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The Impact of Timber Price Uncertainty and Flexible Harvesting on Bidding behavior in N + 1 Price Forest Biodiversity Auctions

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Master of Science in Economics

Master Thesis

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Declaration

I, Stephen Oppong Adu, hereby declare that except for references to other people´s work which has been duly acknowledged, this work is the result of my own original research, conducted under the supervision of Eirik Romstad, and that it has neither in whole, nor in part, been presented for a degree elsewhere.

Signature:………………………………………………………………………………………

Stephen Oppong Adu

Date: 15th July, 2020

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Eirik Romstad

Supervisor

Date:

Dedication

I dedicate this thesis to my children, Kwaku Otchere Adu-Oppong and Owusuaa Adu-Oppong.

Acknowledgement

I thank Norwegian University of Life Sciences for the opportunity given me to study for a Master of Science in Economics. I am grateful to the Lecturers and the administrative staff of the university for their support and guidance in the course of my study.

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Abstract

Conservation auctions have received increased attention since the turn of the century. Improved management of forests for biodiversity is one of the areas where this has been the case. Previous studies have to my knowledge not accounted for the impact of timber price variability on forest owners' bidding behavior. This thesis fills this void in the literature.

Brazee and Mendelsohn (1988) showed that timber price fluctuations affect the timing of timber cutting as the forest owners' reservation prices for cutting increase under higher price variability. A basic insight from auction theory is that no bidder will submit a bid that makes him or her worse off. This is also the case for conservation contract auctions.

I combine the above two insights to show that bids for forest conservation auctions will become higher under timber price variability compared to cases with timber prices without such fluctuations.

Key words: *Conservation auctions, forestry, timber price variability, bidding behavior*.

Table of Contents

Chapter One: Introduction

1.1 Motivation

Biodiversity is a source of numerous benefits to mankind. We depend on biodiversity in ecosystems for provisioning services such as food, water, timber, and fiber; regulating services related to climate, floods, diseases, wastes, and water quality; cultural services such as recreation, aesthetic enjoyment, and spiritual fulfillment; and supporting services such as soil formation, photosynthesis, and nutrient cycling (MEA, 2005). The rate of biodiversity loss at a time when our knowledge of its importance has grown immensely, has made many concerned, leading to efforts to preserve biodiversity.

Scarcity of public funds and resources make it imperative to use cost effective ways of controlling biodiversity losses. Cost effectiveness is a necessary condition for maximizing benefits from the use of public funds. A cost-effective biodiversity policy requires identifying which service providers have management strategies that are least cost.

Well-designed procurement auctions have been identified as potentially cost-effective for engaging biodiversity management services from potential suppliers. Uniform-price auctions based on Vickery (1961) have been regarded (Romstad, et al, ibid.) as an instrument which can potentially resolve the double matching problem. It is expected to allocate conservation contracts to least-cost providers and lowers the compensation payments needed for landowners to voluntarily accept changes in their forest management practices.

Owners of private forestland set out to get the most value out of their lands. They make decisions with the goal of maximizing net returns from their assets, in our context, their forestland. As rational economic agents, they will participate and comply with biodiversity management contracts if they expect that their pay-off under conservation is equal to or more than other alternative uses of their lands. What bids can be expected from landowners in forest biodiversity auctions when the next best alternative value is the return from forestry business as usual?

Forest biodiversity management is such that the buyer cannot monitor seller completely. When the agent expects significant positive net returns from non-compliance, the agent´s probability not comply increases and when the agent expects a negative return on non-compliance, compliance probability tends to increase, holding penalty and monitoring constant (Shavell, 1987; Mitchell & Shavell, 2000). This means that the design of any cost-effective instrument for payment of ecosystem services generally and auction as a specific instrument of interest in this thesis, must be cognizant of these issues.

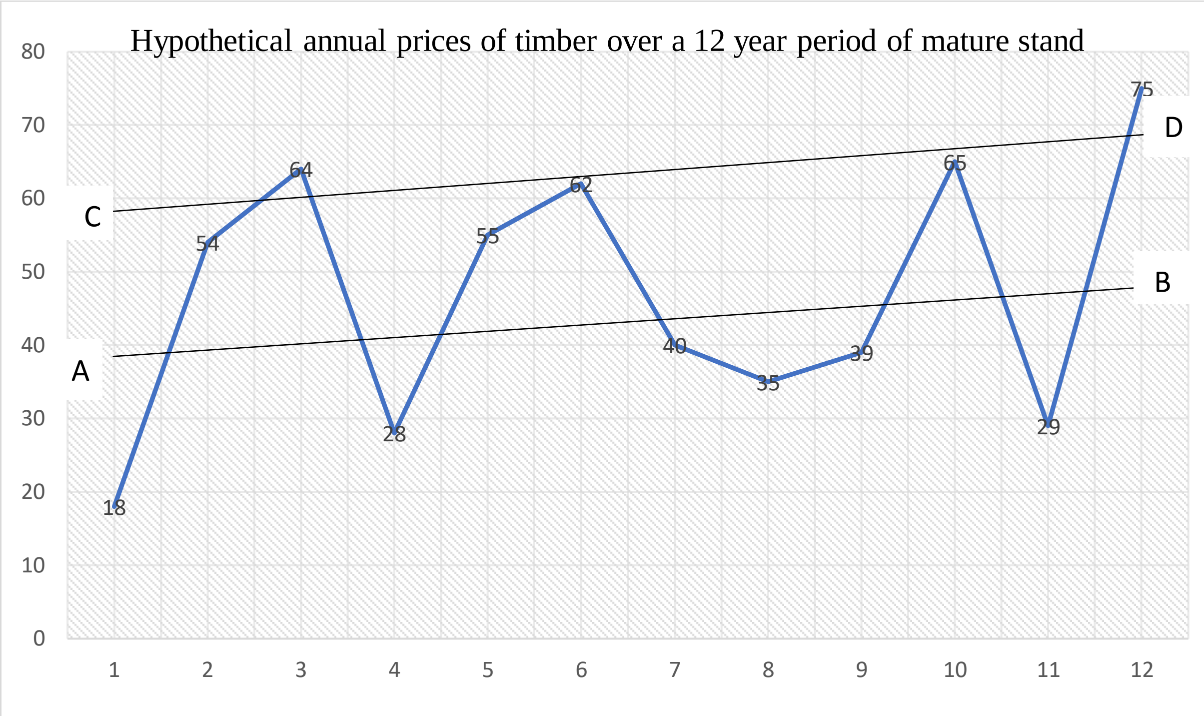
Auctions that are designed to elicit truthful revelation of agents´ potential net returns on non-compliance provides reliable information about the value of not meeting contract obligations and hence enabling award of contracts to least cost service providers. This information can be used to improve the effectiveness of monitoring as well as minimizes cost of monitoring (Romstad & Alfnes, 2011).

1.2 Optimal harvest timing, the Hotelling rule and bid formation

Landowners seek to maximize net returns from their land. This implies that returns from forest biodiversity management contracts must at least be equal to the returns from other uses of their land. Timber harvesting times are flexible to some extent. This allows landowners a space of time to cut a tree stand a few years earlier or later than the planned harvest time to benefit from an expected local peak in the timber price. When a tree stand is near ready to harvest, foresters aim for harvesting at local price peaks in order to maximize revenues.

The implication of this framing for bid formation is that landowners will aim to bid to the level at which they are indifferent between net present value of returns from conservation and harvesting. Thus, bidders will aim to bid to the extent that opportunity value per unit of harvest (evaluated at the time of bidding) are consistent with local peak prices overtime when forming bids. This valuation is affected by price uncertainty and oscillation arising from unpredictable market forces. This also implies that the opportunity income is at an expected local peak, i.e., above the mean price line. Thus, the optimal harvest time is a reference point for bid formation and opportunity to practice flexible price harvesting is important for bid formation.

Figure 1.1: Hypothetical annual prices of timber showing fluctuations from one period to another



Source: Author´s Design. Remark: Add NOK 400 to the figure scale to get prices matching typical Norwegian timber prices for spruce per cubic meter.

Figure 1.1 shows hypothetical plot of annual price level of timber within a 12-year period of biological maturity. The 12-year time window is chosen for simplicity – the length of the time window varies depending on the type of forest. It is within this period that forest owners consider harvesting. Harvesting at an earlier time is unlikely to be optimal because the trees are still growing at a higher rate and increasing potential timber volume and forest value relative to returns on the present value of existing forest value. Beyond period 12, the landowner keeps the trees standing at a relatively higher opportunity cost as the tree volume growth is below the risk-free interest rate. This means that landowners will maximize forest value with this period depending on the price level at which he/she cuts, given constant interest rate and cutting cost (planting costs has already been incurred at the time the forest was planted).

We can observe price fluctuations over the period from NOK 418 per cubic meter of timber in period 1 to as high as NOK 475 per unit in period 12. Three local peaks occurred over the period at NOK 464 in period 3, NOK 462 in period 6, and NOK 465 in period 10. Line AB show the mean price over the period. Line CD gives the price level landowners will try to aim for as they make the cut or wait decision. Given the flexible nature of harvest Brazee and Mendelsohn (1988) have shown that landowner stand to benefit for these random fluctuations in price if they implement a flexible price harvesting strategy.

