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Toward a Forest Bioeconomy

Four Essays on Applied Economics

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Toward a Forest Bioeconomy

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Toward a Forest Bioeconomy: Four Essays on Applied Economics

Abstract

The forest bioeconomy is an economic paradigm that aims to replace fossil-based materials with forest-based renewable materials to advance societal aspirations for more sustainable futures. Increasing wood production to advance forest bioeconomy through intensive forest management may reduce other ecosystem benefits and create tensions with other societal demands and forest policy goals.

This Thesis contributes to the growing forest bioeconomy literature by investigating the public's perceived values on wood products and forest management intensity, and through empirical analyses of trade-offs emerging from intensive forest management. It consists of four academic papers of thematic and geographical diversity. Paper I investigated public acceptance of multi-story wooden buildings as a residential alternative across seven European countries. Results show commonly high public acceptance, with differences in the strengths of selected behavioral drivers across countries. Paper II elicited Norwegian and Swedish preferences for forest management intensity in private production forests and explored their relationships with climate change beliefs. Some differences were detected, but both sampled populations preferred less intensive management aimed at enhancing biodiversity, with such preferences positively associated with higher climate change awareness. Paper III analyzed welfare changes among the Swedish public in supporting less intensive management in private production forests through increased taxation. Analyses revealed the prevalence of two groups with contrasting welfare, highlighting the relevance of exploring voluntary support mechanisms to mitigate welfare loss. Paper IV turned to empirical analyses of potential trade-offs from the intensification in forest management supported by the forest bioeconomy in other contexts. Exemplified by the increase in industrial wood pellet production in the US state of Georgia in response to European demands for wood energy, Paper IV assessed whether it had negative impacts on forest health and found a lack of such evidence.

The papers suggest that increasing wood production to pursue forest bioeconomy goals is broadly acceptable to the society. Nonetheless, public policy instruments to help balance and to continuously monitor trade-offs between wood production and other ecosystem benefits seem warranted. Any oversight measures should be tailored to specific socio-ecological conditions.

Keywords: Forest bioeconomy, Wood products, Forest management intensity, Trade-offs, Public values, Empirical analyses

Vägen till skoglig bioekonomi: Fyra uppsatser i tillämpad ekonomi

Sammanfattning

Skoglig bioekonomi är ett ekonomiskt paradigm som syftar till att ersätta fossila material med förnybara skoglige resurser för att uppnå samhälleliga ambitioner om en mer hållbar framtid. Ökad produktion av trä för att främja den skoglig bioekonomin genom intensivt skogsbruk kan dock minska andra ekosystemtjänster och skapa konflikter med andra samhällskrav och skogspolitiska mål.

Denna avhandling bidrar till den växande litteraturen om en skoglig bioekonomi genom att undersöka allmänhetens upplevda värden av träprodukter och skogsbrukets intensitet, samt genom en empirisk bedömning av avvägningar kopplade till intensivt skogsbruk. Avhandlingen består av fyra vetenskapliga uppsatser med tematiskt och geografiskt varierat innehåll. Uppsats I undersökte allmänhetens acceptans för flerbostadshus i trä som bostadsalternativ i sju europeiska länder. Resultaten visar generellt hög acceptans, men med varierad betydelse i vissa beteendemässiga faktorer mellan länderna. Uppsats II kartlade preferenser för skogsbrukets intensitet i privata produktionsskogar i Norge och Sverige, och analyserade deras samband med uppfattningar om klimatförändringar. Vissa skillnader identifierades, men båda urvalsgrupperna föredrog generellt mindre intensivt skogsbruk för att främja biologisk mångfald, där sådana preferenser var positivt relaterade till hög klimatmedvetenhet. Uppsats III analyserade hur förändringar i välfärden hos den svenska allmänheten kopplas till stöd för ett mindre intensivt skogsbruk i privata skogar genom höjd beskattning. Resultaten visade på två grupper med olika välfärdläge, vilket understryker betydelsen av frivilliga stödsystem för att minska välfärdsförluster. Uppsats IV använde empiriska analys för att utvärdera potentiella avvägningar från ett intensifierat skogsbruk för att uppnå en skoglig bioekonomi i andra sammanhang. Detta exemplifieras här med en ökad industriell produktion av träpellets i delstaten Georgia i USA för att fylla den europeiska efterfrågan av bioenergi, så undersökte uppsatsen om detta haft negativa effekter på skogens hälsa, men fann inget stöd för sådana effekter.

Uppsatserna indikerar att en ökad träproduktion för att uppnå målen inom skoglig bioekonomi i stort sett är accepterad av allmänheten. Offentliga styrmedel för att balansera och kontinuerligt övervaka avvägningar mellan träproduktion och andra ekosystemtjänster förefaller dock motiverade. Sådana åtgärder bör anpassas till specifika socio-ekologiska förhållanden.

Nyckelord: Skogslig bioekonomi, Träprodukter, Skogsbrukets intensitet, Avvägningar, Allmänna värderingar, Empirisk analys

산림생물경제에 관한 네 편의 응용경제학적 연구

국문요약

산림생물경제는 우리 사회의 지속가능성을 높이기 위해 화석 기반의 재생 불가능 자원을 산림 기반의 재생 가능 자원으로 대체하고자 하는 새로운 경제 패러다임이다. 산림생물경제 달성을 위한 목재 생산 확대는 산림 경영을 집약화하여 다른 생태계 서비스를 감소시킬 수 있으며, 이는 다른 사회적 수요 및 산림 정책 목표와의 갈등을 초래할 수 있다.

본 논문은 목제품 및 산림 경영 강도에 대한 대중의 가치 인식을 분석하고, 집약적 산림 경영으로 인한 목재 생산과 기타 산림 생태계 서비스 사이의 잠재적 상충관계를 실증적으로 분석함으로써 산림생물경제 연구에 기여한다. 본 논문은 다양한 주제적, 지리적 배경을 가진 네 편의 응용경제학적 연구로 구성된다. 첫 번째 연구는 유럽 7 개국에서 대중의 다층목조건물 거주 의사를 분석하였다. 응답자들은 공통적으로 높은 거주 의사를 보였으나, 그 결정 요인의 상대적 중요도는 국가별로 상이하였다. 두 번째 연구는 사유 생산림에서의 산림 경영 강도에 대한 노르웨이와 스웨덴 대중의 선호를 도출하고 기후변화 인식과의 관계를 조사하였다. 약간의 차이는 있었으나 양국 응답자 모두 생물다양성 증진을 위한 완화된 산림 경영을 더 선호하였으며, 이러한 경향은 기후변화를 심각하게 인식할수록 더욱 강하게 드러났다. 세 번째 연구는 세금 인상을 통해 사유 생산림의 산림 경영 강도 완화를 재정적으로 지원하는 시나리오에서 스웨덴 대중의 후생 변화를 분석하였다. 대중은 상반된 후생 변화를 보이는 두 집단으로 나뉘었으며, 이는 후생 손실 완화를 위해 대중이 자발적으로 지원금을 부담하는 방식을 고려할 근거를 제시한다. 네 번째 연구는 산림 경영의 집약화가 초래할 수 있는 목재 생산과 다른 생태계 서비스 간 잠재적 상충관계에 관한 실증적 분석으로 초점을 전환하였다. 해당 연구는 유럽의 재생에너지 수요 충족을 위한 미국 조지아주의 펠릿 생산 증가가 초래한 산림 경영의 집약화가 산림 건강에 미친 영향을 분석하였다. 분석 결과, 부정적 영향을 뒷받침하는 증거는 확인되지 않았다.

종합하면, 산림생물경제를 뒷받침하기 위한 목재 생산 확대는 큰 틀에서 볼 때 사회적으로 용인할 수 있으나, 다른 생태계 서비스와의 균형을 달성하고 집약적 산림 경영이 야기할 수 있는 잠재적 상충관계를 지속적으로 관찰하기 위한 공공정책 수단의 도입을 고려해야 한다. 이러한 수단은 사회생태적 조건에 맞게 설계되어야 한다.

핵심어: 산림생물경제, 목재, 산림 경영 강도, 생태계 서비스 상충, 대중의 가치 인식, 실증적 분석

Dedication

멀리 한국에서 한결같은 사랑과 격려를 보내주신 부모님과 형, 곁에서 큰 힘을 주며 인생과 학문의 길을 함께 걸어가는 가은이에게 이 논문을 드립니다.

To my parents and brother for their unwavering love and encouragement from afar in Korea, and Gaeun for standing by my side and walking the lifelong and academic journey together.

Contents

List of publications

This Thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I. Kim, D.-h., Franzini, F., Thorsen, B.J., Berghäll, S., Aguilar, F.X*. (2023). Greener Homes: Factor underpinning Europeans' intention to live in multi-storey wooden buildings. Sustainable Production and Consumption, 39, pp.373-381. https://doi.org/10.1016/j.spc.2023.05.030

II. Kim, D.-h*., Sjølie, H.K., Aguilar, F.X. (2024). Psychological distances to climate change and public preferences for biodiversity-augmenting attributes in family-owned production forests. Forest Policy and Economics, 163, 123021. https://doi.org/10.1016/j.forpol.2024.103201

III. Kim, D.-h*., Sjølie, H.K., Martinez-Cruz, A.L., Aguilar, F.X. Paying for biodiversity-increasing management in non-industrial production private forests: Evidence of divergent public welfare consequences. Revised and resubmitted to Journal of Forest Economics.

IV. Kim, D.-h*., Sudekum, H., Aguilar, F.X. Spatio-temporal impacts of the US Southeastern wood pellet industry on forest health: evidence from Georgia. Manuscript.

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* Denotes correspondence

The contribution of Dohun Kim to the papers included in this thesis was as follows:

I. I am the lead author. I conducted econometric analyses and wrote the manuscript together with coauthors.

II. I am the lead and corresponding author. I developed research design together with coauthors. I collected data, conducted econometric analyses, and wrote the manuscript together with coauthors.

III. I am the lead and corresponding author. I developed research design together with coauthors. I collected data, conducted econometric analyses, and wrote the manuscript together with coauthors.

IV. I am the lead and corresponding author. I developed research design and collected data together with coauthors. I conducted econometric analysis and wrote the manuscript.

List of figures

1. Introduction

This Thesis compiles a diverse thematic and geographic collection of four scholarly manuscripts under the umbrella of forest bioeconomy. The forest bioeconomy is an emerging economic paradigm seeking to substitute fossil-based materials with forest-based wood products to enhance sustainability in our society. Increasing wood production with intensive forest management is needed to support transition to the forest bioeconomy, but this may incur reduction of other forest ecosystem services and conflicts with other societal demands and policy.

As a collection of scholarly works, the research presented in this Thesis contributes to forest bioeconomy research by examining the broad sustainability of forest bioeconomy from social and empirical perspectives. The Thesis complements current research in the field, largely dominated by scenario-based projections, by providing evidence grounded in public evaluations for wood products and forest management intensity (papers I – III), and empirical assessment of trade-offs associated with increased wood production (papers IV).

Specifically, Paper I investigates public intention to dwell in multi-story wooden buildings in seven European countries. Papers II and III elicit public preferences for forest management intensity in private production forests in Norway and Sweden to assess perceived trade-offs between wood production and biodiversity and welfare implications of management interventions. Paper IV assesses whether increased wood pellet production in the US State of Georgia has compromised forest health.

The papers in this Thesis take a positive approach, but their collective findings point to three broad policy-relevant implications to enhance the sustainability of forest bioeconomy transitions:

- **Increasing wood production seems acceptable, but…** The majority of the public commonly approve of the increased use of wood products (paper I). On average, the public accepts intensive forest management (paper III). There is a lack of evidence that intensification in forest management has undermined the forest health (paper IV).
- **Long-term social acceptability will depend on balancing wood production with other ecosystem benefits.** The majority of the public supports less intensive forest management intended to enhance biodiversity over wood production (papers II and III). Continued inten-

sive management could potentially compromise the forest health (paper IV).

- **One size does not fit all**. Public evaluations for wood products and forest management intensity differ across countries (papers I and II). Public policy instruments to advance the forest bioeconomy and monitor its impacts, and to achieve balance with other forest policy goals, should be tailored to account for diverse socio-ecological contexts.

The rest of this introductory chapter is structured as follows. Section 2 introduces the concept of the forest bioeconomy. Section 3 explains the need to increase wood production to support transitioning to a forest bioeconomy and potential conflicts with other forest policies and societal demands. Section 4 conceptualizes the forest bioeconomy via a coupled natural and human system lens and outlines how the papers included in this Thesis address the key elements. Section 5 explains the econometric approaches used in the papers. Section 6 provides summaries of papers. Section 7 concludes this chapter with reflections on future research directions. Full published papers (Papers I and II) and manuscripts (Papers III and IV) are provided after this introductory chapter.

2. Concepts of Forest Bioeconomy

Bioeconomy refers to an economic system that utilizes renewable biological resources to produce goods and services throughout all sectors (EC 2012; 2018). It has emerged as an alternative to the contemporary non-renewable fossil-based economy that exacerbates sustainability challenges, including climate change, pollution, and ecosystem degradation. Over the past decades, the bioeconomy has attracted increasingly more attention from scholars and policymakers as a research and political agenda (Kleinschmit et al. 2025; Pülzl et al. 2014).

As the largest terrestrial ecosystem, forest provides a multitude of ecosystem benefits crucial to sustain our society (TEEB 2010). Forests contribute to climate mitigation and adaptation in multiple aspects, among others, carbon sequestration, microclimate and water regulation, and biodiversity conservation (IPCC 2023). Wood products contribute to economic development, replace fossil-based materials and store carbon throughout its life cycle (FAO 2022a). Non-wood products and recreational use of forests play integral roles in local economy and contribute to social well-being (Chamberlain and Smith-Hall 2022).

Forest bioeconomy (or forest-based bioeconomy) is a term reflecting the critical role of forest in transitioning to bioeconomy. Interpretations of the forest bioeconomy are diverse across different contexts (Ludvig et al. 2019), but it is generally understood to be a sustainable economic system in which forest-based renewable resources replace fossil-based materials and are utilized to produce goods, materials, and services, based on sustainable forest management (Winkel 2017; Wolfslehner et al. 2016). The forest bioeconomy is an umbrella concept that includes multiple discourses and approaches (Piplani and Smith-Hall 2021; Pülzl et al. 2014). *Biotechnology* is grounded on technocratic beliefs and focuses on the use of biotechnology to develop innovative products; *bioresources* is grounded on neo-industrialization and eco-modernism and emphasizes the substitution of fossil-based materials and economic contribution through wood products; and *bioecology* is grounded on sustainable environmentalism and prioritizes conservation, degrowth, and stakeholder participation (Bugge et al 2016; Piplani and Smith-Hall 2021). *Bioresources* is the most dominant paradigm in the political strategies and research on the forest bioeconomy (Piplani and Smith-Hall 2021).

Enthusiasm in the forest bioeconomy is strong in the EU28 (EU27 and United Kingdom) (Malkamäki et al. 2022). European forests, occupying approximately 35% of total EU28 land area and on an expanding trend since 1990, serve as a critical base for renewable resources and socio-economic benefits (EC 2021; Forest Europe 2020). The EU bioeconomy strategy recognizes forestry, forest-based products and the forest industry as one of major pathways to achieve its five objectives: specifically, *managing natural resources sustainably* (objective 2), *reducing dependence on non-renewable resources* (objective 3), and *mitigating and adapting to climate change* (objective 4) (EC 2012; 2018). The New EU Forest Strategy for 2030 states that EU forests should be utilized and managed to support the EU bioeconomy transitions (EC 2021). Twelve European countries with dedicated national bioeconomy strategies all include forestry and forest-based products (e.g., pulp and paper) as part of their strategies (EC 2025). Countries in Northern Europe with abundant forests and developed forest industry (e.g., Sweden and Finland) are putting the forest bioeconomy at forefront of their national development strategies, and research on the forest bioeconomy is most active in these countries (Finnish government 2022; FORMAS 2012; Hetemäki et al. 2024; Widmark et al. 2020).

3. Wood Production and Trade-offs

Transition to a forest bioeconomy is expected to bring a substantial increase in the demand for wood products (Bell et al. 2018; Philippidis et al. 2024). Growth in demand for wood products is anticipated to be the largest among all forest products due to their high fossil fuel substitution potential, e.g.: mass-timber engineered wood products and wood energy (FAO 2022b).

Wooden constructions – buildings that utilize engineered wood products partially or fully as load-bearing materials – are conceived as an appealing pathway for transitioning to a forest bioeconomy (Aguilar et al. 2023; EC 2018). The building sector is a major source of carbon emissions, accounting for 36% of the total EU27 emissions (EU, 2024). Technological advancements have substantially increased fire resistance, durability, and stability in engineered wood products (e.g., cross laminated timber and laminated veneer lumber) and made them as viable alternatives to concrete and steels in load-bearing structures even in high-rise buildings (Loss et al. 2018). Substituting concrete in load-bearing materials with engineered wood products can potentially reduce 20 to 50% of carbon emission from a building, while engineered wood products store carbon inside throughout their life cycle (Hurmekoski 2017). In an ambitious scenario that 50% of new residential buildings are built as wooden construction from 2023, 18% of carbon emission can be avoided in the EU28 building sector by 2030 (168 million ton CO_2-eq) compared to the business-as-usual scenario, which would require an estimated increase of 26 million m^3 in the utilization of engineered wood products (Haisma et al. 2023).

