un-redd.org/better-with-forests

Toft, Martin (2023): "UiO-professor Bård Harstad gir prispengar til Regnskogfondet." *University of Oslo.* Published: Mar 13, 2023. Assessed: Nov 9, 2023. https://www.uniforum.uio.no/nyheter/2023/03/uio-professor-gir-prispengar-til-regnskogfondet.html

Harstad, Bård (2023): "Hvorfor svikter politikere sine velgere?" *Dagens Næringsliv.* Jun 2, 2023. Assessed: Aug 28, 2023. https://www.sv.uio.no/econ/personer/vit/bardh/dokumenter/xdn230602_skogsvikt.pdf

Harstad, Bård (2023): «Kan noen skru på lyset?». *Dagens Næringsliv.* Published: March 9, 2023. Assessed: Oct 15, 2023. https://www.dn.no/fredagskronikken/politikk/lobbyvirksomhet/lobbyregister/lobbyregister-kan-noen-skru-pa-lyset/2-1-1416224

Harstad, Bård (2013): "Redd «REDD»." *Aftenposten.* Jun 6, 2013. https://www.sv.uio.no/econ/personer/vit/bardh/dokumenter/130606-redd.pdf

Harstad, Bård (2019): "Sertifisering av substitutter." *Dagens Næringsliv.* Published: Jun 21, 2019. Assessed: Oct 15, 2022. https://www.sv.uio.no/econ/personer/vit/bardh/dokumenter/xdn190621_substitutter.pdf

Harstad, Bård (2017): "Villmarken kaller - for siste gang?" *Dagens Næringsliv.* Published: Sept 1, 2017. https://www.sv.uio.no/econ/personer/vit/bardh/dokumenter/xdn170901_villmark.pdf

Volckhausen, Taran (2019): "Land grabbing, cattle ranching ravage Colombian Amazon after FARC demobilization." *Mongobay.* Published: May 30, 2019. Assessed: Aug 28, 2023. https://news.mongabay.com/2019/05/land-grabbing-cattle-ranching-ravage-colombian-amazon-after-farc-demobilization/

Wasley, Andrew et al. (2023): "More than 800m Amazon trees felled in six years to meet beef demand." *The Guardian.* Published: Jun 2, 2023. Assessed: Aug 28, 2023.

https://www.theguardian.com/environment/2023/jun/02/more-than-800m-amazon-trees-felled-in-six-years-to-meet-beef-demand

Regjeringen (2022): "Norge og regnskog." *Regjeringen.* Last updated: Jul 7, 2022. Retrieved: Oct 10, 2023. https://www.regjeringen.no/no/tema/klima-og-miljo/klima/klima--og-skogsatsingen/id2000712/?expand=factbox2922844

Spring, Jake; Stargardter, Gabriel (2023): "'Narco-deforestation' in focus at upcoming summit of Amazon nations." *Reuters.* Published: Aug 3, 2023. Assessed: Oct 30, 2023. https://www.reuters.com/sustainability/narco-deforestation-focus-upcoming-summit-amazon-nations-2023-08-03/

Radwin, Maxwell (2023): "Drug trafficking fuels other deforestation drivers in the Amazon: report." *Mongobay.* Published: Jul 14, 2023. Assessed: Oct 10, 2023. https://news.mongabay.com/2023/07/drug-trafficking-fuels-other-deforestation-drivers-in-the-amazon-report/

Djupesland, Marianne and LittleGreen, Nina Norset (2023): "Green corruption." *Økokrim.* Published: Dec 9, 2021. Updated: Apr 8, 2022. https://www.okokrim.no/green-corruption.6424619-411472.html

UN (2023): "The nexus between drugs and crimes that affect the environment and convergent crime in the Amazon Basin." https://www.unodc.org/res/WDR-2023/WDR23_B3_CH4_Amazon.pdf

Harstad, Bård (2023): "Lecture 5: International climate action with Bård Harstad." *Youtube.* Published: Oct 17, 2023. Assessed: Nov 8, 2023. https://www.youtube.com/watch?v=j0zg8cH7nGU

Ursin, Lars (2018): "Ekspertintervjuet: Kan REDD+ redde regnskogen?" *Energi og klima.* Published: Nov 6, 2018. Assessed: Oct 31, 2023. https://www.energiogklima.no/to-grader/ekspertintervjuet-kan-redd-redde-regnskogen

Kane, Julia (2023): "How to Convince a Country Not to Chop Down Its Rainforest". *Stanford Graduate School of Business.* Published: Oct 12, 2023. Assessed: Oct 15, 2023. https://www.gsb.stanford.edu/insights/how-convince-country-not-chop-down-its-rainforest.