Timber revenues are a function of prices times harvest volume. Hence, waiting for a higher price may be a beneficial strategy, not only because it improves targeting for a maximum price, but it may also generate benefits from increased volumes as long as the forest grows at a good pace. This implies that waiting for higher prices may come with benefits of a higher volume. Conversely, if the forest owner expects lower prices for a prolonged period, he or she may choose to harvest a few years early. This brings about an extra benefit – earlier arrival of revenues at the cost of a slightly lower tree harvest volume. For instance, from figure 1.1, assuming the Faustmann optimal rotation age coincides with period 7, a landowner may decide to cut earlier in periods 3, or 6, or later in period 10 through a flexible price harvest strategy and benefit from the respective price peaks that exists in such period.

There is a cost of waiting. Timber revenues arrive on the day the forest is harvested. Waiting implies forgoing all interests on forest value with could have accrued to the landowner had he/she cut earlier and deposited the money in a bank. In addition, waiting pushes forward the next replanting period. This implies a loss of some interest on the site value of land.

In a similar framework, the landowner bidding in a forest biodiversity auction is expected to use information about the potential gains from flexible price harvest during bid formation. In evaluating his/her opportunity value, the bidder will aim to maximize the present value of the expected profits from the forest based on an expected price higher than the mean price. This thesis tries to show this tendency by modelling the expected bids of forest owner in a N+1 price conservation auction when their opportunity value arises from expected returns from the forest industry and random price fluctuation exist

It is expected that landowner´s bid N+1 price auction is equal to the opportunity value of the land. With these perspectives, one could argue that logging decisions and the bidding decisions in conservation contracts are similar. Unfortunately, there has been so few auctioned conservation contracts out there that produce data suitable to econometrically test if there are similarities. This study therefore explores in a theoretical analysis the implications of optimal harvest timing in an environment of uncertain timber prices and flexible harvesting in bid formation.

1.3 Conceptual framework

The study is based on a conceptual framing of a rational forest owner trying to maximize net returns on their forest when subjectively valuing their opportunity value in a forest biodiversity auction bid formation. This framework is deemed similar in context to a landowner choosing an optimal rotation age that maximize dynamic efficiency in an infinite rotation forest model. This landowner has a problem of deciding subjectively, his/her opportunity value in order to maximize returns from conservation. This is just like the satisfying the dynamic efficiency condition. The optimal harvest time that maximizes expected revenue from the stand is important in the forest owner´s subjective valuation of opportunity value in bid formation in order for to maximize net returns from conservation. This is relevant for evaluating true opportunity cost for the landowner, identification of least cost providers for the buyer and the design of effective monitoring strategy for biodiversity management auction.

Price uncertainties during the harvest periods and flexibility in harvest timing enable landowners to implement a flexible price-harvest strategy (Brazee & Mendelsohn, 1988) in order to maximize the value of their harvest. This achieved by waiting for a stumpage price that is greater than the forest owner´s reservation price when he/she expects higher prices. On the other hand, the landowner may harvest earlier when landowners expect lower prices.

1.4 Objectives and research questions

The goal of this thesis is to demonstrate the impact of inherent price uncertainty and flexible harvesting associated with forest biodiversity conservation on bidding behavior in N+1 price conservation auction.

Objectives:

1. To explore how timber price uncertainty, affect agents bid formation in N+1 price Forest biodiversity auctions;
2. To explore some implications of timber price uncertainty relevant aspects of N+1 price conservation auction design and implementation.

1.5 Method of study

I conduct a decision analysis based on a dynamic model that reflect the behavior of a rational landowner maximizing net revenue from forest land use in conservation auction when alternative value arises from timber production in a context of price uncertainty. Assuming a single uniform stand model of forest in the context of a dynamic forest, I demonstrate the sequential decision process as similar to a cut or wait decision in forest industry business as usual in the context of fluctuation timber prices and flexible harvesting. I then explore implications of price uncertainty and harvest in a conserve or harvest decision context.

1.6 A brief outline of the rest of the thesis

In chapter two I review some relevant literature on key aspects of the thesis. I continue with the method of study and the model used in the study under chapter three. Chapter four comprises a decision analysis conducted based on the model and using chosen parameter values for history data in the forest industry in Norway. In chapter five in discuss the findings of the analysis in relation to N+1 price auction design and implementation. Chapter six presents the summary conclusions and recommendations of the study.

Chapter Two: Literature Review

2.0 Introduction

In this chapter I review some of the relevant literature for my thesis on biodiversity conservation. Please recall my problem statement on the implications of price uncertainty on the formulation of bids in procurement auctions related to the optimal harvesting rule of Brazee and Mendelsohn (1988). I will not discuss this issue further in this chapter as I will return to that in chapter three. Now, I look at the broader background on biodiversity conservation and relevant economic policies, including auctions.

The societal objective of environmental sustainability under which biodiversity conservation goals arise, fall within the mandate of political authorities. They decide the goals and have a responsibility to use cost effective mechanisms to attain them. In Norway, the objective as indicated in the Nature Diversity Act, chapter one, section one, is “to maintain the diversity of habitat types within their natural range and the species diversity and ecological processes that are characteristic of each habitat type” (Norwegian Ministry of the Environment, 2009).

The cost-effectiveness of policy mechanisms aimed at meeting environmental goals and particularly biodiversity conservation targets, requires careful consideration of relevant principles and contextual issues. Such policies should be designed with reasonable certainty of reaching stated goals. The forest industry competes with forest biodiversity for land use to a large extent. As mentioned in the introduction this thesis explores how the price uncertainty in the forest industry may impact bid formation in auctions designed to elicit truthful revelation of sellers´ opportunity value. In this chapter I first review some relevant literature on forest biodiversity management issues including design considerations for cost effectiveness. I continue the literature review with a focus on the applicability of procurement auction in addressing some of these concerns.

2.1 Biodiversity and Ecosystem Services

The ecological concept of biodiversity is inherently complex there exist a large number of competing biodiversity definitions and an even larger number of measures (DeLong 1996).

According to Delong (1996, p. 745) "Biodiversity is an attribute of an area and specifically refers to the variety within and among living organisms, assemblages of living organisms, biotic communities, and biotic processes, whether naturally occurring or modified by humans". He adds that it can be observed and measured at any spatial scale ranging from microsites and habitat patches to the entire biosphere. The Millennium Ecosystem Assessment (MEA) (2005) defines biodiversity as the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part.

In connection with human wellbeing, biodiversity forms the basis for complex ecosystems that provides humans with "ecosystem services", defined by the Daily & Dasgupta (2005, p. 353) as " the wide array of conditions and processes through which ecosystems and their biodiversity confers benefit on humanity, these include the production of goods, life-support functions, life-fulfilling conditions and preservation of options". The benefits people obtain from ecosystems include provisioning services such as food, water, timber, and fiber; regulating such as the regulation of climate, floods, disease, wastes, and water quality; cultural services such as recreation, aesthetic enjoyment, and spiritual fulfillment; and supporting services such as soil formation, photosynthesis, and nutrient cycling (MEA, 2005).

Barthkowski (2016) summarizes the literature on the economic value of biodiversity, identifying four sources: biodiversity contributes to ecosystem functioning (insurance value), is the carrier of future options (option value), provides 'efficient' support for migrating species (spill-over value) and influences the aesthetic appreciation of ecosystems (aesthetic value). Being only a property of ecosystems, biodiversity does not have value per se, but only contributes to the overall value of an ecosystem (Barthkowski, ibid.).

It is estimated that the value of ecosystem services (e.g. organic waste disposal, soil formation, bioremediation, nitrogen fixation and biocontrol) provided each year in agricultural systems worldwide may exceed US$ 1542 billion (reference – is it Sumila et al., 2018? – if so, add it here). About 100 000 species of insects as well as birds and mammals pollinate more than two-thirds of food plants. Pollinators have been found to be worth more than US$ 200 billion per year to the global food economy, which amounts to 9.5% of the total value of the world's agricultural food production (Sumaila, et al., 2018).

Brockerhoff et al. (2017) review forest ecosystem services including biomass production, habitat provisioning services, pollination, seed dispersal, resistance to windstorms, fire regulation and mitigation, pest regulation of native and invading insects, carbon sequestration and cultural ecosystem services based on forest type, structure and diversity. Part of their findings was that published studies were lacking in empirical studies that establishes quantitative and causal relationship between forest biodiversity and many important ecosystem services. They indicated that pressure from human activities have led to forest loss, fragmentation and degradation which have cost us much biodiversity decline and homogenization (Brockerhoff, et al., ibid.). Their review identified some mechanisms such as niche complementarity in time and space, complementary functional effect traits and functional response traits and facilitation among plant species growing together, to be ways in which forest biodiversity is suspected to relate to ecosystems services supply and acknowledges that there is still considerable uncertainty about the extent of a `functional relationship` between biodiversity and the provision of ecosystem services.

2.2 Concerns about biodiversity loss

The Convention on Biological Diversity defines biodiversity loss as "the long-term or permanent qualitative or quantitative reduction in components of biodiversity and their potential to provide goods and services, to be measured at global, regional and national levels (Brockerhoff, et al., 2017. p.2). Globally factors such as continued expansion of the human population leading to increased exploitation of natural resources, pollution, land-use change and climate change underly biodiversity loss. For all aspects of biodiversity, current pace of change and loss is hundreds of times faster than previously in recorded history and the pace shows no indication of slowing down (Brooker, et al., 2007).