Wood energy is another promising means for transitioning to a forest bioeconomy. The EU Renewable Energy Directive, first adopted in 2009 and revised most recently in 2023, sets a binding target to increase the share of renewable energy to at least 42.5% of the total energy consumption, currently staying at 24.5% (EU, 2023). The EU Renewable Energy Directive acknowledges woody biomass as a renewable energy source. European countries are heavily relying on wood energy, such as wood pellet, to meet their respective targets. The annual consumption of wood pellets in the EU28 – an estimated 32.1 million ton as of 2022 – have almost quadrupled since the adoption of the first EU Renewable Energy Directive in 2009 (Bioenergy Europe 2024; USDA 2024a; 2024b). This large growth in consumption has been met by increases in wood pellet imports from the United States (US) and continuous increases in EU28 domestic production of wood pellets (Camia et al. 2021; USDA 2024a). With empirical evidence that the growth in consumption of wood energy contributed to reduction in carbon emissions in EU28 over the 1990-2017 period (Sulaiman et al., 2020), demand for wood energy is predicted to rise further (FAO 2022b).

Intensive forest management – including increases in timber harvest levels, thinning frequency, plantation of fast-growing species, and shortened rotation periods – are needed to meet growing demands for engineered wood products and wood energy (FAO 2022b; Frank et al. 2016; Winkel 2017). Roundwood is the primary feedstock for engineered wood products and more than 20% of the total wood energy produced in EU28 (Camia et al. 2021). Roundwood procured from the US Southeastern timberlands is the primary feedstock for wood pellets imported from the US to EU28 (Aguilar et al. 2022; Bays et al. 2024). Across the EU28, an 55% increase in harvest levels by 2030 – compared to the business-as-usual – is anticipated under a scenario that the wood pellet consumption in 2030 is twice as high as that in 2015 following its gradual increase (Jonsson et al. 2018). Under an RCP4.5 scenario with moderate reductions in carbon emissions, the harvest demands in Sweden and German Bavaria is projected to increase by 22% and 37% by 2100, respectively (Blattert et al. 2023).

Forest management intensification may reduce the provision of other ecosystem services such as carbon sink, biodiversity conservation, and water regulation – i.e., trade-offs (Blattert et al. 2023; Schulz et al. 2022; Vallet et al. 2018). These potential trade-offs could put the forest bioeconomy at odds with other EU land management initiatives emphasizing biodiversity conservation and climate adaptation (e.g., the EU Biodiversity Strategy) and raises concerns about the sustainability of the forest bioeconomy (Gregor et al. 2024; Lerink et al. 2023; Ruml et al. 2025). Balancing wood production with other forest ecosystem benefits, informed by analyses of trade-offs and societal evaluations, is needed to pursue the forest bioeconomy strategies in tandem with other policy objectives (Beland Lindahl et al. 2023; Hetemäki et al. 2024).

4. Social and Empirical Approaches to Forest Bioeconomy

The majority of existing studies in forest bioeconomy employ scenario-based projections to inform forest bioeconomy strategies with trade-offs analyses. Scenarios can provide valuable long-term insights but are not without limitations: they are sensitive to assumptions (e.g., carbon substitution rates of woods) and uncertainties, the scenario-building processes are often not socially inclusive (Hoogstra-Klein et al. 2017; Hurmekoski et al. 2023), and they often lack empirical evidence grounded in observed data.

Transition to a forest bioeconomy is a socio-economic process dependent on finite forest resources facing diverse and sometimes competing demands. Its success will depend on the broader social acceptance for increased use of wood products and intensive forest management (Malkamäki et al. 2022; Ranacher et al. 2020; Sadeghzadeh et al. 2025). Empirical analyses of trade-offs across spatial and temporal scales as a result of intensification in forest management can provide evidence-based information to forest bioeconomy strategies (Hetemäki et al. 2024).

A coupled natural and human system (Aguilar and Kelly 2019; Liu et al. 2007) offers a useful framework to conceptualize the forest bioeconomy to encompass the social (i.e., human) and empirical (i.e., natural) dimensions. Such a system, depicted in **Figure 1**, highlights interactions between policy, society, and forests. The forest bioeconomy strategies influence how production forests are managed with decisions made and implemented by forest landowners, as depicted by curved black arrow and thick black arrow, respectively. Management affects the supply of ecosystem benefits, classified into wood products and other benefits in the context of the forest bioeconomy, which are potentially in trade-offs. These benefits are evaluated by the stakeholders, particularly the public who are the largest stakeholder group, as represented by two thick arrows from the production forests to the public: here, value denotes the extent of subjective importance individuals attach to an object and encompasses both behavioral and economic aspects (Brown 1984; Sánchez-Fernández and Iniesta-Bonillo 2007). These values and trade-offs in ecosystem benefits observed in the forest jointly inform and reshape the forest bioeconomy strategies: this is illustrated in **Figure 1** by a black straight arrow from the public to forest bioeconomy, and a green curved arrow from the trade-offs to forest bioeconomy, respectively. While landowners also influence the forest bioeconomy strategies, this element is not investigated in this Thesis and thus represented as a dashed arrow.

The papers included in the Thesis explore some key elements in the suggested system as depicted in **Figure 1**. Papers I, II, and III address the human dimension by investigating the public evaluations for wood production and other benefits. These papers are grounded in decision-making theories from economics and social psychology, which offer insights into behavioral and socio-economic drivers underlying the values and allow estimation of these in monetary terms (Kleinschmit et al. 2014; Sadeghzadeh et al. 2025). Paper I examined public intentions to dwell in wooden constructions. Papers II and III analyzed preferences for forest management intensity accounting for values for wood production and biodiversity. Paper II further analyzed associations between preferences and climate change beliefs, while paper III examined welfare changes among the public when they financially support management interventions in private forests, which partly addresses the interaction between the public and landowners. Paper IV turns the focus to the natural dimension by conducting an empirical assessment of trade-offs between increased wood pellet production and forest health.

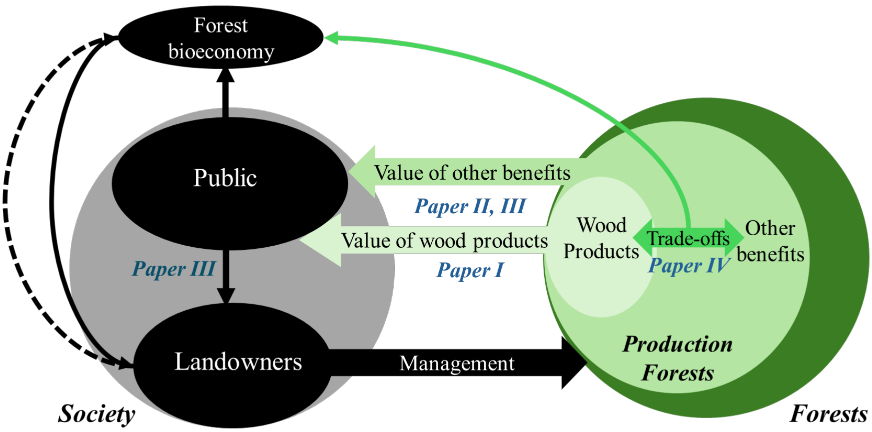

Figure 1. Description of the forest bioeconomy in a coupled natural and human system framework and how the papers in the Thesis address its key components.

5. Econometric Analyses

All the papers included in this Thesis apply econometric approaches to explore the relationships between an outcome and explanatory variables. The papers refrain from making a strict causal interpretation of the estimated relationships, acknowledging the limitations of the observational nature of the data.

The models employed in papers I, II, and III belong to the class of latent variable models as they include both observed variables and unobserved variables introduced to capture underlying processes or heterogeneities. Among these, models employed in papers II and III are classified as discrete choice models. Paper IV utilizes spatial panel regressions using observed variables alone. The model includes spatially dependent variables and two-way fixed effects to account for heterogeneity across observation units, time, and space.

This section intends to describe fundamental concepts of the econometric models used in the papers without excessive details. Readers are encouraged to refer to published papers and full manuscripts provided after this introductory chapter for detailed treatments of model specification and estimation procedures.

5.1 Paper I, II, III: Latent Variable Models

Latent variable models denote a variety of econometric specifications containing latent variables whose values are not observed directly but need to be inferred from observed indicators (Aigner et al. 1984; Hair et al. 2013). These variables include behavioral constructs (e.g., attitudes and perceptions), unobserved heterogeneity in estimated coefficients, and latent classes within the sample (Hair et al. 2013; Skrondal and Rabe-Hesketh 2007). Observed indicators denote variables that are directly measurable, such as respondents' answers to survey questions in Likert scales and socio-economic characteristics (e.g., income and education).

Specifying latent variables in the econometric model, when they exist, is more advantageous than using observed indicators alone. *Measurement* models that define the relationship between latent variables and observed indicators allow better representation of theoretical constructs – often measured by multiple indicators – while reducing measurement errors and increasing the reliability of the latent variables (Hair et al. 2013; Lattin et al. 2003). Latent variable models often incorporate *structural* models that specify the relationships between outcome and explanatory variables, which can be either latent or observed depending on the model specification (Hair et al. 2013; Skrondal and Rabe-Hesketh 2007). **Figure 2** illustrates the elements in latent variable models and their relationships. Here, X's refer to explanatory variable, Y refers to an outcome variable, and ε's capture errors arising from imperfect measurement and other unexplained variations. Rectangles indicate observed variables or indicators, while circles denote unobserved variables. Solid black arrows denote structural paths, and dashed arrows denote measurement paths.

Econometric models used in papers I, II, and III all belong to the class of latent variable models as they commonly integrate measurement models of latent variables with structural models. Paper I employed a structural equation model (Hair et al. 2013). Behavioral constructs of the theory of planned behavior (Ajzen 1991) tailored to the study context – attitudes, social norms, behavioral control, and intention (the latent variables) – were all measured by 7-point Likert-scale items (the observed indicators). The structural model explored the relationships between these constructs with intention as a dependent variable. Paper II employed hybrid choice models (Ben-Akiva et al. 2002). Climate change beliefs were measured by 5-point Likert-scale items. The measurement models for these beliefs were incorporated into the structural model used to analyze the choice data. Paper III utilized latent class logit model (Mariel et al. 2021; Train 2009). In this model, the measurement model identifies the latent class structure within the sample, and the structural model relates class membership to the observed choice behavior.

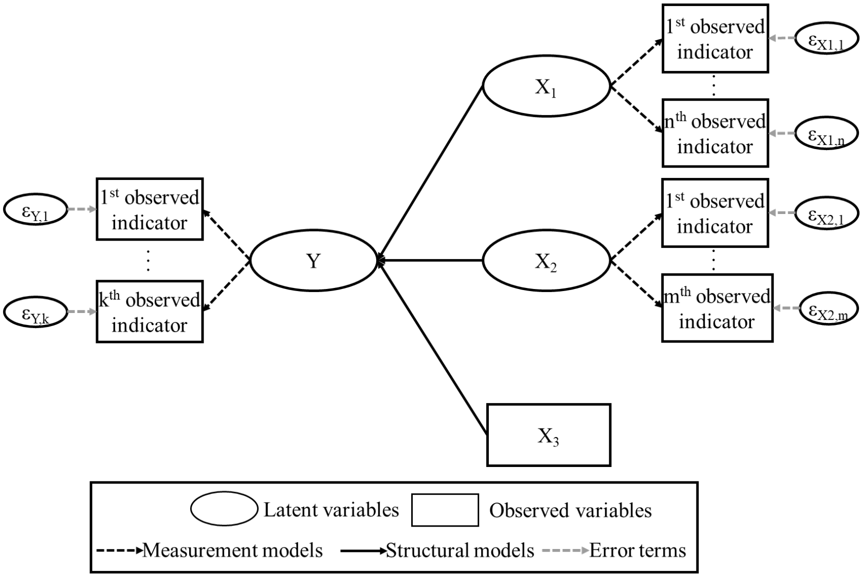

Figure 2. A general description of latent variable models. Outcome variable was described as a latent variable here, but it can also be an observed variable.

5.2 Paper II and III: Discrete Choice Models

Discrete choice models analyze an individual's behavioral choice among a set of two or more mutually exclusive alternatives (McFadden 1980; Train 2009). Discrete choice models estimate the probability of choosing each alternative based on the random utility maximization framework (McFadden 1980).

The outcome variable is the observed choice, which is discrete in nature since it can only take a countable number of values (Train 2009). Underlying the observed choice is a latent utility function that represents the level of satisfaction an individual derives from each alternative. Utility can be decomposed into an observable component and unobservable component (Train 2009). The observable component is composed of individual-specific characteristics including socio-economic characteristics and measured behavioral constructs and alternative-specific attributes, while the unobservable component is unknown to the researcher (Greene 2018). A utility maximizing individual chooses an alternative that yields the highest utility between a set of available alternatives (Greene 2018; Train 2009). **Figure 3** provides a graphical illustration of the discrete choice models as a type of latent variable model.

Discrete choice models are the primary econometric approach for analyzing data obtained from stated preference methods used to estimate economic values of non-market goods (e.g., forest biodiversity) and associated policy interventions (e.g., conservation programs) (Johnston et al. 2017; Mariel et al. 2021). A discrete choice experiment is a stated preference method that presents goods or policy scenarios as hypothetical alternatives, each defined by a bundle of attributes with discrete levels. It includes a price attribute that represents the amount of money an individual is willing to pay or accept to support the chosen alternative (Johnston et al. 2017). This enables the estimation of economic values of a change from the *status quo* to the chosen alternative, often referred to as *willingness-to-pay* or *willingness-to-accept*. It reflects the perceived trade-offs between levels within attributes and allows estimation of welfare change from the *status quo* to the chosen alternative (Mariel et al. 2021; McConnell 1995).

Logit-based discrete choice models, such as conditional logit, latent class logit, and random parameter logit, are commonly applied for data analysis. Latent class logit and random parameter logit are often preferred as they account for individual-level heterogeneity in estimated economic values, relax restrictive assumptions of the conditional logit, and reduce bias in estimation (Greene and Hensher 2003; Train 2009). Hybrid choice models incorporating behavioral constructs into the random utility framework are increasingly more applied to better reflect real-world decision-making processes (Hoyos et al. 2015; Mariel et al. 2021).

Paper II and III utilized data from a discrete choice experiment designed to infer economic values for less intensive forest management scenarios, constructed considering plausible trade-offs between biodiversity and wood production. The hybrid choice model used in paper II aimed to incorporate the climate change beliefs into the utility framework. The latent class logit and random parameter logit models used in paper III capture heterogeneity in economic values to assess the welfare implications of the management intervention.

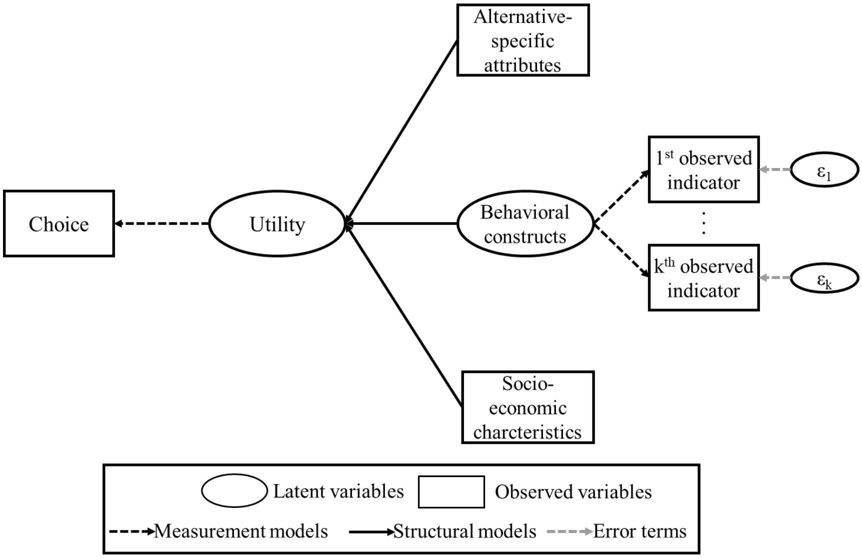

Figure 3. A general description of discrete choice models.

5.3 Paper IV: Spatial Panel Regression

Panel data refers to repeated observations of the same cross-sectional units over time, divided into time periods of equal length. One key advantage of panel over a pure cross-section is that it mitigates the omitted variable bias by including unobserved effect μ_i at the unit level (Wooldridge 2010).

μ_i is treated as *fixed effects* if allowed to be correlated with observed explanatory variables and as *random effects* if assumed to have zero correlations (Wooldridge 2010). Test statistics such as the Hausman test are often used to choose between fixed and random effects specifications (Hausman 1978; Wooldridge 2010), but fixed effects are often preferred as the assumption of zero correlation is difficult to justify (Cameron and Trivedi 2005). The fixed effects model is easily extended to a two-way fixed effects model that includes both time- and unit- fixed effects. Two-way fixed effects are widely used in contemporary microeconometric applications, particularly in causal inference and impact assessments, though criticisms against such a trend exist (de Chaisemartin and D'Haultfœuille 2020; Imai and Kim 2021).