MEA (2005) reported that virtually all of Earth's ecosystems have been dramatically transformed through human actions, for example, 35% of mangrove and 20% of coral reef areas have been lost. More than half of the 14 biomes that was assessed have experienced a 20–50% conversion to human use, with temperate and Mediterranean forests and temperate grasslands being the most affected (approximately three quarters of these biome's native habitat has been replaced by cultivated lands). In the last 50 years, rates of conversion have been highest in tropical and sub-tropical dry forests. "The overwhelming evidence of the Intergovernmental Science-Policy

Platform on Biodiversity and Ecosystem Services (IPBES) Global Assessment, from a wide range of different fields of knowledge, presents an ominous picture," said IPBES Chair, Sir Robert Watson (United Nations, 2019). In Norway, 2355 species have been classified as threatened. This corresponds to 11.3 % of the approximately 21 000 species that were assessed (Norwegian Ministry of Climate and Environment, 2015).

Concerns over the accelerated rate of loss of biodiversity have been growing even as our scientific knowledge on the importance of biodiversity has increased. Some of the literature (Brockerhoff, et al., 2017;Bartkowski, 2016; Augustyncziket et al, 2019) shows that the primary threats to biodiversity are habitat fragmentation, overexploitation of resources, the invasion of exotic species and chain extinctions resulting from these factors. Climate change is currently an important factor as it destabilizes natural environment even more. Romstad, et al. (2012) argues that this is partly due to the failure to identify and implement cost effective policies for managing habitats and protecting threatened species.

Global vision to improve biodiversity loss is captured in the Aichi Biodiversity Targets and the Convention on biodiversity´s Strategic Plan for Biodiversity 2011- 2020. These international efforts translate into respective biodiversity conservation management procurement at the national and subnational levels. Forest biodiversity management services are undertaken to achieve forest biodiversity goals as part of the larger effort towards nationally determined conservation policy goals. Norway considers biodiversity conservation essential to her long-term goal of becoming a greener society (Norwegian Ministry of Climate and Environment, 2015). The objective is to maintain the diversity of habitat types within their natural range and the species diversity and ecological processes that are characteristic of each habitat type and maintain ecosystem structure, functioning and productivity to the extent this is considered to be reasonable. (Norwegian Ministry of the Environment, 2009).

2.3 Challenges with existing Forest biodiversity conservation management policy regimes

A number of challenges to achieving biodiversity targets have been identified in the literature. Sironena, et al. (2020) make the point that conservation decisions have implications for different stakeholders and typically draw on multidisciplinary knowledge bases, incorporating natural, physical and social sciences, politics and ethics. This imposes a heavy information requirement on policy making process. They indicate that uncertainties relating to relationship between biodiversity and various ecosystem services is a crucial limitation to efforts on evaluating the economic value of biodiversity conservation and the impact of biodiversity loss in policy making.

Basquill et al. (2016), state that there exists “no common ecological standard for producing and summarizing current land cover conditions. This inconsistency makes it difficult to ensure landscape and natural resource assessments are comparable across management units, regions, or between government and non-governmental partners”. Biodiversity conservation decisions are multifaceted and are further aggravated in a context where deterioration of biodiversity has resulted from an intensive management practice by hundreds of thousands of forest owners, who have operated under different conservation policy instruments (Sironena, et al., 2020).

Uncertainties arising from incomplete information about functional relationship biodiversity between ecosystem services and also the complications introduced by climate change on the dynamics of both forest and forest biota (Augustynczik et al., 2019). Climate change is expected to modify a variety of forest processes and interactions, e.g. forest growth rates, species composition and disturbance activity (Lindner et al., 2014).

Romstad et al. (2012) indicate that conflicts between landowners and the regulatory agency on issues of compensation is a major concern. Vatn et al. (2005) identify four forms of conflicts in this amount biodiversity management actors; Conflict of value – conflicts involving disagreement about which values are involved, Conflict of facts or data – conflicts that are characterized by disagreement about cause-effect relationships, technical questions, Conflict of interest – conflicts that can be characterized by agreement with respect to facts and values involved, but disagreement with respect to allocation of costs and gains and Conflict of rights – conflicts that involve different realizations of the prevailing legal rights or what rights that should prevail.

For Bergseng & Vatn, (2009), such conflicts arise because the changes in forest management practices entails extra costs on most existing users of forests. To a large extent all these conflicts can be partly attributed to the levels of uncertainty and information asymmetry that surrounds biodiversity management procurement, a state of affairs that both the buyer (the environmental protection agencies) and the seller (the landowner) have reason to exploit. Theoretically, the buyer seeks to be cost effective and the seller seeks to maximize economic returns.

These conflicts partly fuel sentiments among landowners that they are not being fully or fairly compensated for their service to society. For example, Norway is noted to have a relatively higher conflict level compared to other Nordic countries. This has been found to be due in part to landowners receiving a smaller fraction of full compensation than in other Nordic countries (Romstad et al, 2012). When landowners feel inadequately compensated, they will not be motivated to voluntary participate in the intervention as they perceive that they will be made worse-off. This will undermine the attainment of policy objectives. Another implication is that the unit cost to society for forest biodiversity conservation will be higher on landowners as compared to the rest of society. One more implication of this sentiment is that, post-contract compliance probability may fall when new information confirms their suspicions.

2.4 Forest Biodiversity as a public good

Property rights to forests are often clearly defined or can be allocated through the market at reasonable level of transaction cost. Land (forest) may be either be owned by the state, local community or privately owned. However, forest biodiversity, which is a characteristic of the forest Delong (1996), does not lend itself easily to clear property right allocation. Thus, even though more biologically diverse forest has known benefits to society, access to it is to a large extent non-rivalry and non-exclusiveness, making it a public good. This means that the market will failure to generate the socially optimal level of output.

2.5 Forest Biodiversity Conservation Management through Payment of Ecosystem Services

As a public good, and with government's social welfare maximization goal in mind, various instruments have been developed by economists to pay for ecosystem services, known as Payments for ecosystem services (PES) (Engela, Pagiola, & Wunder, 2008). Direct regulation, also known as command-and-control, have been used where applicable but have been with its challenges such as political feasibility issues, administrative costs, information limitations and other constraints (Engela et al., ibid).

In the literature, PES have become increasingly preferred by economists and political authorities due to their potential to delivery least cost results and also other attributes like their voluntary nature of participation, being incentive-based, flexible and dynamic efficiency. Centrally designed forest biodiversity conservation policy has generated severe conflicts during the 1990s, therefore the current approach to conservation is primarily voluntary and reliant on economic incentives (Primmer, et al., 2015).

2.6 Cost effectiveness and Biodiversity management

Being cost effective means adopting policy instruments that achieves a policy target at the least cost (Perman et al., 2011). Thus, a cost-effective policy instrument has the minimum opportunity cost. Socially optimal use of resources requires that agents maximize the net social benefit of the use of available resources or minimize the cost of meeting their chosen social objectives.

The cost-effectiveness of policy instruments used in securing different habitats vary in time and space. For example, conservation of natural forests with abundant amount of decaying wood requires permanent protection and relatively large areas, while herb-rich forests are often relatively small and occasionally require management, which is possible to implement with flexible incentives (Sironena, et al., 2020). Based on Campbell (1987), for cost-effective biodiversity policy the general requirements for a policy mechanism to yield a predictable outcome must be factored at the policy design stage.

Cost effectiveness requires competitiveness amount service providers. This is to prevent the use of market power to engage in rent seeking behavior. However, traditional administrative roles and norms of forestry and environmental forest professionals as regards forests and forest owners have constrained the implementation of competitiveness (Primmer et al., 2013). Even when entering PES schemes is voluntary, their implementation relies heavily on the information and support provided by administration (Sironena, et al., 2020).

Cost-effectiveness is related with the quality of information held by both the buyer and the seller in forest biodiversity procurement. The first best scenario operates on the assumption of perfect information. This implies, in theory, that any informational imbalance is a potential source of information rent by any actor with the informational advantage. Although opportunity cost is the most important consideration in devising an optimal conservation payment system, failure to incorporate information about environmental benefit may undermine the cost-effectiveness of a conservation program. The cost-effectiveness of a conservation program can be enhanced by integrating cost-benefit information into program design (Duke et al., 2014; Sharma, Cho, & Yu, 2019). This is because cost considerations alone will not take into account the quality of service expected from landowner. That will be like assuming homogeneous product which can be a strong assumption in a biodiversity setting.

2.7 Forest management and biodiversity procurement auctions

Procurement auctions are preferred for forest biodiversity management mainly due to the theoretical potential of an auctions to address, to some extent, the challenge of information asymmetry under specific conditions (Vickrey 1961; McAfee & McMillan, 1987). Landowners will tend to have a more detailed understanding than procuring agencies about the opportunity costs of foregoing intensive land uses to pursue conservation practices (Banerjee & Conte, 2018). Through bidder competition, procurement auctions can mitigate the information advantage held by sellers regarding the cost of producing the goods and services available for sale.