Standard panel data econometric models often assume observations are independent between units, but this assumption does not necessarily hold in many contexts. Spatial units could be dependent with its strength larger between units closer to each other, as represented by the first law of geography: "Everything is related to everything else, but near things are more related than distant things" (Tobler 1970). Spatial econometric models account for spatial dependence when making inferences (Anselin 2001). These models can reduce bias in estimation and capture spatial spillover (i.e., influence that a change in one spatial unit has on neighboring units) through use of a spatial weight matrix (Elhorst 2014; LeSage and Pace 2009).

Paper IV used Spatial Durbin panel regressions (Anselin 2001) to assess the impacts of intensive forest management by expanding wood pellet industry on forest health in US state of Georgia using a spatial panel data. The data was constructed over the 2004–2024 period by combining observations from forest inventory and analysis, satellite imagery, the pellet industry, and other socio-economic information sources.

Figure 4 provides a graphical illustration of the data construction process and model specification. Forest inventory and analysis provided information on location of permanent inventory plots classifed as timberland, as well as plot-level abiotic/biotic information; these plots served as the unit of observation and analyses in the regression. Landsat 7 and 8 imagery was used to compute vegetation indices within each plot, which served as indicators of forest health and were specified as outcome variables in the regression. Pellet mill data provided information on operational status and location of pellet mills. A wood procurement area of each operational mill was defined using a pre-selected radius following the convention (Aguilar et al. 2022; Kittler et al. 2020) and plot included in these areas were identified. For each included plot, the distance to the procuring pellet mill and the number of years the plot was included in the area were measured to capture spatial and temporal heterogeneity in its inclusion in the wood procurement area. These variables, together with their interaction, served as key explanatory variables of interest in the regression. A set of anthropogenic and biotic/abiotic variables were obtained from the forest inventory and analysis and other data sources, which were included in the regression as covariates to be controlled for.

The Spatial Durbin panel regressions included two-way fixed effects to control for unobserved heterogeneity across plots and years. Spatial dependence in plot-level vegetation indices and selected covariates was accounted for by including their spatial lags, constructed from an inverse-distance spatial weights matrix.

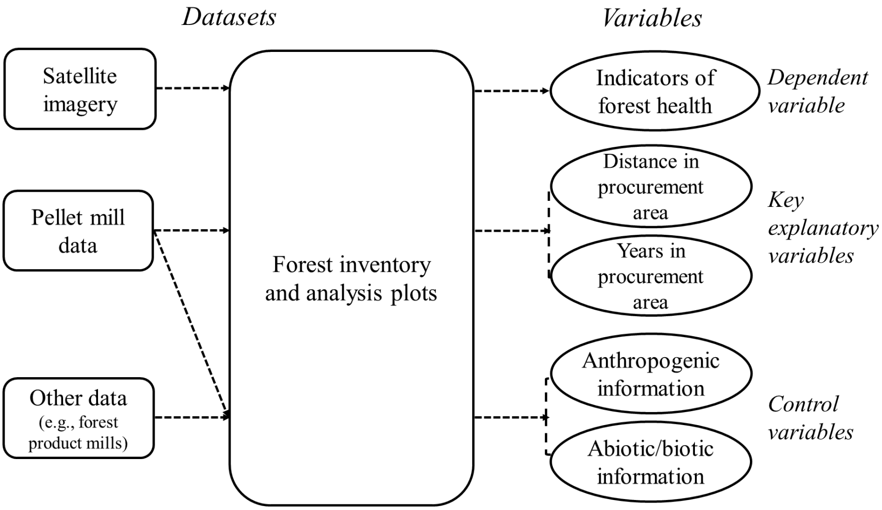

Figure 4. Data construction and model specification in paper IV.

6. Summary of Papers

This section provides summaries of each paper, including objectives, background, conceptual framework, methods, findings and discussions.

6.1 Paper I

This study explores public's intention to dwell in multi-story wooden building across seven European countries: Austria, Denmark, Germany, Finland, Norway, Sweden, and United Kingdom.

Multi-story wooden buildings are an appealing policy instrument for climate change mitigation and transitioning to a forest bioeconomy, but it is a niche innovation with limited uptake. Policy interventions (e.g., regulatory and market-based) and the promotion of social acceptance are essential to encourage a wider adoption of these buildings. Promoting social acceptance requires investigation of the public's willingness to dwell in these buildings and the underlying drivers, an area that remains yet underexplored.

This study utilized the theory of planned behavior to investigate the public's behavioral intention to dwell in multi-story wooden buildings. The theory posits that intention is driven by three factors: attitudes (i.e., the degree to which the behavior is viewed favorably), subjective norms (i.e., perceived social pressure to perform the behavior), and behavioral control (i.e., belief in one's capability to perform the behavior). The theory offers a viable alternative to utility-based models in this study context, as it accounts for normative and perceived constraints from the surrounding environment that are common in residential choices.

A survey incorporating contextualized items from the theory of planned behavior was distributed to online consumer panels in the selected countries between May and June 2021. A total of 7,056 responses – about 1,000 responses per country – were finally collected. The data were analyzed using structural equation models. The models were estimated for both the full sample and each individual country sample.

The findings indicate that a majority of the European public approves of multi-story wooden buildings as a residential alternative. Attitudes, subjective norms, and behavioral control all explain the intention to dwell in such buildings, with differences in significance and coefficient size across countries.

Strategies to encourage the public uptake of multi-story wooden buildings should target these drivers: correct misconceptions about these buildings to improve attitudes; engage influential referent groups (e.g., real estate agents) to strengthen subjective norms; and provide accessible and reliable information about the availability of these buildings to enhance perceived control. These measures should be tailored to each country to reflect the relative importance of the drivers.

6.2 Paper II

This study explores the Norwegian and Swedish public preferences for forest management intensity in family-owned production forests in their respective nations, considering potential trade-offs between wood production and biodiversity. The focus on production forests reflects their instrumental role in supporting the forest bioeconomy. The research further examines association between climate change beliefs and public preferences.

Family-owned production forests in Norway and Sweden are predominantly managed with high management intensity for wood production. Less intensive management in production forests can improve their potential for climate adaptation through increased biodiversity. However, such management can decrease the supply of wood products and subsequent decline in carbon storage and substitution potential. Decision-making in forest management should incorporate public evaluations of biodiversity and wood production to increase social acceptability. Climate change beliefs are likely to affect the values an individual attaches to wood production and biodiversity, and in turn, support for forest management.

A discrete choice experiment was used to estimate public values for less intensive forest management in family-owned private forests. The scope was confined to family-owned private forests, considering their status as the largest ownership class in both countries and the nuanced differences in forest management between private and public forests. The choice experiment was constructed by three attributes that together decide the management intensity and biodiversity levels – set-aside (i.e., proportion of property the landowner voluntarily decides not to harvest), tree ages (i.e., proportion of uneven-aged stands), and tree species composition (i.e., type and number of dominant tree species in a stand) – and a monthly tax attribute, which reflects the amount of money a respondent would pay for selecting a less intensive management option. Climate change beliefs were measured by *psychological distances to climate change* comprised of spatial, temporal, social, and hypothetical dimensions: closer distance reflects a greater sense of perceived personal relevance and reality.

The survey was distributed to samples of the Norwegian and Swedish public via online consumer panels between June and July 2022. A total of 660 Norwegian and 1517 Swedish responses was collected. Hybrid choice models were used to analyze the association between elicited public values and psychological distances. The models were estimated separately for the Norwegian and Swedish samples.

Willingness-to-pay values indicate that, on average, both the Norwegian and Swedish public place higher values on less intensive management attributes, with set-aside being consistently receiving the highest value. The estimated values varied between the two country samples, but these differences were not statistically significant. Closer psychological distances to climate change had a positive association with the inferred values in all dimensions.

The findings suggest that expanding the set-aside area is likely to receive wider public acceptance in both countries. Public demand for less intensive forest management might increase as climate change exacerbates, given its plausible link to a heightened sense of climate change. Communication efforts to inform the public about carbon storage and substitution benefits of wood products are recommended to increase the public approval of the forest bioeconomy in both countries.

6.3 Paper III

This paper investigates welfare changes among the Swedish public under a scenario in which citizens compensate family-owned private production forest owners for less intensive management through increased taxation.

Swedish private forests are under growing pressure to adopt less intensive management practices to increase biodiversity, in line with public policy initiatives (e.g., the EU Biodiversity Strategy). Adopting such practices may impose opportunity costs on landowners due to decreased wood production, as well as implementation costs. Compensation for these costs, funded by the public in line with the beneficiary-pays principle, can encourage the adoption of less intensive practices. Taxation is a realistic and common instrument to finance such compensation schemes.

Policy interventions in forest management should contribute to stakeholders' welfare, particularly to the public which is the largest stakeholder. Welfare changes from an intervention are likely to be heterogeneous across the public. In the presence of welfare heterogeneity, an intervention is Pareto-improving if no group's welfare is harmed and Kaldor-Hicks improving if the aggregate welfare change is positive, and the winners (those who gain welfare) could potentially compensate the losers (those who lose welfare).

This study used data from a choice experiment (the same as in paper II) to estimate welfare changes among the Swedish public under scenarios in which less intensive management in family-owned private forests is financed through increases in monthly taxation. Both latent class logit and random parameter logit models were estimated to capture preference heterogeneity, from which welfare estimates were subsequently derived. The number of classes in the latent class logit model was determined using both statistical criteria and economic reasoning. A set of respondent-level variables such as socio-economic characteristics and forest use patterns was included to explain the probability of class membership.

Findings reveal divergent welfare consequences among the public. Random parameter logit showed average respondent preferences for both less intensive management attributes and the prevalent intensive management. Moving beyond the average, the latent class logit indicated that about 58% of the sample experienced considerable welfare gains, while the remaining 42% experienced slight welfare losses, from compensating private landowners for adopting intensive forest management practices via taxation, making this intervention Kaldor-Hicks improving but not Pareto-improving.

Compensation from winners to losers rarely occurs in practice, and the welfare loss experienced by the 42% of the public is not negligible. Voluntary compensation instead of taxation can ameliorate pareto inefficiency by allowing the losers to opt out of making contributions. This resonates with recent institutional and technological developments in voluntary financing schemes proposed to promote biodiversity conservation.

6.4 Paper IV

This study makes an empirical assessment of the impact of the growing wood pellet industry on forest health in the US state of Georgia over the 2004-2024 period.

Following the EU Renewable Energy Directives that mandate increasing the share of renewable energy in total energy consumption, the EU28 is heavily relying on bioenergy – particularly, wood pellets – to meet respective targets. Wood pellet consumption in the EU28 has been more than quadrupled since the adoption of the first EU Renewable Energy Directives in 2009. Considerable amounts of these wood pellets are sourced from the "wood basket" in the US Southeast. Wood pellet production in the region has grown exponentially in response to rising demands from the EU28. This growth has reportedly had no discernible impact on forest carbon stocks, but its impact on forest health remain largely unassessed despite concerns being raised.

Using Georgia as a case, this study analyzed the effects of industrial wood procurement on forest health over the 2004 – 2024 period to test the sustainability of the US Southeast pellet industry. Observations from a variety of sources, including forest inventory and analysis, Landsat-derived vegetation indices, wood pellet mill data, other wood-extracting facility data, and socioeconomic data were combined to conduct analyses. Forest inventory plots formed the unit of analyses. Plot-level vegetation indices were employed as indicators of forest health. For each plot within a pellet mill's procurement area – defined as 80 km radius from the mill – (1) distance to the pellet mill, (2) number of years of inclusion in the area, and (3) their interactions were calculated to capture the spatial and temporal dimensions of its inclusion in the wood procurement. Spatial durbin panel regressions with two-way fixed effects were utilized to test the relationship between the inclusion in wood procurement area and vegetation indices, accounting for spatial dependence among plot-level observations and controlling for potential effects of other covariates.

The findings indicate little evidence of the negative effects. Inclusion in the wood procurement area did not lead to declines in vegetation indices. Negative interaction effect points to a plausible long-term decline in forest health under intensive and repeated wood procurement. Sustainability of the wood pellet industry seems not have been compromised in this context, but continuous monitoring of forest conditions and management interventions to alleviate wood procurement pressures will likely be needed.

7. Final remarks

Aggregating the findings from the papers included in this Thesis leads to the overall conclusion that expanding wood production to support the forest bioeconomy is largely acceptable: the public embraces the use of wood products and, on average, largely approves of intensive forest management, and intensification in forest management has not undermined forest health. Policy instruments to balance wood production with other ecosystem benefits are likely needed, given the public's greater valuation of less intensive practices aimed at enhancing biodiversity. Monitoring efforts to detect any potential trade-offs associated with intensive forest management are warranted to ensure the long-term sustainability of the forest bioeconomy.

A holistic approach considering both the wood products and management in assessing social values related to the forest bioeconomy is needed. Increasing the supply of wood products is inherently linked with intensification in forest management. However, many studies, including those in this Thesis, often address wood products and management separately. These studies report wider public support for wood products, but a lower approval for intensive forest management (e.g., Giergiczny et al., 2015; Lähtinen et al., 2019; Ranacher et al., 2020). Bridging this gap through the holistic approach will provide more nuanced guidance for forest bioeconomy strategies.

Investigation and integration of values of forest landowners – another key stakeholder in the forest bioeconomy – can complement this Thesis that focused exclusively on the public side. Landowners are the primary providers of wood products and other ecosystem benefits consumed by society. Better understandings of their diverse management objectives and motivations can enhance the effectiveness and social acceptance of management interventions aimed at adjusting the supply of ecosystem benefits (Mazziotta et al. 2025; Westin et al. 2023). Comparing landowner and public values in similar management contexts (e.g., Nordén et al., 2017) can provide insights into the alignment or mismatch between the supply and demand for wood products and other ecosystem benefits.

Empirical assessments of the effects of intensive forest management need to be conducted in a variety of contexts to test the sustainability of the forest bioeconomy comprehensively. Intensification in forest management to supply wood products, beyond wood pellet, has already been observed in many parts of the globe (FAO 2022a). Recent advancements in observation techniques such as remote sensing, combined with developments in econometrics and machine learning, enable the detection of trade-offs over space and time at finer scales (Aguilar et al. 2024; Weiss et al. 2020). Empirical approaches as used in Paper IV can be applied to examine the effects of management intensification on other ecosystem benefits like carbon storage, water supply, and biodiversity, as well as on social outcomes such as income and environmental justice. Together, these analyses can enable a comprehensive evaluation of the broader sustainability of the forest bioeconomy.

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Popular science summary

The unsustainable use of limited resources like coal, plastic, and concrete poses serious threats to our society by worsening climate change and environmental pollution. One promising alternative is to replace these with renewable materials produced from forest biomass such as mass timber for construction and wood energy. This forms the idea of the *forest bioeconomy*, which is actively promoted by many countries, particularly in Europe. Increasing the use of forest products to move toward the forest bioeconomy means harvesting more trees to supply these products. This raises concerns about potential negative impacts on other important forest benefits like biodiversity.

Pulblic policy initatives like the forest bioeconomy need both social acceptance and scientific assessments. My thesis combines four studies conducted in different contexts that jointly address two key questions: (1) do people indeed support using more forest products and harvesting trees to supply them? (2) has increasing harvests harmed the forest health?

My findings suggest that the forest bioeconomy is largely acceptable to society. People support greater use of forest products and are generally accepting of harvesting, although they have stronger preferences for limiting harvests to enhance biodiversity. There is no consistent evidence that increased harvest has harmed forest health.

In conclusion, the forest bioeconomy appears to be a viable path toward a more sustainable society. Nevertheless, it might need to be accompanied by public policy measures to safeguard other benefits from forests, together with monitoring of the effects of harvesting on these benefits. Policy measures should be made considering the socio-economic and forest conditions of the places where they will be applied.

Populärvetenskaplig sammanfattning

Användningen av ohållbara resurser så som kol, plast och betong utgör ett allvarligt hot mot vårt samhälle genom att förvärra klimatförändringar och miljöföroreningar. Ett lovande alternativ är att ersätta dessa med förnybara material som tillverkas av skoglig biomassa, såsom timmer och bioenergi. Detta tillvägagångssätt utgör grunden för den skoglige bioekonomin, som aktivt stöds av många länder, särskilt i Europa. En ökad användning av skogsprodukter innebär att fler träd behöver avverkas för att möta den nya efterfrågan på resurser. Detta väcker oro för möjliga negativa effekter på andra viktiga skogliga värden, såsom biologisk mångfald.

Offentliga politiska initiativ som den skoglige bioekonomin behöver både social acceptans och vetenskapliga utvärderingar. Min avhandling består av fyra uppsatser, utförda i olika sammanhang, som tillsammans besvarar två centrala frågor: (1) Stödjer människor verkligen en ökad användning av skogsprodukter och avverkning av träd för att tillgodose detta? (2) Har ökad avverkning påverkat skogens hälsa negativt?

Mina resultat visar att den skoglige bioekonomin i stort är accepterad av samhället. Allmänheten stödjer en ökad användning av skogsprodukter och är i allmänhet positiva till avverkning, även om de har en tydlig preferens för att begränsa avverkningen i syfte att främja biologisk mångfald. Det finns inga entydiga bevis för att ökad avverkning har försämrat skogshälsan.

Sammanfattningsvis framstår den skoglige bioekonomin som en möjlig väg mot ett mer hållbart samhälle. Den kan dock behöva kompletteras med offentliga styrmedel som skyddar andra skogliga värden, samt med övervakning av hur avverkning påverkar dessa värden. Sådana åtgärder bör anpassas efter de sociala och ekologiska förhållanden som råder i de områden där de ska tillämpas.