The basic idea in procurement auctions is that the buyer receives bids from sellers of the services, bids are then evaluated, and winners are awarded the contract. Payment of the contract payoff is made to compensate winners for their opportunity cost of the conservation measures implemented. Participating and bidding in auctions is voluntary. No agent would participate in an auction if his expected net benefit is negative (Romstad et al., 2012). This is both the curse and the blessing of auctions. A curse in the sense that bidders may seek to extract information rents, i.e., extra benefits beyond the compensation level needed for them to accept a contract. A blessing in the sense that if an auction is well designed, bidders will not seek excessive compensations, but bid what they need to be slightly better off than they were initially (Romstad et al., ibid.).

In procurement auctions for forest biodiversity management, the buyer, often the state, receives bids from multiple sellers and enters into a contract with bidders whose forest plots have the desired conservation attributes at the lowest cost given the budget available. Provided that the bids reflect costs, this maximizes biodiversity benefits for a given available budget. This however does not reflect how bidders will behave in the light of new information that suggest that the contract significantly understates their opportunity cost. Post-contract, the truthfulness of agent type become exposed to the reality checks of new information. The probability to violate the terms of the contract becomes high if new information suggest that agents significantly undervalued their opportunity cost and went this happens it is only the legal barrier created by a contract that stands in the seller´s way to non-compliance.

Sealed bid auctions are the preferred type of auction for (forest) biodiversity conservation. Being sealed means that other bidders cannot observe competing bids. There are other auction types that are opened like the English or the Dutch auction. Sealed auctions are of two kinds, the first price sealed-bid auction, also known as discriminatory price auction and the second-price sealed bid auction. In first-price sealed auctions, each winning bidder is paid an amount equal to their bids. This implies that lower bidders receive lower contract pay off.

Second-price sealed bid auctions are designed following the structure proposed by Vickrey (1961). In Vickrey (1961), the highest bidder is the winner and is paid an amount equal to the second highest bid. The Second-price sealed auctions are referred to as uniform price auctions or N+1 price auction when multiple similar items are sold. In such auctions each winning bidder recieves the same payment which equals the size of the first non-winning bid.

2.8 Asymmetric Information and Information Rent in Forest Biodiversity Auctions

The information structure of conservation procurement auctions has attracted significant attention due to how information asymmetries between sellers and the conservation buyer drive auction outcomes (Conte & Griffin, 2017). Landowners may have relatively less knowledge about the landscape-scale functional processes that generate ecosystem services and the techniques used to estimate the value of these services. In conservation procurement auction experiments in which the assessed environmental quality is an exogenous attribute of a submitted offer, withholding this information has been shown to improve auction efficiency by preventing high offers from landowners with high-quality submissions (Banerjee, Kwasnica, & Shortle, 2015;

On the contrary, Cason, Gangadharan, & Duke, 2003). Conte & Griffin (2017) found that providing ES-quality information allows sellers to identify and submit higher-quality conservation actions, an effect that counteracts previously identified efficiency losses from information rents.

For a private forest owner, you stand to pay a disproportionally high cost per unit relative to other members of society if the true cost of biodiversity is not revealed, something which is also vulnerable to incomplete information. This means that the seller´s subjective valuation and bid formation are also affected by uncertainty. In other words, the subjectively defined opportunity cost of the seller is also constrained by incomplete information too. Thus, this tends to be a negotiation between the buyer and the seller, founded on imperfect information on cost and benefit which has a potential to favor either the buyer or the seller.

Agent-based models, which incorporate the agent's bid-learning behavior, has been applied in studies on multiple-round auctions. These studies found that conservation auctions are more cost-efficient than fixed-rate payment approaches with limited conservation budgets, given bidders with heterogeneous opportunity costs. However, the advantage of conservation auctions erodes quickly when bidders learn in successive auction rounds. (Sharma, Cho, & Yu, 2019).

Seller perceptions of their extent of ignorance about the benefits of biodiversity and their opportunity costs may reinforce their desire to maximizing information rent during bidding. It may also influence them to give a false impression of being a low-cost provider, but only to exploit the lapse in monitoring during contract implementation. From the perspective of a conservation agency seeking to enhance social welfare, socially efficient conservation procurement rests on the value of the provided public good exceeding the provision cost. Therefore, from a social welfare perspective, seller rents are a distributional consideration, not an efficiency consideration (Claassen, Cattaneo, & Johansson, 2008; Conte & Griffin, 2017).

2.9 Truthful Revelation

Truthful revelation is valuable a feature of auctions and critical to cost effectiveness. It reveals seller's subjective valuation of the payoff from the contract based on their privately held information about their respective costs (Romstad et al., 2012). Together with voluntary participation and bidding and the rule that lowest bidders win, truthful revelation delivers cost effectiveness at the auction design stage.

For competent evaluation of their opportunity value seller must conduct systematic assessment of the value of their next best option. This involves estimating the present value of returns from forestry in the case of a forest landowner whose next best option is the value of net returns from forestry. Bid formation is done pre-contract and compliance can be observed post contract. Uncertainty surround the behavior of actors is dynamic, thus the passage of time presents new information that actors use to update old beliefs. This means that a well-informed estimate of seller´s opportunity value improves predictability of procurement outcomes.

According to Sharma, Cho, & Yu, (2019), the impact of integrating cost-benefit information to ensure efficiency gains or to ensure minimal efficiency losses in a multi-round conservation auction (dynamic setting), where landowners learn to extract information rents, has not been explored adequately. Knowledge about the impacts of alternative correlation levels between spatial costs and benefits can guide policymakers in choosing an optimal information strategy that ensures the cost-efficiency of a conservation program in a dynamic setting (Sharma et al., ibid.).

2.10 Compliance issues related to biodiversity management

Translating policy targets into real impactful solutions is done during post-contract delivery of the procured service. At this stage enforcement of the contract terms, monitoring for compliance with contract terms, is essential. It gives effect to the pre-contract policy instrument design effort towards cost-effectiveness and may erode the gains expected from good planning or exposes poor planning. Conservation contracts, aimed at encouraging preservation and maintenance of natural areas, generally involve long-term obligations. Yet, contractors can find it profitable to breach the agreement when the opportunity cost of keeping their land under conservation purposes, and contracts do not provide for adequate early termination penalties (Corato, et al., 2018).

A contract is, “in the simplest definition, a promise enforceable by law. The promise may be to do something or to refrain from doing something¨ (Taylor von Mehren, 2019). The difficulty in observing some forest biodiversity management output means that agents may not produce, or underproduce, the output and still obtain a payment as if the contract had been performed; such that the procurer needs to conduct random inspections and administer a penalty to induce compliance of the agents. (Choi, 2018).

Claassen et al. (2008) reported that USDA conducts annual inspections on 5% of CRP contracts, and non-compliance results in withholding of subsidies in addition to repayment with interests. According to their report most programs administered by the Farm Service Agency and the Natural Resources Conservation Service, require non-compliant landowners to refund all benefits received. In case fraud is proven, non-compliant landowners are liable to penalties.

Choi (2018) makes the point that when the expected efficiency of agents is high, the procurer can save information rents, contracts approach first-best outcome and output distortions are minimal despite the co-existence of information asymmetries.

2.11 Bid Formation and compliance

Bid formation and submission in conservation procurement auctions in particular, can be difficult for bidders (Banerjee & Conte, 2018). In multi-attribute conservation auctions, bids for submitted conservation practices are evaluated on the basis of offered price and the resultant environmental quality (Claassen et al. 2008; Hellerstein et al. 2015). Lack of information about environmental quality could limit a bidder's ability to identify her optimal practice for submission (Banerjee & Conte, 2018).

Compliance and bidding may be related. Compliance can be observing after the contract is implemented. If bidders realize that they underestimated their opportunity cost, they may have increased probability to violate the terms of the contract. This may account for a trend of increasing bids over time in multi-round auctions. It is possible that bidders may genuinely bid truthfully and not comply on account of not adequately valuing their opportunity cost, perhaps owning to incomplete information about opportunity costs. If truth telling is achieved and adverse selection is observed, or negative relationship is observed between bid size and noncompliance what might explain that? These are question relevant to this study. Do least cost bidders systematically violate terms and why? If this relationship holds, then a case will have been made for Uniform price auction because the information rent paid to winning bidders may minimize a tendency to not comply.

Chapter 3: Method of study

3.1 Introduction

In this chapter I present the conceptual framework, model and process based on which the study was done. In order to give some information about the forest setting used in the analysis, I start with a brief description of the forest industry in Norway. I then describe the conceptual framework of the study. Afterwards, I present the model for the study. I end the chapter with a description of the analysis carried in the study.

3.2 Norwegian Forest Industry

Forests cover about 38 percent of Norway's land area, or about 122.000 square kilometers. Of this, around 86.600 square kilometers are productive forests. On average, Norwegian forests increase by about 25 million cubic meters of timber per year. The main tree species by volume and economic importance are spruce, pine and birch. Spruce accounts for half of this growth. Every year about ten million cubic meters of timber are felled. Forestry is an industry practically all over the country (Norwegian Minstry of Food and Agriculture, 2014).

Figure 3.1: A Bird´s-eye view of a typical productive forest in Norway

Credit: Bård Løken/Samfoto

Source (Norwegian Minstry of Food and Agriculture, 2014)

Norwegian Forestry policy aims to facilitate sustainable resource management. Policy makers believe that biodiversity is best served by a combination of conservation and sustainable use. This means ensuring that harvesting does not exceed regeneration, and also other forest values in the form of recreation and ecosystem services are promoted (Norwegian Minstry of Food and Agriculture, 2014).

In 2019, total commercial roundwood removal stood at 11 039 000 cubic metres compared to 10 836 000 in 2018, an increase of 1.87%. Spruce is the main source of timber. It constituted over 70% of commercial timber output in 2018 as well as in 2019.

Table 3.1: Structure of timber commercial timber output in 2018 and 2019

Timber	2018	Percent	2019	Percent
Spruce	8 027 000	74.07	7 934 000	71.87
Pine	2 551 000	23.54	2 802 000	25.38
Broad-leaved	258 000	2.39	303 000	2.75
Total	10 836 000	100	11 039 000	100
Gross Value	4 446 000 000 NOK		4 799 000 000 NOK	

Sources: (Statistics Norway, 2019)

The average prices of timber in Norway in 2019 was 435 NOK per cubic meter, a 6% increase on 2018 price of timber. Between 2007 and 2019, the weighted spruce timber prices have ranged from 307 NOK to 435 NOK per cubic meter.

Table 3.2: Average price of timber and commercial roundwood removals from 2007 to 2019.

Year	Commercial roundwood removals (1 000 m³)	Average Price (NOK) per Cubic Meter of Roundwood
2007	8212	375
2008	8071	364
2009	6631	307
2010	8322	355
2011	8507	362
2012	8787	328
2013	9020	309
2014	9808	349
2015	10113	339
2016	10345	329
2017	10491	354
2018	10793	410
2019	11039	435

Sources: (Statistics Norway, 2019)

3.3 Conceptual Framework

The study is based on a conceptual framing of a rational forestland owner trying to maximize net returns on their forest land when subjectively valuing their opportunity value in a N+1 price forest biodiversity auction. Winners of the contract will be awarded an annual payment with present value *v*, over the duration of the contract. In an N+1 price auction,

$$v = b_i + r_i \qquad (3.1)$$

v is equal for all agents. It is the bid of the first non-winning bidder. $b_i$is the agent i´s bid formed based on their subjective valuation of their opportunity income. $r_i$is information rent paid to agent i as an incentive to ensure truthful revelation.

The landowner´s problem in this setting is similar to choosing an optimal rotation age that maximize dynamic efficiency in an infinite rotation forest model. The landowner has a problem of deciding subjectively, his/her opportunity value in order to maximize returns from conservation.

The optimal harvest time that maximizes expected revenue from the forest stand is important in the landowner´s subjective valuation of opportunity value in bid formation in order for dynamic efficiency. This is relevant for evaluating true opportunity cost for the landowner, identification of least cost providers for the buyer and the design of effective monitoring strategy for biodiversity management auction.

Price uncertainties during the harvest periods and flexibility in harvest timing enable landowners to implement a flexible price-harvest strategy (Brazee & Mendelsohn, 1988) in order to maximize the value of their harvest. This is done by waiting for a stumpage price that is greater than the landowner´s reservation price when the landowner expects higher prices. On the other hand, the landowner may harvest earlier than normal (normal is Faustmann harvest time at mean price) when landowners expect lower prices.

In this context, the first objective of this thesis is to explore the implications of the possibility of a flexible price-harvest strategy for expected bids in a N+1 price auction design, and implementation subsequently I will discuss the implications price uncertainties on forest value for forest biodiversity conservation management.

3.3.1 The basic forest harvest model

Suppose the buyer intends to improve forest biodiversity in a country, say Norway, through N+1 procurement auction. The use of an N+1 auction is preferred for its potential to truthfully reveal sellers´ opportunity cost through their subjective valuation. The state will aim to achieve the most conservation value with the available conservation budget. I assume that the buyer will aim to keep the land under the conservation program for duration of infinite optimal rotations. This means that the standing, biologically mature forest will stand for another optimal rotation age T^* under conservation. The state will set out to identify landowners who have an acceptable balance of conservation value and cost effectiveness. Once a seller wins in the auction, i.e., has an accepted bid, the state will commence an annual payment with present value, v, to the seller over the timeframe of the conservation program as compensation.

Suppose a forestland of interest has a uniform stand of Norwegian spruce. Spruce has a maturity age of 70 years on a high productivity forest land in Norway. The landowner plants and waits up to the biological maturity of the trees, cuts and replants in that cycle infinitely. For simplicity I assume the land can support the growth of only Norwegian spruce and also have the conservation value of interest. I also assume, for simplicity, that land rent is equal whether under forestry or conservation. Norwegian spruce has market value at maturity and generates some net profits for the landowner (who is also the forest owner). I assume that the timber yield function of Norwegian spruce is well-behaved. This means that the yield function, X_t, is concave for the age intervals relevant for timber harvesting.

Suppose that the seller is informed that timber harvesting can be flexibly timed in order to reap the benefits for annual local peaks in prices. These local peaks cannot be known in advance but are characteristic of timber prices. It is a kind of demand driven random price fluctuation that occur in the typical cycle of timber prices (Brazee & Mendelsohn, 1988). Even though in reality the mean price of timber may change overtime, let us assume for simplicity that the mean price of timber is preserved during these annual cycles. This will enable me to focus on the price annual price uncertainty rather the trend in mean price. Prices are assumed to be exogenous. Forest owners operate in a competitive market. This means that individual landowners take the price for given, and harvest the quantity of timber that they are willing and able to supply

The forest owner (seller) is interested in participating in the N + 1 procurement auction and has a problem of subjectively valuing his/her opportunity value. What bids can the buyer expect from the seller in this context? The buyer is interested in compensating sellers to the extent of their true opportunity value. This thesis will show that the seller will endeavor to account for the potential to exploit the price volatility in business as usual by bidding close to prices which he/she would expect to accept in normal forest industry setting when price uncertainty exists.

In order to keep the seller indifferent between remaining in conservation program or returning to forestry business as usual, the buyer must be willing and able to compensate the seller as much as the seller can reasonably expect under a forest industry business as usual scenario.
Under this setting, the landowner will aim to maximize net returns from the forest through an informed estimation of optimal harvest age (T*). The harvest age, T, will be duration (usually in years) at which for a given stand, the benefits deferring harvesting are equal to the cost of deferring the next and all other future rotations. This means that the rate of growth of the undiscounted net

benefit of the present timber stand should be equal to the interest that could have been earned from timber revenues and the returns lost from establishing subsequent stands.

Let planting cost (*a*), marginal harvesting costs (*hc*) and the gross price of felled timber (*P*) be constant in real terms over time. Let net price of timber be (*p*) = *P* – *hc.* Net price, *p*, is assumed to be constant in real terms over time. Let the yield function of Norwegian spruce be represented by X_T. let the interest rate *i* be constant over time, for simplicity. Then the present value of the landowner´s profit function for one rotation will be:

$$pX_T e^{-iT} - a \quad (3.2)$$

Equation (3.2) means the discounted timber value at time *T* minus planting cost. The planting cost *a* is not discounted because it occurs at time 0, the start of the rotation. For an existing rotation, *a* is a sunk cost. It is the net timber value, which is expected at the future time when *T* has elapsed, that is discounted.

The net present value of profits over an infinite sequence of rotations will be given by

$$H = \left[pX_T e^{-iT} - a\right] + e^{-iT}\left[pX_T e^{-iT} - a\right] + e^{-2iT}\left[pX_T e^{-iT} - a\right] + e^{-3iT}\left[pX_T e^{-iT} - a\right] + \cdots \ldots. \quad (3.2)$$

Equation (3.2) can be simplified to

$$H = \left[pX_T e^{-iT} - a\right] + e^{-iT} H \quad (3.3)$$

This can then be solved as

$$H = \frac{pS_T e^{-iT} - a}{1 - e^{-iT}} \quad (3.4)$$

Equation (3.4) gives the present value of profits, *H*, for any rotation length, *T*, given values *p*, *a*, *i*, and timber yield function X_T under an infinite rotation model. This is the familiar Faustmann (1848) formula for infinitely repeated rotations using my notation. *T** will maximize *H*. *T** is the Faustmann optimal harvest time for an infinite rotation model.

Equation (3.4) gives the present value of profits, H, for any rotation length, T, given values p, a, i, and timber yield function X_T under an infinite rotation model. This is the familiar Faustmann (1848) formula for infinitely repeated rotations using my notation. T^* will maximize H. T^* is the Faustmann optimal harvest time for an infinite rotation model.

The solution to (3.4) follows the principles of Faustmann's solution. In order to find the T^*, I find the first derivative of H with respect to T, equate to zero and solve for T^*

$$\frac{dH}{dT} = -1(pX_T - a)\left(e^{iT} - 1\right)^2 ie^{-iT} + \left(e^{iT} - 1\right)^{-1} p\frac{dX_T}{dT} = 0 \qquad (3.5)$$

In line with Faustmann's initial derivations and after some simplification, we obtain

$$p\frac{dX_T}{dT} = ipX_T + iH \qquad (3.6)$$

Equation (3.6) is the efficiency condition for present-value maximization in infinite rotation forestry and given X_T, i, p and a, T^* can be determined. H is interpreted as the site value of land which I assume is constant for simplicity without loss of general insights. It is the maximized present value of an endless number of stands of timber that could be grown on the land.