대중을 위한 연구 요약

석탄, 플라스틱, 콘크리트와 같은 지속가능하지 않은 자원에 의존하는 것은 기후변화와 환경오염을 심화시켜 우리 사회에 큰 위협이 되고 있다. 이러한 문제를 해결하기 위한 한 가지 방법은 건축용 목재나 목재연료와 같이 산림으로부터 생산된 지속가능한 소재로 기존의 소재를 대체하는 것이다. 이와 같은 접근은 산림생물경제(Forest bioeconomy)의 핵심 개념으로, 특히 유럽을 중심으로 많은 나라들에서 적극적으로 추진되고 있다. 산림생물경제를 추진하기 위해 목제품의 사용이 늘어나면 이를 공급하기 위한 벌채 역시 증가하게 되며, 이는 생물다양성 등 산림의 다른 기능에 부정적인 영향을 미칠 수 있다.

산림생물경제로의 전환을 뒷받침하기 위한 공공정책은 사람들이 이를 얼마나 지지하는지, 그리고 실제로 어떤 결과를 가져오는지에 대한 과학적 평가에 근거하여 추진되어야 한다. 따라서, 이 논문은 네 가지 연구를 바탕으로 다음 두 가지 질문에 답하고자 한다. (1) 사람들은 목제품의 사용 증가와 그에 따른 벌채 증가를 받아들이는가? (2) 벌채 증가가 산림 건강에 해를 미쳤는가?

연구 결과에 따르면, 사람들은 목제품 사용 증가에 긍정적인 태도를 보였고, 생물다양성 증진을 위한 벌채 감소를 더 지지하였지만 벌채에 대해서도 대체로 긍정적인 입장을 보였다. 또한, 벌채 증가가 산림 건강을 해쳤다는 뚜렷한 과학적 근거는 발견되지 않았다.

결론적으로, 산림생물경제는 보다 지속가능한 사회를 향한 유효한 접근법으로 보인다. 다만, 산림의 다른 중요한 기능이 훼손되지 않도록 이를 보완할 수 있는 공공정책을 마련하고, 벌채가 산림 기능에 미치는 영향을 지속적으로 관찰할 필요가 있다. 이러한 조치는 적용하려는 지역의 사회적 여건과 산림 환경을 충분히 고려해야 한다.

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I

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Greener homes: Factors underpinning Europeans' intention to live in multi-storey wooden buildings

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ABSTRACT

Climate policies aimed at curbing greenhouse gas emissions embodied in the built environment support the wider implementation of multi-storey wooden buildings. A body of research on public perceptions toward wood as a structural building material is emerging, but close examination of behavioral factors underpinning prospective dwelling is scarce. We used contextualized constructs from the theory of planned behavior to quantify and compare the roles of attitudes, subjective norms, and perceived behavioral control on intentions to dwell in multi-storey wooden buildings. Structural equation models were fitted to survey data from seven European countries (Austria, Denmark, Germany, Finland, Norway, Sweden, United Kingdom; n = 7056). We found that attitudes consistently explain intention to dwell in multi-storey wooden buildings. We also found a varied pattern of relationships between factors underpinning intention across countries. An implication of our results is that national-level policies aimed at promoting social acceptability of dwelling in multi-storey wooden buildings should universally address attitudes toward such novel buildings. But in some countries policies might in addition be tailored to emphasize citizens' subjective norms or perceived behavioral controls.

1. Introduction

The construction of the built environment hinges upon large natural resource flows (Rees, 1992). This demand results in a wide range of environmental pressures owing to the effects of natural resource extraction and management practices (Ioannidou et al., 2017; Olivetti and Cullen, 2018; Torres et al., 2017). The manufacturing of construction materials generates a substantial amount of greenhouse gas emissions that directly contribute to a changing climate (Hertwich et al., 2019; Hertwich, 2021; Lützkendorf et al., 2015). Estimates suggest that the manufacturing of cement, steel, and aluminum construction materials accounts for 6 % of anthropogenic carbon emissions (UNEP, 2022). The global building materials sector must halve its greenhouse gas emissions by 2030 and become a net zero emitter by 2050 in order to meet goals under the Paris Agreement (Pramreiter et al., 2023).

One approach to reducing the negative impacts associated with the built environment is increasing the use of wooden load-bearing material in multi-storey building construction (Wimmers, 2017; Churkina et al., 2020; Pramreiter et al., 2023). These buildings, often referred to as *multi-storey wooden buildings*, are possible due to technological advancements allowing engineered wood products to substitute concrete load-bearing elements (Ramage et al., 2017; Foster and Ramage, 2020). Such a substitution could lead to a downscaling of global cement production and its associated carbon emissions (Churkina et al., 2020). Increasing demand for engineered wood may also trigger a chain of events along the wood product supply chain, extending to forest management and other land use practices (Mishra et al., 2022; Heräjärvi, 2019; Hurmekoski et al., 2020). For example, increased demand for engineered wood products may support the utilization of trees and fibers with low market value (USDA, 2020; Pramreiter et al., 2023) or enable sustainable forest management practices (Heräjärvi, 2019). However, Mishra et al. (2022) caution that drastic new demand for engineered wood products in construction may lead to a loss of unprotected forest or increased reliance on forest plantations, which carry their own set of environmental and management challenges (Malkamäki et al., 2018). Despite the potential drawbacks, Pramreiter et al. (2023) maintain that

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increased demand for wooden construction materials could result in net climate and other environmental benefits through afforestation and reforestation.

For many policy-makers, multi-storey wooden buildings are an appealing pathway to simultaneously reduce greenhouse gas emissions and advance circular bioeconomy goals (e.g., Vihemäki et al., 2019; Toivonen et al., 2021). A challenge to this pathway is that multi-storey wooden buildings remain a niche technological innovation that competes against other well-established construction practices, chiefly concrete multistorey building production (Mahapatra et al., 2012). To date, there are a limited number of multi-storey wooden buildings finalized across the globe (e.g., see: Franzini, 2022: Appendix A; Salvadori, 2021). The wider uptake of multi-storey wooden buildings requires policymakers to institute regulatory and market-based interventions and promote societal acceptance (Mahapatra and Gustavsson, 2008; Mahapatra et al., 2012; Wimmers, 2017).

Promoting societal acceptance requires understanding whether citizens are willing to inhabit multi-storey wooden buildings and discerning the underlying reasons for this (un)willingness. To date, citizens' acceptance of multi-storey wooden buildings remains underexplored. Previous studies (e.g., Roos et al., 2022; Aguilar et al., 2023; Viholainen et al., 2020) provide a baseline for the perceptions citizens hold toward multi-storey wooden buildings, but the relationships underlying the intention to live in multi-storey wooden buildings have not been tested. Establishing these links would be valuable to identify factors explaining the behavior of citizens toward dwelling in these buildings and motivate them dwell there.

Here, we applied the theory of planned behavior (Ajzen, 1991) to study the behavioral intention to live in multi-storey wooden buildings. It posits that human behavior is driven by a combination of subjective perceptions, including attitudes, subjective norms, and behavioral controls. We used structural equation modeling to analyze responses from a survey of seven thousand citizens across seven European countries in order to answer the following research questions: (1) Do attitudes toward living in multi-storey wooden buildings, subjective norms regarding living in multi-storey wooden buildings, and perceived behavioral controls over living in multi-storey wooden buildings explain stated intentions to live in them? (2) Do factors latent to the intention to live in a multi-storey wooden building differ across European nations? Our findings advance behavioral knowledge underlying the choice of multi-storey wooden buildings as housing alternative. Our interpretations strive to provide European policymakers with practical information that could enhance social acceptability of these novel buildings.

2. Literature review

2.1. Citizen's acceptance of wood as a load-bearing housing material

Wood is one of the oldest construction materials, but fears of its combustibility led to its wide replacement with non-combustible elements (Wimmers, 2017). Common load-bearing construction materials used to carry and transfer a building's weight to the ground (e.g., walls, columns, beams) include a combination of steel, bricks and concrete. The contemporary use of wood as a construction material has focused much on non-structural applications, often justified for its aesthetic benefits, in spite of physical properties such as its lightweight with a high strength-to-weight ratio. Nonetheless, wood is amply used as a load-bearing material in low-rise building structures in parts of Asia, in North America and with a strong tradition in Fennoscandic European countries (Duguma and Hager, 2010; Wimmers, 2017). Many recognize the potential benefits of the wider use of wood as a load-bearing material in these markets and other regions of the world (Goverse et al., 2001; Wimmers, 2017; Churkina et al., 2020).

The investigation of citizens' acceptance of wood as a load-bearing housing material has emerged a research thrust in recent years with a number of studies conducted in forest-rich Fennoscandic European countries. Schauerte (2013) suggests that among selected interviewees in Sweden the cost of construction was the most important attribute as an opportunity and barrier to the use of wood in multi-storey buildings. Høibo et al. (2015) found citizens with stronger environmental values had a higher preference for wood as a construction material among Norwegians living in Oslo. Viholainen et al. (2020) found everyday usability and durability of residential materials of wooden buildings are valued among Finnish homeowners who lived in a wooden house for more than a year. Kylkilahti et al. (2020) discovered Finnish citizens appreciate attributes of multi-storey wooden buildings differently by their consumption styles in an explorative study with university students. Lähtinen et al. (2021) elicited housing values and analyzed their association with prejudices against multi-storey wooden buildings in Denmark, Finland, Norway, and Sweden. They report that prejudices against wood as a load-bearing material may not be related directly to wood properties nor building technologies, but to lifestyle preferences. Roos et al. (2022) studied the relationship between perception of sustainability, quality, and design of multi-storey wooden buildings and preference for such buildings among Finnish and Swedish consumers. Vehola et al. (2022) discerned that people with greater concerns over the seriousness of climate change were more likely to have positive views on using wood as a construction material in Finland and Sweden. Roos et al. (2023) analyzed socio-economic and attitudinal factors that affect Finnish and Swedish consumers' beliefs of the climate benefits and disadvantages offered by multi-storey wooden buildings.

Several studies included non-Nordic European countries in the analyses of perceptions toward multi-storey wood buildings. Among them, Viholainen et al. (2021) suggest that consumers generally approve using wood as a construction material but found country-specific differences in perceptions based on responses from a panel comprised of respondents from Austria, Denmark, Germany, Finland, Norway, Sweden, and the United Kingdom. Aguilar et al. (2023), after analyzing socio-economic and attitudinal determinants to preferences toward utilizing wood as a load-bearing material using a panel of the same lists of countries as Viholainen et al. (2021), report that past experience and knowledge dominated higher preferences toward wood over other load-bearing materials. In the US, Larasatie et al. (2018) report that American respondents deem multi-storey wooden buildings to be visually pleasing and welcome the use of renewable building materials, but also expressed concerns over their greater fire risks than other non-combustible materials.

Our study advances the current state of knowledge by investigating structural relationships between perceptions toward multi-storey wooden buildings and dwelling intentions. We estimated these relationships underpinning intention to live in a multi-storey wooden building framed by the theory of planned behavior as our theoretical framework. To the best of our knowledge, this is the first application of the theory of planned behavior to examine citizen's acceptance of wood as a load-bearing housing material.

2.2. Theory of planned behavior

The theory of planned behavior offers a framework positing that human behavioral actions are contingent on an individual's intention to engage in a behavior (Ajzen, 1991). Intentions represent motivational factors that influence a behavior such as willingness and conscious plans to perform the behavior; as a general principle, intention and the behavioral action have a positive relationship (Ajzen, 1991; Conner and Armitage, 1998). Ability to predict behavioral action using intention as a proxy is a strength of this theory since true behavioral actions are not revealed until an action is carried out.

The theory of planned behavior has roots in the theory of reasoned action (Ajzen and Fishbein, 1980). The latter models the intention to engage in a behavior as a function of attitudes toward the behavior (ATT) and subjective norms regarding the behavior (SN). ATT represents the degree to which the behavior is viewed favorably or unfavorably. SN represents the perceived social pressure to perform the behavior. A drawback of the theory of reasoned action is that it is only applicable to volitional behaviors. It provides a poor explanation and prediction of behaviors that require non-motivational factors to be performed, such as skills or resources that are not freely available to the individual (Conner and Armitage, 1998). The theory of planned behavior overcomes this drawback by recognizing perceived behavioral controls over the behavior (PBC). PBC represents the degree of an individual's confidence in his or her ability to perform the behavior. Jointly, ATT, SN, and PBC explain and predict intention; besides, PBC can serve as a direct predictor of the behavioral achievement (Ajzen, 1991). Inclusion of PBC has expanded the applicability of this model to non-voluntary behaviors (Conner and Armitage, 1998). To-date, the theory of planned behavior has been applied to investigate a variety of behaviors in a multitude of fields and found to hold a high degree of empirical validation (Ajzen, 2020; Bosnjak et al., 2020). Moreover, the theory of planned behavior also recognizes that ATT, SN, and PBC may have variable relationships with intention across different contexts (Ajzen, 1991), such as those found across nations.

The theory of planned behavior can be a viable alternative to utility models eliciting prospective consumer behavior from (stated) preferences (Ajzen, 2011, 2016). Utility models typically assess consumer attitudes and preferences in decision making, but rarely consider the role of normative pressure or preventative constraints to decision making (Ajzen, 2016). This is a limitation to housing studies research, because housing choices are shaped by individual preferences (e.g., ATT), but limited by contextual market constraints (e.g., PBC) (Wong, 2002; Jansen et al., 2011; Marsh and Gibb, 2011). Therefore, controlling for ATT, SN, and PBC provides important nuance to a complex phenomenon. Despite this advantage, the theory of planned behavior has seldom been applied in housing research. Some exceptions are found among housing studies researching intentions to purchase sustainable or green housing (Tan, 2013; Judge et al., 2019). In the context of multi-storey wooden buildings, researchers such as Aguilar et al. (2023), Høibo et al. (2015), Gold and Rubik (2009) have yet to explicitly control for subjective norms or perceived behavioral control.

In our research, we contextualized constructs commonly used in past applications of the theory of planned behavior to our prospective behavior of interest: intention to live in multi-storey wooden buildings. Henceforth, ATT denotes attitude toward living in multi-storey wooden building; SN denotes subjective norms regarding living in multi-storey wooden building; PBC denotes the perceived behavioral controls over living in multi-storey wooden building; and INT denotes the intention to live in multi-storey wooden building. We tested whether ATT, PBC, and SN are statistically associated with INT. It is worth noting that we did not evaluate the relationship between PBC and actual or observed residence in multi-storey wooden buildings, but only based on stated intentions to live in them. As the offering of multi-storey wooden building as a residential alternative grows, actual dwelling as an observed behavior could be studied in the future. Moreover, we emphasize our study of structural relationships over causal inferences. Sussman and Gifford (2019) called for caution in interpreting TPB in a uni-directional causal manner due to the possibility of reciprocal relationships between ATT, PBC, SN and INT, and potential endogeneity in cross-sectional models. Hence, given the cross-sectional nature of our data we cannot make any causal inferences. This and other empirical issues such as reverse-directional relationships (i.e. whether INT influences ATT, PBC, and SN) will be investigated in future research.

3. Methods

3.1. Survey instrument

This study is part of the project 'Nordic Forest-Based Sector in Bioeconomy', which focused on the role of forests and wood products in the transition to a sustainable bioeconomy. The data described within this manuscript are part of a larger questionnaire focused on citizens' perceptions toward multi-storey wooden buildings. The questionnaire was developed in English, subsequently translated to six additional languages by native-speaking experts, and pre-tested with native speakers prior to data collection. The final questionnaire was deployed in Austria, Denmark, Germany, Finland, Norway, Sweden, and the United Kingdom. A full copy of the questionnaire is available in the first section of the Supplementary Information (SI).

To frame our study, the questionnaire defined a *multi-storey building* as any building with a minimum of three floors, and *multi-storey wooden building* refers to a multi-storey building with a wooden load-bearing structure (Aguilar et al., 2023). Participants were informed that the structural load-bearing materials of a multistorey building could be made of several materials, including engineered wood products, brick, concrete, and steel. *Engineered wood* was defined as a material composed primarily of wood or wood in combination with other materials.

Past work examining public preferences toward multi-storey wooden buildings (Section 2.2) served as the foundation to our crafting of questions to study intention to live in a multi-storey wooden building. It is important to note that, as stressed by Fishbein and Ajzen (2011), there is no standard questionnaire for the application of the theory of planned behavior and specific questions should be selected for their appropriateness to the behavior in question, the target population, and time period, among others. We developed 19 questions in total, of which five measured ATT, five measured SN, five measured PBC, and four measured INT. Kline (1998) has previously suggested the inclusion of about five items to identify a concept in structural equation modeling. Though subject to controversy, we included both positively- and negatively-worded items within each construct as it is recommended to reduce response bias (Churchill, 1979). All responses were recorded using a unipolar 9-point scale (i.e., 1 = Strongly disagree, 9 = Strongly agree). Both unipolar and bipolar scales in the context of theory of planned behavior are equally justified (Ajzen, 1991). The full questionnaire also included a battery of socio-demographic and open-ended questions.

3.2. Data collection

Data collection was conducted online by the market research company Syno International (Syno, 2022) using consumer panels between May and June 2021. Consumer panels may be subject to bias (e.g., self-selection) that can challenge the integrity of a sample (Chandler et al., 2019; Smith et al., 2016). On the other hand, online consumer panels offer an affordable alternative to collecting data across multiple countries applying identical sampling windows and commonly have lower item non-response rates relative to other methods, which will also come with issues of self-selection and other sources of bias (Kwak and Radler, 2002; Barrios et al., 2011). Previous studies have successfully applied consumer panels to make market inferences about the wood products sector (e.g., Aguilar and Cai, 2010).

A link to the survey was distributed via email to a demographically representative sample of residents 18 years of age and older in each of the seven selected countries. Samples were drawn from Syno International's existing panels based on age, gender, and urban-rural dwelling. Data collection quality controls included the avoidance of multiple responses per participant and survey links shared only within socio-demographic segments to meet pre-determined study quotas (1000 complete questionnaires per country). Data collection and archiving followed European General Data Protection Regulation and complied with ISO quality standard 20252 for market and social research (ISO, 2019). On average, 42 % of individuals who received an email invitation to participate in the study completed the questionnaire. Additional details regarding survey response rates are available in the SI (Section 2). All data used in this manuscript are available online at the Harvard Dataverse [https://doi.org/10.7910/DVN/KTNTIL].

3.3. Statistical analyses

We parameterized structural relationships among ATT, SN, PBC and INT (Fig. 1) using structural equation models (SEMs). A SEM is comprised of a measurement and a structural model (Hair et al., 2010). The measurement model quantifies exogenous and endogenous latent constructs using observable items. The structural model describes the relationship between exogenous and endogenous latent constructs. Following Lattin et al. (2003), a measurement model can be expressed as:

$$X = \Xi \Lambda_x + \delta \quad (1)$$

$$Y = H \Lambda_y + \epsilon, \quad (2)$$

where Eqs. (1) and (2) denote exogenous and endogenous constructs, respectively. X and Y represent matrices of observed items, Ξ and H are matrices of latent constructs, Λ_x and Λ_y are matrices of factor loadings of observed items to latent constructs, and δ and ϵ are random error matrices. The structural model can be expressed as:

$$HB = \Xi \Gamma + u, \quad (3)$$

where B and Γ are coefficient matrices that capture the relationship between endogenous and exogenous latent constructs, and u is a measurement error matrix.

Our SEM was specified according to the contextualized theory of planned behavior constructs, where ATT, SN, and PBC are interrelated latent constructs forming INT. Our final specification included 11 reflective items from the original pool of 19 measures (see section 3 in the SI for additional information). We arrived at this selection after omitting prospective items that shared low internal consistency as indicated by lower Cronbach's alpha values (Anderson and Gerbing, 1988) as was the case for negatively-worded items (e.g., "People whose opinions I value prefer that I do not live in a multi-storey wooden building"). The adequacy of the final 11 items was ascertained through validity measures including standardized factor loadings, discriminant validity, composite reliability, and the average variance extracted after confirmatory factor analyses of the measurement model. Statistical thresholds of these validity measures are disclosed in the fourth section of the SI.

SEMs were estimated for the entire dataset and for each country in our sample. These estimations allowed us to test the ability of SEMs to assess structural ATT, SN and PBC relationships across all countries and by country-specific context. All SEMs were estimated using maximum likelihood. Other SEM estimation procedures include generalized least squares, weighted least squares, and partial least squares (see e.g., Hair et al., 2010), but we employed maximum likelihood because it is more robust in the presence of non-normality in large datasets with few missing values (Tanaka, 1984). Note that we conducted a robustness test by estimating SEMs using diagonally weighted least square mean-variance adjusted estimator (see SI section 5 for details). We calculated log-likelihood ratio tests to examine statistically-significant differences between ATT, SN and PBC structural path coefficients within a particular SEM (Gonzalez and Griffin, 2001). These tests helped guide our interpretations regarding the tailoring of policy interventions by country. We first estimated a full SEM model without parameter constraints. Then, we estimated a restricted model with the constraint that two parameters in Eq. (3) ($\Gamma_i = \Gamma_j$; $i \neq j$; i,j = ATT, SN, PBC) were equal. We estimated the χ^2 probability of log-likelihood ratio of the full and restricted models to test the null hypothesis:

$$\Gamma_i - \Gamma_j = 0, \quad (4)$$

with the alternative being $\Gamma_i - \Gamma_j \neq 0$.

4. Results

4.1. Descriptive statistics

Our sample held equal gender representation, with the highest proportion of males in Austria (50.8 %) and the lowest proportion in the United Kingdom (48.2 %). The average respondent age was 45.0, the highest sample mean found in Denmark (47.3) and the lowest in Austria (38.6). The average household size was between two to three individuals, with about 30 % of respondents having at least one child. Most respondents (39.9 %) resided in a metropolitan environment of at least 100,000 inhabitants, of which the Finnish (47.4 %) and Danish (32.8 %) samples had the largest and smallest proportions, respectively. About 44 % of respondents had obtained a bachelor's or equivalent degree, with the highest and lowest proportions found, respectively, in

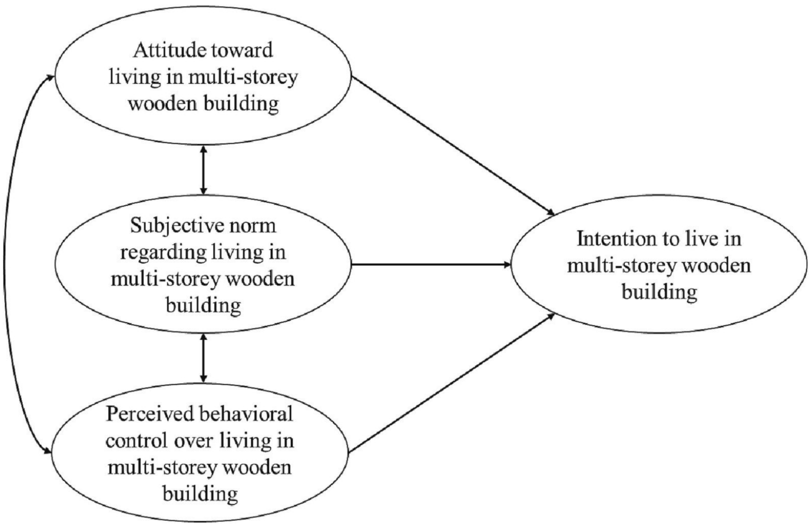

Fig. 1. Contextualized theory of planned behavior to living in multi-storey wooden building. Adapted from Ajzen (1991).

Norway (54.8 %) and Germany (36.2 %). These values are higher than the values reported in official statistics at the EU level among adults with tertiary education attainment in 18–69 years, which were 32.5 % for Austria, 36.2 % for Denmark, 28.1 % for Germany, 37.0 % for Finland, 42.2 % for Norway, 41.4 % for Sweden in year 2021 and 41.2 % for the United Kingdom in year 2019 (Eurostat, 2022). See SI section 6 for additional details on the sample demographic profile are disclosed. With the caveat of likely overrepresentation of individuals with higher education level than adult population averages, commonly found in online surveys (Shih and Xitao, 2008), our sample represented well countries' adult population profiles.

4.2. Structural Equation Models

Standardized factor loadings for the SEM estimated using the whole seven-country dataset are presented in Table 1. Heterotrait-Monotrait discriminant validity values <0.85 indicate the latent constructs were statistically distinctive from one another (Henseler et al., 2015). The standardized factor loadings were all strongly significant ($p < 0.001$). Overall, the model met acceptable fitness values commonly found in the literature (see: Hair et al., 2010), with the exception that PBC's average variance extracted (0.44) was lower than the commonly accepted threshold (0.50). PBC's composite reliability (0.69) was slightly low but still very close to the commonly accepted threshold of 0.70. A low average variance extracted of PBC indicates that the variance captured by PBC is lower than the variance attributable to measurement errors. This might question the convergent validity of PBC and items comprising this construct (Fornell and Larcker, 1981), with a common empirical remedy being to drop an item that lowers its convergent validity. We chose to keep all three items comprising the PBC measure because each of them represents important theoretical aspects: perceived current and future availability of multi-storey wooden buildings (PBC1, PBC2), and adequacy of information to make a decision to dwell in multi-storey wooden building (PBC3). Given that all the other fitness indicators met commonly accepted thresholds, we deemed the slightly low convergent validity of PBC to be an empirical challenge that does not compromise our findings. As a measure of this premise, we dropped PBC3 from the PBC and estimated the measurement model again. Though it provided a sufficient average extracted variance value of PBC (0.541), it slightly decreased the composite reliability to 0.67, and the discriminant validity between PBC against the other constructs. Fitness indicators of this alternative measurement model are provided in SI section 7.

The SEMs structural path coefficients, goodness-of-fit measures, and log-likelihood ratio tests of equality are shown in Table 2 for the whole dataset and individual countries. Goodness-of-fit measures fell within acceptable ranges, except for the root mean square error of approximation in the SEMs for Finland and the United Kingdom. Data from both countries showed slightly higher values than the acceptable threshold (> 0.80). Results of SEM estimations using diagonally weighted least square mean-variance adjusted estimator are available in section 8 of the SI.

The structural path coefficients values and statistical significance varied between datasets. ATT held the strongest relationship to INT as denoted by the larger coefficients for their structural paths, which is consistent with past reports investigating samples drawn from the same countries (Aguilar et al., 2023). ATT was statistically significant across the whole dataset and in each country. This relationship (Fishbein and Ajzen, 2011) indicates that positive attitudes toward dwelling in a multi-storey wooden building were associated with a positive intention to live in one, implying that studies on consumer perceptions about multi-storey wooden buildings are important probes to assess if consumers will be motivated to live in them. SN was statistically significant for the whole dataset and all countries except Austria and Germany. A statistically significant relationship between SN and INT likely indicates that citizens intend to live in multi-storey wooden buildings if influential referents' (e.g., family, friends) approve of the idea. This is in line with previous consumer housing research suggesting that household family members play a critical role in housing selection processes due to their involvement in the negotiation process (Levy et al., 2008). PBC was statistically significant for the whole dataset and all subgroups except Denmark, Finland or Norway. A statistically-significant effect between PBC and INT likely suggests that if a prospective citizen believes they can access the necessary resources to live in a multi-storey wooden building, they will have stronger intention to dwell in the building.

Log-likelihood ratio tests of equality varied depending on the dataset used. When testing equality of effects between paths to INT, we found that ATT and SN were different within all countries, with the exceptions of Finland and Norway. Tests reveal that structural path effects between ATT and PBC were only statistically significantly different in the case of Finland and Norway. The PBC coefficient was statistically significantly different from SN in all countries except the United Kingdom. Such heterogeneity found between countries may have various underlying causes worthy of future investigation. We refrain from speculating about what may be driving such differences between countries and focus on how these findings may be of value to European public policymakers interested in enhancing the social acceptance and demand for multi-storey wooden buildings.

Table 1
Standardized factor loadings, composite reliability (CR), average variance extracted (AVE) and discriminant validity of latent constructs in the measurement model (whole dataset, n = 7053).

Latent constructs	Items	Standardized factor loadings[†]	CR	AVE	Discriminant validity[a]			
					ATT	SN	PBC	INT
Attitude (ATT)	ATT1	0.72***	0.84	0.64		0.63	0.60	0.67
	ATT2	0.87***						
	ATT3	0.82***						
Subjective norm (SN)	SN1	0.66***	0.78	0.54			0.78	0.69
	SN2	0.77***						
	SN3	0.78***						
Perceived behavioral control (PBC)	PBC1	0.62***	0.69	0.44				0.66
	PBC2	0.76***						
	PBC3	0.60***						
Intention (INT)	INT1	0.83***	0.83	0.71				
	INT2	0.85***						

CR = Composite reliability (fitness threshold: >0.7).
AVE = Average variance extracted (fitness threshold: >0.5).
[†] Statistical threshold: >0.5; Type-I errors: * < 0.05, ** < 0.01, *** < 0.001.
[a] Heterotrait-Monotrait discriminant validity ratio (fitness threshold <0.85).

Table 2
Standardized structural path coefficients, robust standard errors, type I errors, log-likelihood ratio (LR) tests, and goodness-of-fit of estimated structural equation models using maximum likelihood estimation.

	All	AT	DE	DK	FI	NO	SE	UK
Sample size	(7053)	(1005)	(1006)	(1010)	(1009)	(1007)	(1008)	(1008)
Structural paths[a]								
ATT → INT	0.33***	0.38***	0.40***	0.21***	0.54***	0.27***	0.26***	0.17**
	(<0.001)	(0.052)	(0.046)	(0.050)	(0.055)	(0.074)	(0.065)	(0.053)
SN → INT	0.29***	0.15	0.12	0.44***	0.43***	0.39***	0.18**	0.46***
	(<0.001)	(0.085)	(0.063)	(0.069)	(0.120)	(0.088)	(0.068)	(0.086)
PBC → INT	0.24***	0.35**	0.43***	0.13	−0.05	0.10	0.35**	0.24**
	(<0.001)	(0.104)	(0.070)	(0.072)	(0.117)	(0.082)	(0.098)	(0.074)
LR test[b]								
ATT = SN	Reject	Reject	Reject	Reject	✓	✓	Reject	Reject
ATT = PBC	Reject	✓	✓	✓	Reject	Reject	✓	✓
SN = PBC	✓	Reject	Reject	Reject	Reject	Reject	Reject	✓
Goodness-of-fit								
RMSEA	0.063	0.067	0.061	0.070	0.085	0.065	0.067	0.087
GFI	0.967	0.955	0.966	0.955	0.940	0.952	0.961	0.942
CFI	0.968	0.963	0.973	0.962	0.947	0.961	0.967	0.948
TLI	0.953	0.946	0.961	0.945	0.923	0.943	0.953	0.925
SRMR	0.034	0.038	0.033	0.040	0.046	0.037	0.039	0.043

Type-I errors (* < 0.05, ** < 0.01, *** < 0.001).
[a] Robust standard errors.
[b] LR test based on non-robust standard errors.

5. Discussion

5.1. Policy implications: behavioral factors underpinning citizens' intention to live in multi-storey wooden buildings

The statistical significance of ATT, SN, and PBC in the whole seven-country SEM indicates that stated intentions to dwell in these novel wooden buildings may be explained by all three determinants identified by the theory of planned behavior. Differences between and within countries reflect on how the same theory recognizes that ATT, SN, and PBC may have variable relationships with INT across different contexts (Ajzen, 1991). Table 3 summarizes possible approaches to enhance the behavioral prospects for citizens to live in multi-storey wooden buildings and identifies in which countries each approach would on average be most effective guided by our SEM results.

Attitudes are formed according to a person's salient evaluations of attributes of the behavior (Fishbein and Ajzen, 2011). Thus, it is important for policymakers to deliver accurate information about multi-storey wooden buildings relevant to marked concerns of public to promote positive attitudes toward multi-storey wooden buildings. The existing literature suggest that consumers are concerned about the fire safety, structural durability, and environmental sustainability of multi-storey wooden buildings (e.g., Larasatie et al., 2018; Viholainen et al., 2020; Lähtinen et al., 2023). Limited knowledge of public about multi-storey wooden buildings (Kylkilahti et al., 2020; Larasatie et al., 2018) may result in misconceptions that contribute to negative attitudes toward multi-storey wooded buildings (Roos et al., 2022). Accordingly, an effective strategy to promote positive attitudes might include (1) ascertaining the most important attributes of multi-storey wooden buildings that saliently shape consumer attitudes, (2) identifying misconceptions about selected important attributes among the public in focus, and (3) rectifying misconceptions (e.g. through targeted information campaigns) existing in the public in focus. Given that ATT was significant in all the country-specific models, such a strategy might be tenable regardless of country-specific contexts.

Table 3
Summary of policy recommendations and possible strategies to support prospective citizens' intention to live in multi-storey wooden buildings.

Policy recommendation[a]	AT	DE	DK	FI	NO	SE	UK
ATT: Information campaigns targeting citizen misconceptions about wood	✓	✓	✓	✓	✓	✓	✓
SN: Information campaigns targeting real-estate agents' knowledge on wood and best practices for discuss wooden homes with clients	X	X	✓	✓	✓	✓	✓
PBC: Accessible wooden construction information platforms for citizens	✓	✓	X	X	X	✓	✓

[a] '✓' indicates that the policy approach is recommended for a particular country; 'X' indicates that the approach is likely unsuitable for that particular country.

Information channels, such as traditional media and social networks, may be important normative references shaping consumers' perception. Past research reports that real estate agents and developers may serve as key references due to their intermediary role promoting housing options in the context of multi-storey wooden buildings (Viholainen et al., 2020; Lähtinen et al., 2023). Therefore, policymakers in countries with a significant SN path coefficient to INT are advised to work closely with influential intermediaries (e.g. real estate agents). Policy initiatives may include (1) the use of information campaigns to raise recognition about multi-storey wooden buildings in the housing market, and (2) encourage real estate agents to communicate positively about this housing alternative to homebuyers.

Critically, PBC captures *subjective* perceptions about control - and not *actual* control - that constrain INT. To present a hypothetical situation, potential dwellers may subjectively believe a multi-storey wooden building is too expensive to purchase thereby driving down their intention to live in the building, while in actuality the market price was within their budget. Conversely, dwellers may believe multi-storey wooden buildings are cheap and affordable and thereby intend to live in them. However, dwellers might be constrained by market prices. This hypothetical example indicates that a statistical significant PBC reflects those subjective beliefs about constraints, regardless of what the actual constraints are. Limited information has been identified as a major constraint to the housing decision making process (e.g., Marsh and Gibb, 2011), thereby implying that subjective perceptions about limited information may lead to poor PBC. Based on this, policymakers from countries where PBC is a significant construct should consider the use of public information platforms to motivate consumer intentions. In some cases, these information platforms may generate a double benefit, if the new information also rectifies misconceptions that lead to negative attitudes.