3.3.2 The basic forest harvest model when participation in a conservation program

For a landowner that is considering participating in a N+1 forest biodiversity auction, the buyer should be willing and able to compensate the landowner with a value equivalent to pX_T at T^* per rotation over the multiple rotations possible. Let v be the present value of an annual payment to be made by the buyer to the landowner for per rotation as opportunity value compensated for comply with conservation contract terms and let Y be the present value of total compensation to be made to the seller per rotation. Then

$$Y = vT = pX_T e^{-iT} - a \qquad (3.7)$$

for any given rotation. For all rotations, a similar calculation like what was done with equations (3.2) and (3.3) will lead to equation (3.4),

$$H = \frac{pX_T e^{-iT} - a}{1 - e^{-iT}} \qquad (3.8)$$

However,

$$\frac{dY}{dT} = \frac{d(vT)}{dT} = v \qquad (3.9)$$

Thus, equation (3.8) becomes

$$p\frac{dX_T}{dT} = ipX_T + iH = v \qquad (3.10)$$

Equation (3.10) means that *v*, the present value of the annual payment to be made to the seller under the conservation program should be equal to the seller's opportunity value that maximizes present value of net profit under forestry in order for the buyer to be fully compensated for the participation constraint to hold.

3.3.3 The basic forest harvest model with conservation options and random timber prices

To this point the model has assumed constant stumpage prices *P* and cutting cost *a*, thus net price *p*, has been constant. However due to price uncertainties and the flexibility of timber harvest time, the landowner can be expected to try to exploit price fluctuations that occur annually in the forest industry in a bid to maximize forest profits, as shown by Brazee & Mendelsohn, (1988). Timber owners know today´s price but are uncertain about tomorrow´s prices. Traditional Faustmann harvesting as shown above ignores these random annual price fluctuations and prescribes harvests on the basis of expected prices.

Given price uncertainty and the ability to postponed harvesting for an expected higher price, the landowner´s expected bids will tend towards annual local peak prices. This is because in practical forestry, during harvest period, the landowner can deviate from T* and harvest earlier of later in order to benefit from a higher actual market price (the mean price plus its random increase). The flexibility of choice of harvest time givens forester´s the opportunity to maximize revenue from the mature stand because they can follow price and then decide whether to cut or wait, just like how traders follow prices of stocks or commodities. By tailoring harvests to variations in prices, the present value of all future timber revenues can be greatly enhanced over the standard Faustmann model (Brazee & Mendelsohn, 1988). This goes on for a given rotation and can be expected to be repeated over multiple rotations since the multiple rotation is essentially a repetition of single rotation activities multiple times in a sequence.

The basic intuition of this model is that the owner should cut timber today only if today´s timber value is higher than what he expects the present value of future timber value to be. The expected future timber unit value, in turn depends on a set of uncertain future prices as well as the yield function. The present value of this maximum expected future timber value becomes the current reservation price. When the current price is below the reservation price, the owner delays harvest for the age class for and additional period. When the current price exceeds the reservation price, the owner harvests the entire age class (Brazee & Mendelsohn, 1988).

In this thesis, I assume the predicted value of *P* based on time to be the agent´s reservation price. Based on a good model of timber price development, a better prediction can be used. I am interested in showing that an agent that engages in flexible price harvesting should be expected to bid higher that the price. The bids of such a landowner will tend towards annual local price peaks due to flexible harvesting and price uncertainty.

In order to model the landowner´s flexible harvesting behaviour, I make some additional assumptions. I assume that the landowner can determine the expected mean and variance of the random component of future prices. However actual prices are assumed to be unpredictable, drawn randomly from this known distribution. I also assumes the error structure around an empirical model´s predictions is normally distributed. I assume that the landowner is risk nuetrality for simplicity at this stage. This based on the notion that the forester has sufficient wealth that he is risk-neutral to the timber in a particular year. Being a risk-neutral bidder, the management objective should be to maximise the expected present value of net returns.

The current price P_t is known in year t and is assumed constant for the entire year. A new random price, P_T is established each year, which I assume to be statistically independent of the previous year´s price.

With constant prices, the rotation age of the forest should be determined by equation (3.6).

$$p\frac{dX_T}{dT} = ipX_T + iH$$

In practice, because prices are not constant, the expected value of prices E(P_T) is used as the estimate of price in the Faustmann equation. With fluctuating prices, the owner must decide between a certain price today and unknown prices in the future. The reservation price is based on the expected return one could earn by delaying harvest.Whenever the offered price is above the reservation price, the owner accepts the price and cuts. Conversely, whenever the offered price is below the reservation price, the owner delays harvest another period. Because prices below the reservation price tends to be rejected, the accepted price have a higher expected value than the offered prices. Compared to a more rigid harvest rule such as the Faustmann model, Brazee & Mendelsohn, (1988) demonstrate that the flexible harvest strategy can increase expected revenue by more fully utilizing available information.

The expected present value of a flow of net revenue with varying prices is the sum of the discounted net revenue generated by the product of accepted prices times volume in each period weighted by the likelihood that the owner sells his timber in that period. Since a forest owner who accepts a given price will always accept a higher price that period, we can characterise the price accepted by the owner in each period t in terms of a minimum accepted $P_{min,t}$ (the reservation price). The expected value of a harvest in year t given a reservation price of $P_{min,t}$ is :

$$H_t = \int_{Pmin,t}^{\infty} (pX_t \; + E\;[Z])f(p)dp \qquad (3.11)$$

where *f(p)* is the probability of price $p = P_t > E(P_T)$ occurring that year. The first element of this payoff, pX_t, is the expected revenue in the first period for havesting the standing timber, the product of accepted price and timber volume weighted by the likelihood of being offered those prices. The second element , $E[Z]$ in the expected payoff is the present value land rent. The value of waiting includes not just the revenue from next period but also the possible revenue from all future harvest dates which owners may end up waiting for.

Brazee & Mendelsohn, (1988) find that a greater spread of offered prices around the mean will increase the present value of future forest net revenue to the owner, other factor unchanged. A reservation price that leads to the rejection of some offered prices, implies that the expected net present value from a flexible price-harvest strategy will exceed the present value of revenue associated with Faustmann rotations. If the owner ever finds it desirable to cut his timber earlier or later than the Faustmann rotation, he does so only to increase expected profits. This is because in reality, landowners have the opportunity to maximize benefits from market information when deciding to execute cutting. Since the increased number and severity of lower prices can be truncated and therefore ignored, increases in spread tends to raise the expected revenue from accepted prices.

Chapter Four: Decision Analysis

4.0 Introduction

In this chapter I conduct a decision analysis of the forest owner´s decision problem based on data from the Norwegian forest industry in order to demonstrate how price fluctuations might affect agents´ bids. First, I use available price data, and an assumed interest rate and growth rate to demonstrate the basis for expected bids under complete information. This analysis reveals what timber price would have formed the basis of the cut or conserve decision of forest owners with the benefit of hindsight. I continue with a forecast analysis of the decision process under timber price uncertainty. Finally, I analyze the implications of timber price uncertainty for bidding under N+1 price conservation auction.

4.1 Analysis of past data from Norwegian forest industry

In order to demonstrate the implications of flexible price harvesting on expected bids I use yearly timber price data for 2007 to 2019 to show expected bids under complete information. In doing this analysis the forest owner looks back in time to understand which random price would have generated the highest timber value. This period is presented as a 13-year time window which within a mature forest is most profitable to harvest under no price uncertainty. I believe that for a tree like Norwegian spruce and under the economic, climatic and land conditions in southeastern Norway, a period of 13 years is reasonable for illustrating the impacts of price uncertainty on the optimal harvesting time. Other kinds of trees and other environmental and economic conditions may warrant a shorter or longer period.

I make a simplifying assumption that the decision to cut or conserve is to be made in a single rotation context. This means that $p\frac{dX_T}{dT} = ipX_T$ (equation 3.6 in a single rotation model) is the dynamic efficiency condition for the landowner to maximize the timber value of a mature forest. The use of *t* in this section represents time periods within the 13-year period. In times before this 13-year period forest growth rate exceeds the interest rate, and in times beyond this period, forest growth rate becomes less than the interest rate. This provides a window with which the effects of flexible harvesting and timber price fluctuations on the forest owner´s decisions can be observed and analyzed. I used average commercial roundwood timber prices in Norway from 2007 to 2019 as the random prices that exist with this 13-year period. As discussed earlier, these random prices cannot be observed ahead of time. Table 4.1 shows summary statistics on the random gross prices in the period.