5.2. Policy implications: other contextual actions to advance citizens' intention to live in multi-storey wooden buildings

Citizens are often met with numerous constraints in their ability to find desirable housing choices (Wong, 2002; Marsh and Gibb, 2011). Past studies have identified a low level of citizens' self-reported understanding and knowledge about multi-storey wooden buildings (e.g., Larasatie et al., 2018; Viholainen et al., 2020; Kylkilahti et al., 2020) as a major constraint to the social acceptance of these buildings. Our results also point to limited awareness and we have noted informational actions targeting citizens and real estate agents to possibly advance positive INT. Here, we point to similar informational efforts across other decision-makers who can facilitate or obstruct the availability of multi-storey wooden buildings. The development and adoption of multi-storey wooden buildings is complex, among others, affected by public regulations, companies' business choices, and path dependency within the building sector (Hildebrandt et al., 2017; Lähtinen et al., 2019). Business practices, along with technological progress and an evolving regulatory framework, have enabled the expanded use of wood in load-bearing structures (Pelli and Lähtinen, 2020), but some have noted the lack of knowledge or hesitation to adopt (e.g., Roos et al., 2022; Hemström et al., 2011; Markström et al., 2018) or approve of (e.g., Franzini, 2022) the use of wood as a structural material as a general and major barrier to adoption in Europe. Context-specific gatekeepers might be identified and targeted for awareness campaigns to overcome other social barriers to expand the actual building of multi-storey wooden buildings.

In addition to communication-based strategies, other market-based interventions to address the cost-competitiveness of wood as a structural building material might be necessary. Some are already underway. For example, the EU's Carbon Border Adjustment Mechanism (European Commission, 2022) adopted by the EU Council and Parliament on 13 December 2022 aims to levy a carbon tax to imports of selected carbon intensive items carrying the greatest risk of carbon leakage beyond EU borders (cement, iron and steel, aluminum, fertilizers, electricity and hydrogen). The Mechanism is designed to support the decarbonization of EU industry and its transitional phase is expected to start by 1 October 2023. *Ex ante* evaluations of the Mechanism by the United Nations Conference on Trade and Development (2021) suggest it could favor production in developed countries that are relatively carbon efficient, could help reduce carbon emissions across the EU and beyond its borders, but overall reduction might be only a small percentage of global carbon emissions. Beyond carbon taxes over imported materials, potential carbon taxes levied based on all net carbon emissions could increase the economic competitiveness of wooden buildings due primarily to lower costs for energy used to manufacture wood construction materials (Sathre and Gustavsson, 2007). Expansion in the use of long-live engineering wood in the construction sector could lower the cost of reducing carbon emissions through the substitution of non-renewable products (Winchester and Reilly, 2020) also advancing European goals for a stronger bioeconomy.

5.3. Limitations and future research

There are several caveats inherent to our research. The first includes potential biases introduced when collecting self-reported information through questionnaires written in six different languages. This is a common challenge in multilingual surveys, as complex questions may lead to differing interpretations among respondents. We attempted to ameliorate this shortcoming through careful survey translations and language checks by bilingual experts. Another caveat relates to the measurements applied in the study. In later works, Fishbein and Ajzen (2011) have reformulated the theory of planned behavior into the theory of reasoned action. The latter model posits that ATT, SN, and PBC are respectively formed by behavioral beliefs, norm beliefs, and control beliefs. These beliefs constitute the formative measures for ATT, SN, and PBC. Ajzen (2020) maintains that ATT, SN, and PBC are best measured through reflective indicators. For example, reflective measures of attitude are collected using semantic differentials (e.g., Fishbein and Ajzen, 2011). The items collected for our research represented a mix of both reflective and formative measures. It is possible that mixing of reflective and formative measures contributed to relatively low measures of internal consistency among the indicators ultimately omitted from the study, which resulted in the relatively low Cronbach's alpha of the PBC construct. Beyond such caveats, the SEMs presented here represent stated behavioral intentions among our sample of prospective dwellers as of May–June 2021. As the supply of multi-storey wooden building is likely to grow in the future, their wider availability and likely increased awareness and knowledge among prospective dwellers will warrant the future examination of the structural relationships we have reported.

Future research should identify the salient beliefs underlying the ATT, SN, and PBC driving intentions to dwell in multi-storey wooden buildings. For example, residential attributes forming ATT toward multi-storey wooden buildings deserves greater research attention, as Franzini (2022) found that technical attributes of buildings are more important than evaluations of environmental attributes among Finnish municipal civil servants. Whether similar patterns are observed across the public requires further investigation. By extension, future research should ascertain which specific referents groups drive SN and what resources can effectively drive PBC. Of additional value, future efforts might also be well invested in determining possible co-causality and using formal causality tests on INT of ATT, SN, PB beyond the structural relationships reported here.

6. Conclusions

Transitioning toward a built environment that incorporates sustainable natural resource flows will require institutional frameworks and public acceptance. In the case of multi-storey wooden buildings, it is apparent that further work addressing shortcomings in public perceptions is necessary. To this end, this research identified that citizens' intention to reside in multistorey wooden buildings is driven by attitudes, subjective norms, and perceived behavioral control. However, the relationship between these perceptions is complex and varied across multiple European countries. Given this variation, and in the context of housing as a complex decision, we propose three target strategies which can be adjusted according to the most important determinants of TPB in that geographical context. Where ATT is significant, policy strategies to rectify misconceptions about multi-storey wooden buildings would be highly effective. In countries where SN is significant, we recommend working with influential referent groups (e.g., real estate agents) to increase the social appeal of multi-storey wooden buildings, Where PBC is significant, policymakers should prioritize accessible information platforms for citizens. We recommend future studies could investigate salient drivers underpinning the formation of ATT, SN, and PBC, and these to be contextualized to particular national market conditions in order to better guide policies promoting multi-storey wooden buildings.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.spc.2023.05.030.

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Psychological distances to climate change and public preferences for biodiversity-augmenting attributes in family-owned production forests

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ABSTRACT

Understanding public perceptions on how management can help adapt forests to climate change is fundamental to the design of socially-acceptable policies. A binary discrete choice experiment in Norway and Sweden was conducted to elicit public preferences for biodiversity-augmenting changes in three forest management attributes (set-aside, proportion of uneven-aged tree stands, and number and type of tree species) compared to typical *status quo* conditions in family-owned production forests. Importantly, how self-constructed psychological (spatial, social, temporal and hypothetical) distances to climate change were associated with management preferences was investigated. Following integrated choice and latent variable modeling approaches to account for their latency, our econometric results show that closer psychological distances to climate change were associated with increased support for biodiversity-augmenting changes in management attributes from *status quo* conditions of family-owned production forests. On average, the Norwegian public preferred larger set-asides and introducing one more broadleaved species, while the Swedish public favored changes in all attributes. The highest utility was derived from increasing set-aside areas from the *status quo* (5%) to 10% and 20% in both countries with respective average WTP of about 10 to 11 EUR/month in Norway, and approximately 10 to 14 EUR/month in Sweden. Findings point to universal acceptability of increasing set-aside areas in both nations, and public approval for uneven-aged and mixed forest management in Sweden.

1. Introduction

Management has an integral role in supporting the capacity of forest ecosystems to mitigate and adapt to climate change. Land management strategies that increase the storage of carbon on land, and utilization that supports long-term carbon fixed in wood products, are recognized for their potential to reduce net greenhouse-gas emissions (Behr et al., 2015; Geng et al., 2017; IPCC, 2023). Public policy can enhance the forest sector's capacity to mitigate and adapt to climate change impacts by promoting, among others, silvicultural practices that reduce the intensity of timber harvesting and promote diversity in age and species composition, and in adopting cascade-use principles along the wood product value-chain (FAO, 2018; Verkerk et al., 2022).

The 'New EU Forest Strategy for 2030' aims to adapt Europe's forests to the new conditions, weather extremes and high uncertainty brought about by climate change (European Comission, 2021). The Strategy stresses biodiversity conservation goals over the supply of products sourced from European forests. Among other considerations, the Strategy maintains that the possible loss of forest carbon sinks are unsurmountable to the benefits of additional carbon fixed in forest products, and silvicultural practices such as clear-cutting should only be used exceptionally (European Commission, 2021). However, reducing timber harvest to enhance forest carbon stocks and biodiversity may decrease wood product supply and its substitution potential with non-renewable or carbon-intensive products. It could plausibly lead to long-term decline in biome carbon storage due to lower investments in forest management (Duncker et al., 2012; IPCC, 2019). Such trade-offs may impair the social welfare of some stakeholders, particularly those

Abbreviations: AIC, Akaike information criterion; AVE, Average variance extracted; BIC, Bayesian information criterion; CFA, Confirmatory factor analysis; CR, Composite reliability; DCE, Discrete choice experiment; HTMT, Hetrotrait-Monotrait discriminant validity; Hyp-P, Hypothetical proximity; ICLV, Integrated choice and latent variable model; MWTP, Marginal willingness-to-pay; Ov-P, Overall proximity to climate change; PD, Psychological distances; RE, Random-effects binary logit; SpSo-P, Spatial and social proximity; Tem-P, Temporal proximity; TemHyp-P, Temporal and hypothetical proximity; WTP, Willingness-to-pay..

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dependent on active forest management activities, timber harvest and industrial processing (Howe et al., 2014). The European forest industry and forest owners have criticized the Strategy for being excessively centralized and misinformed of the importance of wood products in achieving carbon neutrality (Gordeeva et al., 2022; EUSTAFOR, 2021).

Motivated by this policy background and the fundamental role of understanding public preferences in the design of socially-acceptable forest management (Eriksson et al., 2013), we implemented a discrete choice experiment to elicit public preferences and willingness-to-pay (WTP) for biodiversity-augmenting forest management considering climate change beliefs. We surveyed the adult populations of Norway and Sweden, two Nordic European countries with a high share of family-owned forested area where production-oriented management practices are common. We focused on the general public as the largest stakeholder to forest management, anchored in longstanding Fennoscandic social and legal traditions (Bengtsson, 2004; Sheppard and Meitner, 2005). Both countries are endowed with boreal forests vulnerable to climate change, but also of considerable adaptation potential through alternative biodiversity-augmenting practices (Hof and Svahlin, 2016; Högberg et al., 2021; Reich et al., 2022). We inferred WTP for selected attributes using an increase in monthly taxes as an instrument that could channel resources to compensate landowners for likely losses in timber-related revenues. Specifically, we framed this compensation aimed at family-owned production forests as being the largest ownership class in both nations (Nordic Forest Research, 2020). Family-owned production forests account for 78% (5,453,236 ha) and 48% (11,374,000 ha) of production forests – defined as forested area with timber growth of more than $1m^3$/ha/year – in Norway and Sweden, respectively (Official statistics of Sweden, 2022; Statistics Norway, 2022).

This study generates empirical results to inform a current forest policy issue, and makes a direct contribution to current understanding of how psychological distances to climate change as comprehensive measures of one's climate beliefs are associated with stated forest management preferences. Climate beliefs are known determinants of support for climate policy (Bergquist et al., 2022; Bumann, 2021; Drews and van den Bergh, 2016), but these have been understudied when examining forest management preferences. It remains a major knowledge gap considering the high level of European concern for climate change and the pivotal roles of forest management in climate strategies (European Commission, 2020). Here, we employed psychological distances to climate change to comprehensively measure how climate beliefs econometrically explain stated choices (Spence et al., 2012; Trope and Liberman, 2010). To the best of our knowledge, this is the first study to investigate the association between psychological distances to climate change and stated preferences for forest management. Next, we describe the theories framing our study, and our empirical approach to answer the following research questions: (1) what are the public's preferences for selected attributes that constitute forest management strategies? (2) what are the statistical relationships between psychological distances to climate change and stated choice for forest management strategy?

2. Theoretical framework

2.1. Extended random utility

Random utility maximization offers a framework to study explanatory factors to stated preferences using discrete choice experiments. In an experimental setting, choices made by participants from mutually exclusive and exhaustive alternatives can help discern their underlying preferences (Train, 1986). Preferences are subjective and comparative evaluations of alternatives that can be expressed in a utility function under completeness and transitiveness axioms, where utility is a latent variable manifested in observed choices (Ben-Akiva et al., 1999; Varian, 1992). Random utility maximization posits that a rational utility-maximizing individual chooses an alternative that yields the highest utility among a set of given alternatives (McFadden, 1980).

Utility functions have been conventionally considered as invariant and specified in terms of observable characteristics, such as attributes of the alternatives and individuals' socio-demographic characteristics (McFadden, 2001). However, decision-making is a process highly dependent on a variety of factors, such as the context of decision-making situation and behavioral constructs of an individual including motivation, attitudes, perceptions, and beliefs (Ben-Akiva et al., 1999; McFadden, 2001). An individual's behavioral constructs have profound effects in the decision-making process (Ben-Akiva et al., 1999). Several extended frameworks of choice models explicitly include behavioral constructs as viable elements of utility function (see: e.g. Ben-Akiva et al., 2002; Morikawa et al., 2002). The incorporation of behavioral constructs in choice models can increase construct validity and explanatory power of the models (Faccioli et al., 2020; López-Mosquera and Sánchez, 2012; Shan et al., 2019).

Discrete choice experiments (DCEs) grounded on random utility maximization have been extensively used to elicit preferences for environmental goods and programs (Johnston et al., 2017). Yet, DCE studies in environmental domains infrequently incorporate behavioral constructs in their econometric models. Some studies reported evidences that environmental values and attitudes construct preferences (Aguilar et al., 2018; Börger and Hattam, 2017; Choi and Fielding, 2013; Faccioli et al., 2020; Hoyos et al., 2015; Milon and Scrogin, 2006; Ouvrard et al., 2019). Somewhat recently, factors behind theory of planned behavior (attitudes, subjective norms, perceived behavioral control) have been used as predictors to the intention to perform environmentally-minded behaviors (Ajzen, 1991; Börger and Hattam, 2017; Nocella et al., 2012; Ouvrard et al., 2019; Shan et al., 2019). However, there is a lack of agreement on how beliefs are associated with forest management preferences in the particular context of climate change adaptation and mitigation.

2.2. Psychological distances to climate change and preferences for forest management

Psychological distances (PDs) are built upon construal level theory which posits that PDs are formed at multiple levels of an individual's mental construals of particular events (Trope and Liberman, 2010). PDs refer to the extent to which an individual evaluates an event as nearby or far from one's self, place, and the moment where one is; an event is likely to be perceived as more psychologically distant when it is construed at higher levels (Trope and Liberman, 2010). PDs are comprised of four dimensions: *temporal* distance representing the extent an event is perceived as temporally near or far; *spatial* distance representing geographical distance to an event; *social* distance representing perceived distance of an event to social groups to which one belongs; and *hypothetical* distance referring to perceived probability that an event will happen (Liberman and Trope, 2014). These distances are not constant but subject to change by new information and events (Keller et al., 2022). Multiple dimensions of PDs to climate change can overlap and change simultaneously (Maiella et al., 2020; McDonald et al., 2015).

PDs to climate change are considered viable determinants of support for climate actions and their four dimensions can overlap and change simultaneously (Maiella et al., 2020; McDonald et al., 2015). It has been argued that closer PDs to climate change lead to increased support for climate action (Van Lange and Huckelba, 2021). Plausibly, closer PDs to climate change may lead to greater willingness to endorse mitigation and adaptation behaviors (Maiella et al., 2020; McDonald et al., 2015), pointing to their social acceptability. Several studies (Jones et al., 2017; Singh et al., 2017; Soliman et al., 2018; Spence et al., 2012) have reported that climate change being perceived as closer in at least one dimension is associated with stronger intentions to adopt pro-environmental behaviors, including increased support for climate policy. Raising awareness on the proximity of PDs to climate change can increase public engagement and support for adaptive policy (Lee et al., 2020; Scannell and Gifford, 2013; Van Lange and Huckelba, 2021). In the context of our study, discerned relationships between PDs to climate change and DCE choices reflect on the overall association between perceptions of climate change proximity and preferred forest management strategies.

3. Methods

Our methods included the development of a survey that incorporated a DCE following an orthogonal main-effects design. The DCE allowed us to elicit preferences for biodiversity-augmenting changes in selected forest management attributes, which were selected based on their prospect to adapt and mitigate climate change in the specific context of European Nordic forests of Norway and Sweden. The survey included a battery of questions to measure PDs to climate change. Socio-demographic information (e.g. gender, income, education level) was collected at the end of the survey. Self-reported survey data were gathered from a random sample of the adult population of Norway and Sweden and were analyzed using integrated choice and latent variable models.

3.1. Binary discrete choice experiment

The DCE was structured as a binary choice between two forest management profiles: one representing the *status quo* and another as an alternative strategy. We chose this relatively parsimonious design because it can increase response efficiency and consistency by relieving respondent fatigue. Our selection for a binary choice design also aimed at facilitating participants' evaluation of clear contrasts between the *status quo* and varying alternative strategies. Further, a binary DCE is incentive-compatible[1] (i.e. a truthful response to a question is the actual optimal strategy for a respondent) in the context of a public good, and its convergent-validity has been supported in empirical analyses (Carson and Groves, 2007; Weng et al., 2021).

In the survey, the DCE was preceded by descriptions of prevalent forest management practices denoting *status quo* conditions, and descriptive information on how management could advance climate mitigation and adaptation goals. For instance, we explained that net carbon emissions might be reduced by increased harvest as it can create forest structures that sequester carbon more efficiently and in more forest products; increased biodiversity could enhance resiliency of forests to climate disturbances. Explanations were accompanied by visual images to standardize knowledge. We also identified potential trade-offs when deviating from the *status quo* to alternative management attributes. For example, we explained that increasing set-aside areas from 5 to 10% may increase forest biodiversity, but may also decrease wood production, income to landowners, and tax revenues.

Three attributes described *status quo* and alternative forest conditions in the DCE: set-aside, tree age variation, tree species composition. Our attributes and levels – including those corresponding to biodiversity-increasing changes from the *status quo* – are outlined in Table 1. Base levels defined *status-quo* production-oriented management practices in Norway and Sweden. Alternative strategies had at least one attribute level that differed from the *status quo*. They represent scenarios for augmented forest biodiversity in comparison with the *status quo*, such as larger tree age class variability or species composition, but with plausible reduction in wood product supply.

[1] Incentive-compatibility requires other conditions, including (1) the survey question is consequential, i.e. the respondent interpret the result of survey as actually influencing one's action and should care about the consequence of the action; (2) the payment instrument is coercive; (3) the choice sets in DCE are independent; (4) at most one policy can be implemented; (5) one-to-one correspondence between the alternative strategy and possible policy, i.e. the alternative strategy in a choice set exactly describes only one possible policy (Carson and Groves, 2007; Vossler et al., 2012).

Table 1
Attributes, descriptions and levels used in the design of the discrete choice experiment.

Attribute	Description	Levels
Set-aside	Areas that forest owners voluntarily decide not to harvest	• *5% (base)* • 10% • 20%
Tree age variation†	Age variation within a group of trees in a forest stand	• *90% even-aged stand (base), 10% uneven-aged stand* • 80% even-aged stand, 20% uneven-aged stand • 70% even-aged stand, 30% uneven-aged stand
Tree species composition	Type and number of dominant tree species in a forest stand	• *One conifer (base)* • Two conifers • One conifer and one broadleaved
Monthly tax	Tax paid to subsidize the implementation of a new forest management strategy	• *0 (base)*, 50, 100, 200, 350, 500 NOK(SEK)/ Month₸

† 70% even-aged stand, 30% uneven-aged stand; 60% even-aged stand, 40% uneven-aged stand; 50% even-aged stand, 50% uneven-aged stand for the Norwegian survey considering its national context.
₸ 1 NOK = 0.086 EUR (€); 1 SEK = 0.084 €.

The identification of attributes and selection of levels was done after reviewing the scientific literature on family-owned production forest management (Gundersen and Frivold, 2008), and validated after consultation with Norwegian and Swedish forestry experts. Set-aside was defined as an area that a forest owner decides not to harvest to maintain biodiversity and growth of old-aged trees. Setting aside 5% of the total forest area was defined as a base level as it is the minimum requirement to be granted forest certification which is ubiquitous in commercially-managed Norwegian and Swedish forests (FSC, 2019; PEFC, 2022); alternative levels were 10% and 20%. Tree age variation was defined as variation in ages within a forest stand and expressed as proportions of even-aged and uneven-aged stand. Commercial forests in Norway and Sweden are dominated by even-aged stands (Savilaakso et al., 2021). Base levels corresponded to 70% of all forest stands as even-aged in Norway, and 90% of all forest stands as even-aged in Sweden; alternative levels were commonly defined as increasing the proportion of uneven-aged forest by 10% and 20% from the base level. Tree composition was operationalized as types and number of dominant tree species in a forest stand. Following the prevalent monoculture of coniferous species (e.g., *Picea abies* – Norway spruce or *Pinus sylvestris* – Scots pine) in Norwegian and Swedish production forests (Felton et al., 2016), we set base level as one coniferous specie; alternative levels were defined as adding a coniferous or a broadleaved species to the base level.

A fourth attribute in the DCE captured WTP for changes in forest management attributes instrumentalized as an increase in monthly taxes. These revenues would be used to compensate family forest owners for costs and revenue losses associated with changes in forest management attributes. Respondents were informed that remaining at the *status quo* will not cause an increase in monthly taxes. This payment instrument was chosen as one likely to be perceived as real and binding is required, along with information on who pays and payment methods and amounts (Johnston et al., 2017). Hypothetical taxation ranged across six levels from 0 to 500 NOK/SEK per month.

An orthogonal main-effects experimental design was used to generate our binary choice sets (Kuhfeld, 2010). Our experimental design had a final statistical D-efficiency of 1.16 and contained 25 choice sets. We divided the DCE design into five blocks of five choice sets each to increase response efficiency without influencing expected utilities (Kuhfeld, 2010). A respondent was asked to answer only one complete block of five choice sets. We randomized the five blocks in an effort to collect same number of samples for all blocks. Our questionnaires including a block of DCE sets are available as **Supplementary Information**.

3.2. Measurement of psychological distances to climate change

Items measuring PDs to climate change were adapted from Jones et al. (2017) and Spence et al. (2012) (Table 2). Following Maiella et al. (2020) and McDonald et al. (2015), we measured all four dimensions to allow testing mutual influences. Respondents were asked to use a 1 to 7 Likert scale (1 = strongly disagree, 4 = Neither agree nor disagree, 7 = strongly agree) to express agreement to each statement.

3.3. Survey and data collection

The survey was developed in English and translated to Norwegian and Swedish by native-speakers with expertise in the forest sector. It was pre-tested with about 20 individuals resembling our target population. We distributed our survey after amending several questions and descriptions for clear layperson understanding following the pre-test. Our sample was comprised of Norwegian and Swedish residents at least 18 years old. Data collection was conducted online by the market research company Syno International (2022) using consumer panels between June and July 2022. Online surveys may be susceptible to over-representation of certain demographic groups, but allow collecting samples at a relatively lower cost and higher response rates than mail surveys (Barrios et al., 2011; Kwak and Radler, 2002). Previous DCE studies have successfully applied online consumer panels to elicit WTP estimates for forests and other natural resources (e.g. Aguilar et al., 2018; Giergiczny et al., 2015; Weller and Elsasser, 2018). Our survey had a final response rate of 46% for Norway and 53% for Sweden. 1420 Norwegians and 2889 Swedish were invited to the online survey, and 660 responses and 1517 responses were collected, respectively. Johnson and Orme (2010) suggests $(n \times t \times a)/c \geq 1000$ as a general guideline to determine the sample size for a main-effects DCE, where n is the sample size, t is the number of choice sets per respondent, a is the number of alternatives per set and c is the largest number of levels for an attribute. A sample size exceeding 600, thus, sufficed to statistically generalize findings to Norway and Sweden in case of our DCE design.

Table 2
Measurement items of psychological distances to climate change.

Dimensions	Variable	Items[†]
Spatial	Sp1	I believe climate change is likely to affect the local area where I live
	Sp2	I believe climate change is likely to affect the country where I live
	Sp3	I believe the effect of climate change is worse in other parts of world
Social	So1	Climate change will affect me and my family
	So2	Climate change will affect people whose income is similar to mine
	So3	Climate change will affect people whose income level is lower than mine
Temporal	Tem1	I believe climate change is happening now or will happen in my lifetime
	Tem2	I believe climate change will not happen in my lifetime, but sometime in future generations
	Tem3	I believe climate change is not likely to happen, and even if it does it might be in a remote future
Hypothetical	Hyp1	I am uncertain that climate change is really happening
	Hyp2	I am certain about the negative consequences of climate change
	Hyp3	I believe there is a substantial agreement among scientists that climate change is happening

[†] Self-reported items measured in 7-point scale (1 = Strongly disagree, 4 = Neither agree nor disagree, 7 = Strongly agree).

3.4. Econometric analysis

Survey data were analyzed using an integrated choice and latent variable (ICLV) approach to econometrically model how participants' choices were explained by DCE attribute levels underlying utility, and the association of PDs to climate change with the probability of choosing a particular alternative management strategy as latent explanatory factors. Our ICLV approach consisted of a measurement equation for latent PDs to climate change, a structural equation that explains latent PDs to climate change by observed socio-demographic characteristics, and a choice modeling equation that includes DCE attributes, latent PDs to climate change and observed socio-demographics as its components (Fig. 1).

An ICLV is a suitable method to implement an extended random utility maximization framework as it contains latent psychometric explanatory variables to choice (Ben-Akiva et al., 1999). Earlier studies have incorporated psychometric items directly into a latent utility function (Aguilar et al., 2018; Börger and Hattam, 2017; Shan et al., 2019), but this approach may be susceptible to inconsistent estimators, endogeneity, and/or inefficient estimators (Hoyos et al., 2015; Kim et al., 2014). ICLV avoids these issues when combining a latent variable model with discrete choice models and using a simultaneous estimation; the latent variable model allows identifying latent psychometric variables from sets of measurement items and capture the associations between latent psychometric variables and observed socio-demographic variables (Kim et al., 2014). Several empirical studies have applied ICLV to analyze discrete choices including latent psychometric variables (Alemu and Olsen, 2019; Groothuis et al., 2021; Soto et al., 2018).

Our ICLV estimation procedures are described in detail next. We implemented confirmatory factor analysis (CFA) on each country sample to compare our measurement of PDs to climate change with the conceptual four-dimensional structure, prior to ICLV estimations. CFA is an appropriate method to check the measurement of latent variables with strong prior notions (Hair et al., 2010). Standardized factor loadings>0.7, composite reliability>0.7, average variance extracted>0.5, heterotrait-monotrait discriminant validity<0.85 were used as fitness thresholds to evaluate our CFA solutions (Brown, 2015; Hair et al., 2010; Henseler et al., 2015).

CFA solutions guided our specification of ICLV measurement equation as follows:

$$I_{ik} = \gamma PD_i + \xi_i; \quad \xi_i \sim N(0,\ 1), \tag{1}$$

where I_{ik} denotes the observed response of individual i on k-th measurement item of PDs to climate change, PD_i denotes latent PDs to climate change, γ is a parameter vector to be estimated, and an error term ξ_i following a standard normal distribution. I_{ik} has ordered discrete values since PDs to climate change were measured using a 7-point Likert scale. Thus, we used an ordered probit link function in our measurement equations with threshold parameters $\tau_1 \ldots \tau_6$:

$$I_k = \begin{cases} i_1 & -\infty < PD_i \leq \tau_1 \\ i_2 & \tau_1 < PD_i \leq \tau_2 \\ \vdots & \vdots \\ i_7 & \tau_6 < PD_i \leq -\infty, \end{cases} \tag{2}$$

where $i_1 < i_2 \ldots < i_7$ denote observed discrete values for k-th measurement item in I_k.

The structural equation examined the associations between latent PDs to climate and socio-demographic variables. It is specified in a linear form:

$$PD_i = \rho Z_i + \varepsilon_i\,, \tag{3}$$

where Z_i is a vector of individual-specific socio-demographic variables, ρ is a parameter vector to be estimated, and ε_i an idiosyncratic error term.

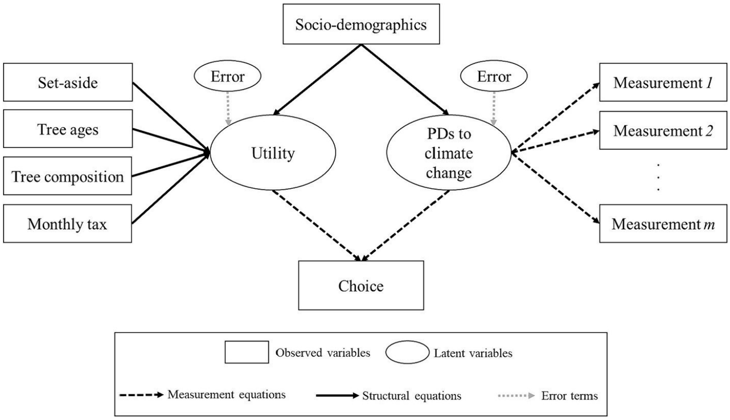

Fig. 1. Depiction of the integrated choice and latent variable model used in this research.

Our econometric modeling of the probability of the i^{th} individual choosing an alternative strategy ($Y = 1$) over the *status quo* ($Y = 0$) was expressed as a random-effects binary logit (RE), since a central premise of our DCE is that a respondent chooses an alternative strategy if it provided a higher utility than the *status quo*, otherwise the *status quo* was chosen. This can be expressed as:

$$Prob\left(Y_{ij} = 0, 1|X_j, PD_i, Z_i\right) = \frac{exp\left(\omega\alpha + \beta X_j + \theta PD_i + \delta Z_i + v_i\right)}{1 + exp\left(\omega\alpha + \beta X_j + \theta PD_i + \delta Z_i + v_i\right)}, \quad (4)$$

where j refers to choice sets presented to the i^{th} participant, α denotes monthly tax attribute of alternative strategy at choice j, X_j denotes non-monetary DCE attributes vector of the alternative strategy at choice j, and ω, β, θ, and δ are parameters to be estimated.

Eq. 4 included an error component at the i^{th} level (v_i) that follows a normal distribution and is assumed to be uncorrelated with other explanatory variables (i.e. random-effects for every individual) (Train, 2009; Wooldridge, 2010). Use of random-effects is not common in the analysis of DCE data but justified in our case of binary discrete choice (Conaway, 1990; Kjaer, 2005). The inclusion of this idiosyncratic term is due to the panel structure of our data since every respondent answered five choice tasks. Random-effects is one way to control for unobserved individual-specific effects in panel models (Wooldridge, 2010). Several studies, largely within health economics, have empirically applied RE to analyze binary DCE data (Černauskas et al., 2018; Chavez et al., 2020; Tappenden et al., 2007). Indeed, RE can be considered as a simplified mixed logit where choice probability is the mixture of a logistic distribution and a normal distribution (specified for the error component v_i), with DCE parameters (β) fixed across individuals (Brownstone and Train, 1998; Greene and Hensher, 2007; Train, 2009). ICLV estimates eqs. 1 to 4 simultaneously using maximum likelihood. We estimated ICLVs for the Norwegian and Swedish sample separately, with standard errors clustered at i^{th} level to reflect on the multiple choices observed per respondent.

As a degree of robustness to our results regarding attribute preferences and WTP, we also ran a more parsimonious RE to our DCE responses with attributes and socio-demographic variables as its systematic components. This RE model that excluded PDs (partly due to empirical challenges in computational estimation) allowed us to discern whether DCE attribute coefficients were statistically different between countries. We implemented Chow-like test of equality of coefficients (Chow, 1960) after pooling Norwegian and Swedish data to test the null hypothesis (H_0):

$$\beta_P = \beta_N = \beta_S, \quad (5)$$

where β_P is a coefficient vector from the pooled data, β_N is a coefficient vector from the Norwegian data, β_S is a coefficient vector from the Swedish data, and alternative hypothesis (H_1) being $\beta_P \neq \beta_N \neq \beta_S$.

Post ICLV and RE estimations, we calculated marginal willingness-to-pay (MWTP) to quantify the perceived utility for DCE attributes (Juutinen et al., 2014). It can be used to assess trade-offs an individual makes in his or her choice between the attribute levels (Boxall et al., 1996). MWTPs were obtained as marginal rate of substitutions between non-monetary attributes and monthly tax attribute:

$$MWTP_m = -\left(\frac{\widehat{\beta_m}}{\widehat{\omega}}\right) \ \forall m \in M. \quad (6)$$

where M = {*set-aside, tree age variation*, *tree composition*} and m are its elements, $\widehat{\beta_m}$ and $\widehat{\omega}$ denotes estimated coefficients for non-monetary DCE attributes and the monthly tax attribute from eq. 4, respectively. All estimations were conducted in Stata MP 18.0.

4. Results

4.1. Descriptive statistics

Table 3 shows descriptive statistics of our sample which can considered as an adequate representation of the adult population in both countries. Our sample had nearly equal gender representation with a slightly higher proportion of males. The average respondent age was about 45 in both countries. Some 42% of Norwegian and 38% of Swedish respondents self-reported having a bachelor's or higher academic degree. These values correspond with those reported in official statistics at EU level with minor deviations. Tests reveal that the gender proportions in both country samples are not significantly different from the values reported in official EU statistics, but average ages are slightly lower. Official EU statistics in 2022 reports that proportion of male and female was 50.5% and 49.5% in Norway and 50.3% and 49.7% in Sweden; average age of adults over 18 years old were 48.6 for Norway and 49.7 for Sweden, and 42.2% of adults (18–69 years) in Norway and 41.4% in Sweden have tertiary education (Eurostat, 2022).

4.2. Confirmatory factor analysis

We obtained the same three-latent variables solution for both countries after omitting items with low internal consistency. Our solution had sufficiently acceptable fitness thresholds except for a slightly lower factor loading of Hyp3 than the threshold in the Swedish sample

Table 3
Descriptive statistics of socio-demographic profiles of respondents by country.