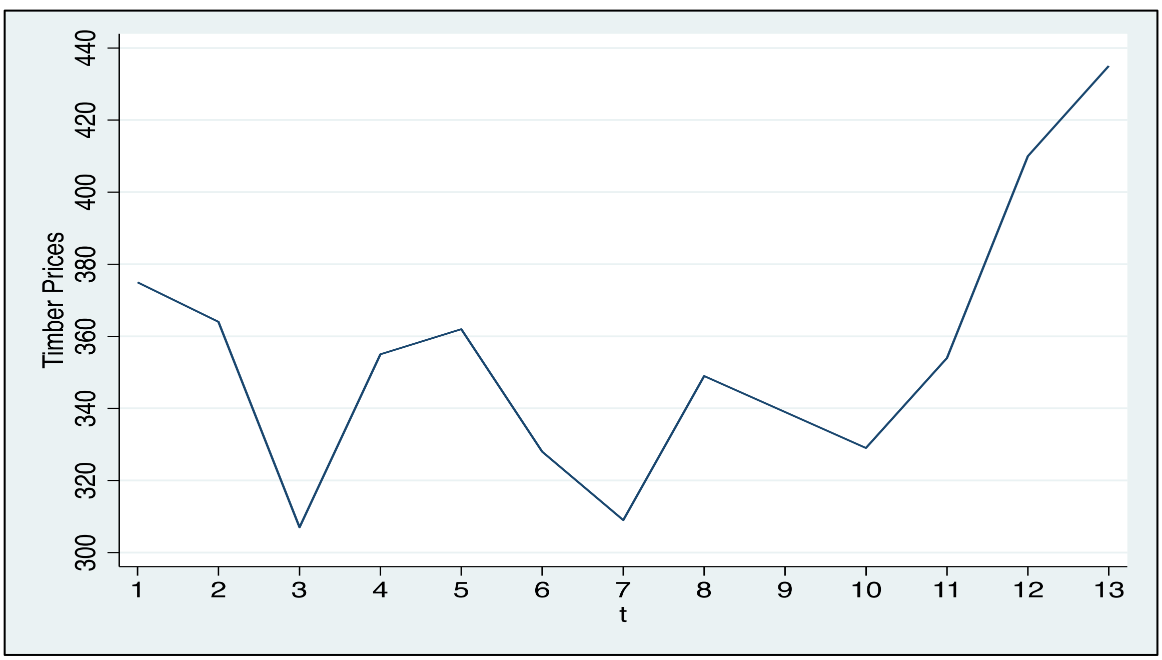
Table 4.1: Summary statistics on gross average annual timber prices for 2007 to 2019

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Gross Timber Prices	13	355	36.6	307	435

Source: Author´s analysis of data

Table 4.1 shows that within the period, ranged from a minimum of 307 NOK to a maximum of 435 NOK, with a mean value of 355 NOK. Figure 4.1 shows fluctuations in the random price with the 13-year period of interest.

Figure 4.1: Gross timber prices used in the Analysis:



Source: Author´s plot of timber price data

Forest owners make optimal harvesting decides based on their net timber price expectation in comparison with their reservation price in a given year under flexible price harvesting. In order to focus on random timber prices, I assume that the effects of timber growth rate and interest rate on timber value over the period are negligible. This assumption is important because over the 13-year period, a positive value of tree growth rate will have a positive effect on timber value over time through an increase in the timber volume.

The determination of the optimal harvest age (based on $(P_t - hc)\frac{dX_t}{dt} = i(P_t - hc)X_t$) within this period depends on the value of random net price p_{at} at period t, harvest cost hc, interest rate i, forest growth rate, g. To calculate net price, I assume a constant real harvest cost, of 120 NOK per cubic meter in the 13-year period. This is consistent with current timber harvest costs which varies between 100 NOK and 130 NOK per meter cube (Viken Skog, pers. mess). I also assume an interest rate and growth rate of 1%. Table 4.2 shows calculated values of p_{at}

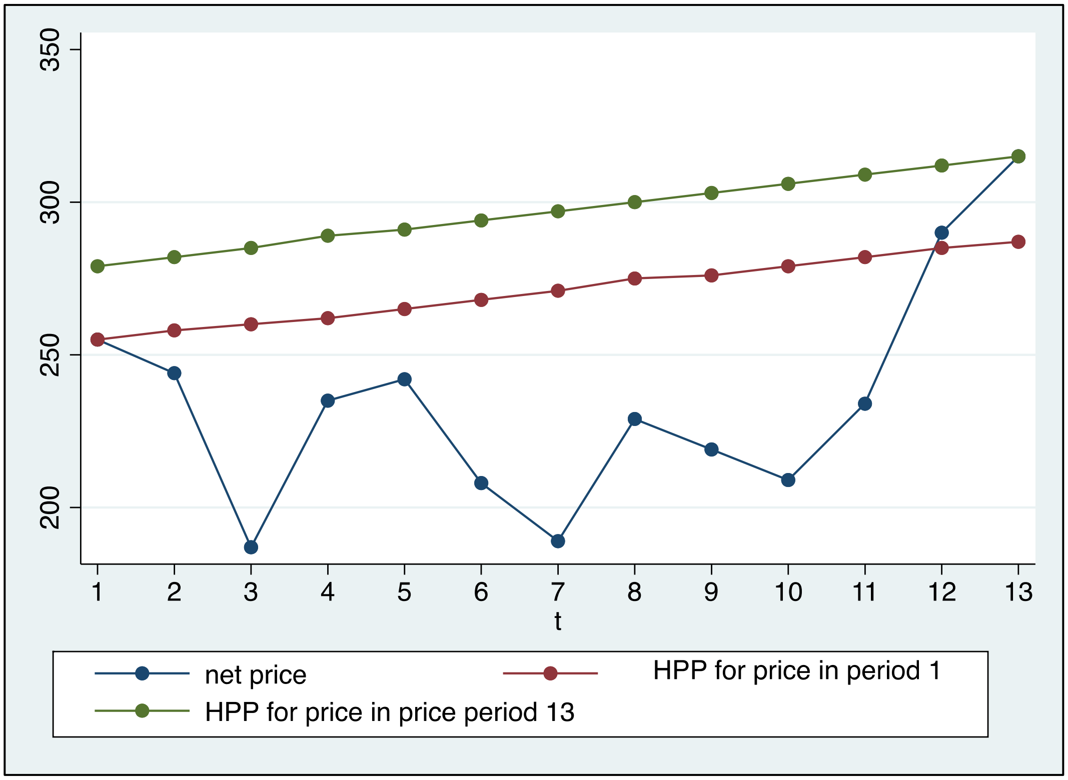
Table 4.2: Net timber prices for the period t = 1,2,3….13

Period (t)	Gross prices	Net price (p_{at}) = P_t - hc
1	375	255
2	364	244
3	307	187
4	355	235
5	362	242
6	328	208
7	309	189
8	349	229
9	339	219
10	329	209
11	354	234
12	410	290
13	435	315

Source: Author´s Calculations

Figure 4.2 shows five periods within which Stumpage prices would have been of interest to the forest owner. These are periods 1, 4, 5, 8 and 13. Based on figure 4.2 and with the benefit of hindsight, period 13 presented the highest peak price. If forest owners could observe random prices with full certainty, they would have based their conservation contract bids on the random net price of 315 NOK in period 13 (the 2019 prices).

Figure 4.2: Net prices for the period and Hotelling price path for periods 1 and 13



Sources: Author´s analysis of data

The decision of cutting in period 13 brings maximum timber value to the forest owner compared to the other 12 periods. This is possible due to some flexibility in the time of timber harvesting, and this choice is easier under complete information compared to when future timber prices are uncertain. Cutting in period 13 comes with an added marginal benefit in the form timber growth with the periods that the forest owner waited. In this analysis that will be 12 more years of timber growth as a result of the wait. The next best price occurs in period 1. However, not only is this price lower, cutting in period 1 would have denied the forest owner the added benefits that waiting would have generated in the form of growth in timber volume. It is important to note that where a particular forest owner finds lines in the period under consideration depends on when he or she entered this window. This means that what is period one can be a different period for another forest owner base on their context.

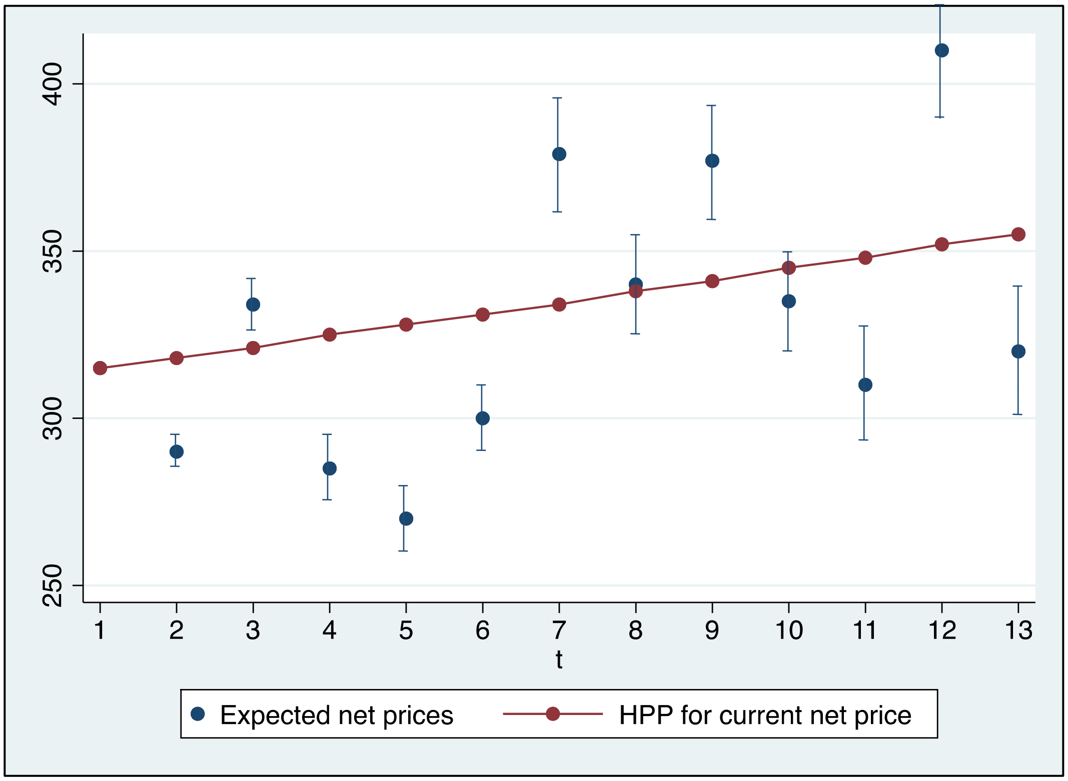
4.2 Forecasting of timber prices

The cut or conserve decision is made by the forest owner based on recent past timber market data, the forest owner´s interpretation of the present demand and supply conditions in the market and most their prices expectations in the relevant future. At any given period, the forest owner is fully informed about the current random net price. The decision to cut or conserve depends on whether the current net price exceeds their reservation price.

The optimal decision rule of the price search is that for the forest owner to cut when the current random price exceeds their reservation price, otherwise wait (Brazee and Mendelsohn, 1988). This implies that all prices below the reservation price will be rejected by the forest owner. It is a sequential process. At the early periods of the decision window if one is certain that higher peaks will arise in the future, it is optimal for to wait. Once you decide to wait in the current period, your reservation price is updated. The decision to cut or wait also depends on the individual forest owner's degree of risk aversion. A more risk averse decision maker will have a tendency to cut early while one with relatively lower risk aversion is more likely to wait. The reason for this is that the more risk averse the decision maker is, the stronger is his or her preference for the secure outcome, in this case cut early.

In order to illustrate this point, I show in figure 4.3 below a forecast of net prices of timber per cubic meter for the next 13-year period. Assuming that a forest owner expects higher net timber prices in the periods ahead, he or she will wait and update his or her reservation price to the current price. The current price used in this illustration is the net price of period 13, net price for 2019.
I use the Hotelling price path generated at an interest rate of 1% to show price path of the current price over the next 12 periods. The mean values of the expected prices for each period are shown together with standard errors of the forecast. Expected prices in the distant future are shown to be more uncertain and have greater standard errors associated with them compared to expected prices in the immediate succeeding periods.

Figure 4.3: Hypothetical expected prices and Hotelling price path for current price



Source: Author´s design

Figure 4.3 shows that a forest owner with this pattern of expected prices looks forward to most future prices been below the current price path except in periods 3, 7, 9 and 12. This pattern may be due to the current price being significantly high and not frequently occurring. Moreover, this pattern will be informed by the forest owner's analysis based of prevailing market condition and expected changes in them. All expected prices below the current reservation price within the decision window will be rejected. As there are several expected prices above the Hotelling price path, namely in periods 3, 7, 9 and 12, the expected optimal decision based on available data in period 1, is not to cut in period 1. In period 2, new price data becomes available, and hence updated forecasts are made.

In succeeding periods in the decision window, as new data become available and forecasts are updated, the decision to cut or wait is repeated. As the time window nears closing, there will be fewer prices above the reservation price line, and not delaying becomes a more likely optimal decision.

Given this state of price expectations in the decision window, a forest owner with high risk aversion is more likely either to cut or not go beyond the third period. This is due to the relatively high uncertainty associated with prices in the periods more distant in window. On the other hand, a relatively less risk averse individual may be inclined to reject the current price and the expected price in period 3 in search for the much higher expected prices in period 7, 9 or even 12. If a forest owner decides not to cut in period 3, his or her reservation price is updated to the price in period 3 and search continues into the future. This is a continuous process within the logging time window and forecasts are updated every year.

Chapter Five

Discussion of Findings

5.1 Introduction

This study aimed to explore through a decision analysis the impact of uncertain timber prices and flexible harvesting have on bid formation in N+1 price forest biodiversity auction. The specific objectives were; to explore how timber prices uncertainty, affect agents bid formation in N+1 price forest biodiversity auction and to explore its implications for other relevant aspects of N+1 auction design and implementation The decision analysis conducted in chapter four used the price search model developed by Brazee & Mendelsohn (1988) to demonstrate how price variability and flexibility in harvesting enables forest owners to access high random prices in the timber market.

In this chapter the findings of the decision analysis are discussed to highlight the implications of uncertain timber prices on bidding and on other relevant aspects of N +1 price auction design. I start with a discussion on implications of timber price uncertainty for bids and continue with discussions on implications for other aspects of the auction like securing participations, issues of informational advantages between parties to the auction, and other practical issues of N +1 auction design.

5.2 Implications timber prices uncertainty for bids

The cut or wait decision analyzed in sections 4.1 and 4.2 because a harvest or conserve decision in a context where a conservation bid is being considered by the forest owner. The net price at which timber is harvest serves as the basis of the bids made by forest owners and all the discussions done so far on how a cut price will be determined will be directly considered when bidding in a conservation auction. The bidder will try to bid an amount enough to fully compensate him or her for the net profit from the forest stand while also avoiding loss of the contract. This is what will secure their participation in the conservation program.

The level of risk aversion will influence the size of bids submitted because it determines bidders´ willingness to take chances on losing a secure outcome in search for a higher price. The reason for this is that the bid a forest owner submits in a conservation auction is one where he or she expects to be indifferent between getting and not getting a contract. Not getting a contract under timber price uncertainty implies waiting for a higher timber price. This will be reflected in the individual forest owner's bid.

Moreover, in a conservation bid, highly risk averse bidders will be less likely to benefit from the extra value that random prices may present because they would rather opt for a secure low net price now ever if there is a good chance that there will be higher net prices in the future. On the other hand, less risk averse bidders will tend to bid higher because they are willing to wait for a higher net price.

In an N+1 procurement bid, the bidder knows that by handing in a low bid, he or she may free ride on other bids because he will be paid based on the first non-winning bid. However, the bidder does not know the degree of risk aversion and the degree of sophistication of other bidders. If bidders rely on a naive understanding of the forest market, they are likely to forfeit some value. On the other hand, a few sophisticated bidders may cause contract pay out to winners to be higher that the buyer expects.

Thus, the levels of bids will reflect to some extent the bidders´ expectations about future prices and their degree of risk aversion. this arises because the bidding decision is been made in a context of timber price uncertainty. Note that expectations about future timber prices are linked to their understanding of the timber market and the economy as a whole. The flexibility in timing the harvest decision and the expectation of a high random price in future credits the forest owner confidence to submit higher bids.

5.3 Implication of timber price uncertainty for other practical aspects of auction design and implementation.

5.3.1 Timing of Auction

In general, the analysis suggests that timing of the offer for conservation bids is important for cost effectiveness. It will serve the buyer of conservation services well if offer for bids are be made in times when the economic outlook suggests low expected timber price. This will result in relatively lower bids as compared to when economic outlook suggests increasing timber prices

5.3.2 Compliance

While naive bidders may submit low bids, compliance may be a challenge if the opportunity cost of conservation (net timber prices) increase by a great margin as compared to bids. If bidders realize that they underestimated their opportunity cost, they may have increased probability to violate the terms of the contract. This is particularly important due to incomplete monitoring associated with most conservation management programs. The N+1price design has an advantage in this regard because of the information rent that winner bidders enjoy.

One way to partly safeguard against noncompliance is to set the penalty sufficiently high. Recall that N+1 price auction lead to truthful bidding, i.e. bids reveal the forest owners' opportunity costs of conservation. Hence, the N+1 price bid can be used to set the penalty for non-compliance. For example, Romstad and Alfnes (2011) suggest to set the penalty, $S = a\ p\ b_{N+1}$, where p is the monitoring probability, b_{N+1}, is the first non-winning bid, and $a > 1$ is an adjustment factor that allows for periodic timber price fluctuations so that the expected profits of compliance exceeds the expected profits on noncompliance.

Chapter Six

Summary, Conclusion and Recommendations

6.1 Summary and conclusion

This study aimed to explore through a decision analysis the impact of uncertain timber prices and flexible harvesting on bid formation in N+1 price forest biodiversity auction. The specific objectives were; to explore how timber prices uncertainty affects agents bid formation in N+1 price forest biodiversity auction and to explore its implications for other relevant aspects of N+1 auction design and implementation.

Based on the price search model proposed by Brazee & Mendelsohn (1988) the analysis demonstrates that price uncertainty increases bids in conservation auctions. This is due to flexibility in timber harvesting and the occurrence of random price peaks over time, assuming the forest owner has no liquidity constraints.

Implications for bidding behavior in conservation auction is that a rational bidder will submit higher bids under larger net price variability as compared to bids when less net price is less variable.

At this point this hypothesis is not empirically tested due to the small number of conservation auctions undertaken. This can be an avenue for future research, but that requires one is able to find other auction settings that resemble conservation auctions. A possible solution for future research: A conservation contract is a restriction on the land use. The ultimate land use restriction is to sell the property. So, can one use property sales prices to capture the variability aspect.

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