	Norway (n = 660)	**Sweden** (n = 1517)
Gender† (%)		
Male	50.76	49.97
Female	48.79	49.51
Not reported	0.45	0.53
Age†‡ (years)	44.94***	45.83***
	(6.23)	(16.30)
Annual household income₸ (%)		
< 400,000 NOK (< 300,000 SEK)	30.15	27.16
400,000– 700,000 NOK (300,000– 600,000 SEK)	35.15	41.73
700,000– 1.2 million NOK (600,000– 900,000 SEK)	26.21	20.76
> 1.2 million NOK (> 900,000 SEK)	6.67	9.49
Not reported	1.82	0.86
Education⁑ (%)		
Elementary	6.36	6.53
Secondary	34.09	36.39
Post-secondary	16.21	18.52
Bachelor's degree or equivalent	29.09	27.09
Master's degree or equivalent	12.73	10.55
Ph.D. or equivalent	1.06	0.66
Not reported	0.45	0.26

† Binomial test or two-sided t-test of equal means (* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$) between country sample and corresponding values reported in official EU statistics.
‡ Standard deviations in parentheses.
₸ Income criteria for Swedish sample in parentheses.
⁑ University education of 3 and 4 years considered Bachelor level in Sweden. University education of 5 years is considered Master level.

(Table 4). Sp1, Sp2 and So1, So2 were loaded on the first latent variable; this can be interpreted as spatial and social proximity to climate change (SpSo-P). Tem3R and Hyp1R (reverse-coded Tem3 and Hyp1) were loaded on the second latent variable; this represents temporal and hypothetical proximity to climate change (TemHyp-P). Reverse-coding of Tem3 and Hyp1 was to ensure that the second latent variable could be interpreted in terms of proximity as other latent variables. Hyp2 and Hyp3 were loaded on the third latent variable; this represents hypothetical proximity to climate change (Hyp-P).

4.3. Integrated choice and latent variable model

4.3.1. Measurement and structural equations

Table 5 shows coefficients, standard errors and p-values of our measurement and structural equations of latent PDs to climate change. All measurement items for SpSo-P were positive and strongly significant in both countries ($p < 0.001$), indicating that SpSo-P can be interpreted as spatial and social proximity. Different from our CFA solutions, only Tem3R was used to measure TemHyp-P due to non-convergence of the models when Hyp1R was included. Tem3R has a positive and significant coefficient in both country samples ($p < 0.05$). This indicates that the interpretation of TemHyp-P in our ICLVs is actually limited to temporal proximity (henceforth referred to as Tem-P). Regarding Hyp-P, Hyp2 was significant in both country samples but Hyp3 was significant only in the Swedish sample ($p < 0.001$). This indicates Hyp-P can be interpreted as hypothetical proximity with a stronger connotation in the Swedish sample. We also estimated an ICLV where all the items comprising SpSo-P, Tem-P and Hyp-P were loaded onto a single latent variable (Ov-P), since multiple dimensions may jointly change overall perceived distance to climate change (Maiella et al., 2020; McDonald et al., 2015). All loaded items were positive and significant in both countries ($p < 0.001$), indicating that Ov-P may be interpreted as overall proximity (encompassing spatial, social, temporal and hypothetical dimensions) to climate change.

Structural models show that latent PDs to climate change are explained by observed individual socio-demographic characteristics. Spatial and social proximity was positively associated with education ($p < 0.05$) but had an inverse relationship with age in the Norwegian sample ($p < 0.001$); in the Swedish sample, being male was the sole and negative predictor ($p < 0.001$). Temporal proximity had a significant and positive relationship with age in both countries ($p < 0.05$); in Sweden, being male had an inverse relationship but education and age were positively related ($p < 0.05$). Hypothetical proximity was positively correlated with education in the Norwegian sample ($p < 0.001$); in the Swedish sample, being male had a negative relationship ($p < 0.05$), while education had a positive association ($p < 0.001$). Overall proximity was positively associated with education ($p < 0.05$) and had a

Table 4
Standardized factor loadings, composite reliability, average variance extracted and heterotrait-monotrait discriminant validity of latent variables in the measurement model of PDs to climate change, by country.

Latent variables	Items	Standardized factor loadings	CR	AVE	HTMT		
					SpSo-P	TemHyp-R	Hyp-P
Norway (n = 660)							
SpSo-P	Sp1	0.833***	0.882	0.654		0.189	0.382
	Sp2	0.843***					
	So1	0.829***					
	So2	0.722***					
TemHyp-P	Tem3R	0.774***	0.819	0.701	0.189		0.456
	Hyp1R	0.896***					
Hyp-P	Hyp2	0.775***	0.715	0.558	0.382	0.456	
	Hyp3	0.718***					
Sweden (n = 1517)							
SpSo-P	Sp1	0.884***	0.915	0.732		0.239	0.382
	Sp2	0.901***					
	So1	0.860***					
	So2	0.772***					
TemHyp-P	Tem3R	0.898***	0.799	0.678	0.239		0.479
	Hyp1R	0.742***					
Hyp-P	Hyp2	0.853***	0.717	0.578	0.382	0.479	
	Hyp3	0.655***					

SpSo-P: spatial and social proximity; TemHyp-P: temporal and hypothetical proximity; Hyp-P: hypothetical proximity.
CR: composite reliability; AVE: average variance extracted; HTMT: Heterotrait-monotrait discriminant validity.
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 5
Measurement and structural equations of integrated choice and latent variable models by country.

	Norway (n = 657)				*Sweden (n = 1509)*			
	SpSo-P	Tem-P	Hyp-P	Ov-P	SpSo-P	Tem-P	Hyp-P	Ov-P
Measurement component								
Sp1	1.715***			1.661***	2.171***			2.054***
	(0.180)			(0.158)	(0.152)			(0.129)
Sp2	1.753***			1.904***	2.355***			2.436***
	(0.163)			(0.161)	(0.147)			(0.153)
So1	1.785***			1.625***	1.887***			1.856***
	(0.183)			(0.147)	(0.110)			(0.102)
So2	1.158***			1.141***	1.359***			1.349***
	(0.117)			(0.112)	(0.080)			(0.078)
Tem3R		1.483***		0.295***		0.563**		0.486***
		(0.073)		(0.064)		(0.165)		(0.044)
Hyp2			0.864***	0.927***			2.656***	1.121***
			(0.142)	(0.081)			(0.559)	(0.066)
Hyp3			2.661	0.775***			0.882***	0.734***
			(1.728)	(0.076)			(0.069)	(0.050)
Structural component								
Gender	−0.086	0.067	0.039	−0.069	−0.219***	−0.320*	−0.132*	−0.216***
(Male)	(0.084)	(0.099)	(0.100)	(0.083)	(0.054)	(0.132)	(0.057)	(0.054)
Education†	0.173*	0.136	0.336***	0.202*	0.059	0.331*	0.208***	0.086
	(0.088)	(0.104)	(0.090)	(0.088)	(0.056)	(0.138)	(0.060)	(0.056)
Age	−0.010***	0.006*	−0.005	−0.010***	0.001	0.017**	0.003	0.001
	(0.002)	(0.003)	(0.003)	(0.002)	(0.002)	(0.005)	(0.002)	(0.002)
Income‡	0.088	0.107	−0.028	0.074	0.037	−0.068	−0.001	0.029
	(0.092)	(0.111)	(0.094)	(0.091)	(0.058)	(0.124)	(0.063)	(0.058)

SpSo-P: spatial and social proximity; Tem-P: temporal proximity; Hyp-P: hypothetical proximity; Ov-P: overall proximity to climate change, a combined measure of SpSO-P, Tem-P, and Hyp-P.
Standard errors in parentheses.
† Below bachelor or equivalent = 0; Equal or above bachelor or equivalent = 1.
‡ Norway: <700,000NOK/year = 0, ≥700,000NOK/year = 1; Sweden: <600,000SEK/year = 0; ≥600,000SEK/year = 1.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

negative relationship with age ($p < 0.001$) in the Norwegian sample, while had an inverse relationship with being male ($p < 0.001$) in the Swedish sample.

4.3.2. Choice models

Table 6 shows coefficients, standard errors clustered at the i^{th} respondent level, *p*-values, and goodness-of-fit indicators (Log-likelihood, Akaike information criterion, Bayesian information criterion) of choice component of our four ICLVs and RE. ICLV 1 included SpSo-P, ICLV 2 included Tem-P, ICLV 3 included Hyp-P, ICLV 4 included Ov-P as a latent variable, respectively. In all ICLVs, variances of the error term of latent PDs to climate change were constrained at one to identify the model (Groothuis et al., 2021; Vij and Walker, 2016). RE included DCE attributes and socio-demographic variables as its components but latent PDs to climate change were excluded. Strong statistical significance of random-effects in all models support controlling for unobserved individual-level effects, and points to evidence of unobserved heterogeneity at the respondent level. Much higher absolute values of goodness-of-fit indicators of ICLVs than REs reflect on the greater complexity of ICLVs.

We found significant effects of latent PDs to climate change on the stated choice across all ICLVs. Overall, our results indicate positive relationships between psychological proximity to climate change and preference for biodiversity-augmenting changes in forest management. In the Norwegian sample, all types of climate proximity were associated with higher probability to choose an alternative strategy compared to the *status quo* ($p < 0.001$). Similar patterns were found in the Swedish sample, with temporal proximity not as strongly significant as the Norwegian case ($p < 0.05$).

Positive and significant coefficients of DCE attributes levels suggest a higher utility compared to the *status quo* levels (e.g. baseline set-aside: 5%), and negative and significant coefficient of monthly tax attribute shows disutility associated with higher taxation payments. Size, sign, and significance of coefficients of DCE attributes were not considerably different between ICLVs and REs except for ICLV 2 in the Swedish sample. Norwegian respondents attached higher utility for increasing set aside areas to 10% and 20% ($p < 0.001$) and preferred introducing one more broadleaved species (ICLV 1, 2, 4, and RE, $p < 0.05$); but they were indifferent to changes in other attributes in all ICLVs. Swedish respondents showed higher utility for changes in all of the forest management attributes, irrespective of model specifications. While we point to some differences in mean values, we cannot conclude that DCE preferences were statistically different between the two samples. Results from a Chow-like test of equality of coefficients revealed that DCE coefficients were not statistically different ($\chi^2 = 15.34$, *degree of freedom* = *11*, $p = 0.168$) between countries.

We also found significant effects of socio-demographic variables on stated choice. In the Norwegian sample, education had a positive and significant association with probability to choose an alternative strategy in ICLV 1 and 2, and RE ($p < 0.05$); age was negatively associated in ICLV 2 and 3, and RE ($p < 0.05$). In the Swedish sample, education had a positive relationship with stated choice for alternative strategy in ICLV 1, 3, 4 and RE ($p < 0.01$); age did not have a significant effect in any of the ICLVs. Gender and income were not significant in any of ICLVs and REs in both countries.

4.4. Marginal willingness to pay (MWTP)

Table 7 shows MWTP point estimates, standard errors and *p*-values across estimated models, by country. There were no large differences in estimated MWTP values between models. The public in both countries commonly had the highest MWTP for increasing set aside to 20% of total

Table 6
Results from random-effects model and choice equation part of integrated choice and latent variable models by country.

	Norway					Sweden				
	ICLV 1	ICLV 2	ICLV 3	ICLV 4	RE	ICLV 1	ICLV 2	ICLV 3	ICLV 4	RE
Attributes ₸										
Set aside	0.456***	0.453***	0.460***	0.456***	0.449***	0.503***	0.684***	0.499***	0.501***	0.497***
10%	(0.120)	(0.123)	(0.122)	(0.121)	(0.120)	(0.076)	(0.173)	(0.076)	(0.076)	(−0.075)
Set aside	0.487***	0.485***	0.485***	0.487***	0.472***	0.702***	0.943***	0.694***	0.701***	0.684***
20%	(0.133)	(0.134)	(0.133)	(0.133)	(0.132)	(0.088)	(0.220)	(0.088)	(0.088)	(−0.087)
+Uneven-aged	0.032	0.029	0.033	0.033	0.025	0.321***	0.404**	0.308***	0.319***	0.304***
10%	(0.127)	(0.129)	(0.128)	(0.127)	(0.127)	(0.089)	(0.132)	(0.089)	(0.089)	(−0.088)
+Uneven-aged	−0.122	−0.128	−0.119	−0.121	−0.125	0.256**	0.320*	0.245**	0.253**	0.246**
20%	(0.124)	(0.126)	(0.125)	(0.124)	(0.124)	(0.085)	(0.124)	(0.085)	(0.085)	(−0.085)
One more	0.185	0.186	0.181	0.185	0.18	0.393***	0.531**	0.394***	0.394***	0.383***
Conifer	(0.126)	(0.128)	(0.127)	(0.126)	(0.126)	(0.088)	(0.158)	(0.089)	(0.088)	(−0.088)
One more	0.274*	0.282*	0.269	0.274*	0.271*	0.327***	0.448**	0.330***	0.328***	0.319***
Broadleaved	(0.137)	(0.139)	(0.138)	(0.137)	(0.136)	(0.090)	(0.149)	(0.090)	(0.090)	(−0.089)
Monthly tax	−0.004***	−0.004***	−0.004***	−0.004***	−0.004***	−0.004***	−0.006***	−0.004***	−0.004***	−0.004***
	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(0.001)	(<0.001)	(<0.001)	(<0.001)
Socio-demographics										
Gender:	0.159	0.083	0.092	0.154	0.115	0.109	0.524	0.047	0.115	−0.035
Male	(0.193)	(0.198)	(0.195)	(0.193)	(−0.196)	(0.120)	(0.412)	(0.121)	(0.119)	(−0.122)
Education†	0.407*	0.446*	0.316	0.381	0.515*	0.430**	0.054	0.345**	0.410**	0.471***
	(0.200)	(0.203)	(0.204)	(0.201)	(−0.201)	(0.125)	(0.328)	(0.128)	(0.125)	(−0.129)
Age	−0.010	−0.019**	−0.013*	−0.010	−0.015*	−0.001	−0.031	−0.002	−0.001	0.000
	(0.006)	(0.006)	(0.006)	(0.006)	(−0.006)	(0.004)	(0.021)	(0.004)	(0.004)	(−0.004)
Income‡	0.035	0.029	0.102	0.039	0.088	−0.007	0.152	0.017	−0.002	0.011
	(0.207)	(0.214)	(0.208)	(0.206)	(−0.212)	(0.132)	(0.263)	(0.133)	(0.131)	(−0.136)
Random-	4.360***	4.576***	4.390***	4.317***	4.582***	3.719***	6.993*	3.810***	3.670***	4.041***
effects ⸸	(0.522)	(0.556)	(0.531)	(0.518)	(0.543)	(0.295)	(3.077)	(0.303)	(0.292)	(0.315)
Constant	0.158	0.143	0.167	0.160	0.138	−0.308	−0.384	−0.299	−0.308	−0.294
	(0.319)	(0.324)	(0.320)	(0.319)	(−0.317)	(0.217)	(0.301)	(0.218)	(0.217)	(−0.215)
Latent variables										
SpSo-P	0.553***					0.660***				
	(0.114)					(0.070)				
Tem-P		0.542***					1.810*			
		(0.132)					(0.744)			
Hyp-P			0.587***					0.629***		
			(0.128)					(0.076)		
Ov-P				0.596***					0.694***	
				(0.116)					(0.071)	
Obs.	3285	3285	3285	3285	3285	7545	7545	7545	7545	7545
n	657	657	657	657	657	1509	1509	1509	1509	1509
Log-likelihood	−21,211.612	−7785.978	−12,692.706	−37,391.121	−1815.550	−46,523.000	−17,634.454	−28,378.942	−81,593.609	−4297.257
AIC	42,515.223	15,621.955	25,449.412	74,916.200	3657.100	93,137.998	35,318.908	56,821.883	163,321.2	8620.513
BIC	42,795.691	15,774.383	25,644.520	75,324.700	3736.363	93,456.715	35,492.124	57,043.600	163,785.4	8710.586

SpSo-P: Spatial and social proximity; Tem-P: Temporal proximity; Hyp-P: hypothetical proximity. Ov-P: overall proximity to climate change, a combined measure of SpSO-P, Tem-P, and Hyp-P.
Standard errors clustered at individual-level in parentheses.
AIC: Akaike information criterion; BIC: Bayesian information criterion.
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
₸ Reference level: set-aside 5%; 70% uneven-aged and 30% uneven-aged for Norway (90% uneven- aged and 10% even-aged for Sweden); one conifer.
† Below bachelor's degree or equivalent = 0; Equal or above bachelor's degree or equivalent = 1.
‡ Norway: <700,000NOK/year = 0, ≥700,000NOK/year = 1; Sweden: <600,000SEK/year = 0; ≥600,000SEK/year = 1.
⸸ Variance of the estimated random effects.

Table 7
Marginal willingness-to-pay estimates for selected forest management attributes, by model and country.

Models	Forest management attributes					
	Set aside 10%	Set aside 20%	+Uneven-aged 10%	+Uneven-aged 20%	One more conifer	One more broadleaved
Norway						
RE	9.74***	10.24***	0.54	−2.70	3.91	5.88*
	(2.67)	(2.93)	(2.75)	(2.72)	(2.73)	(2.97)
ICLV 1	9.84***	10.50***	0.69	−2.64	3.99	5.91*
	(2.67)	(2.93)	(2.74)	(2.71)	(2.72)	(2.97)
ICLV 2	9.65***	10.33***	0.63	−2.73	3.97	6.01*
	(2.68)	(2.92)	(2.74)	(2.72)	(2.73)	(2.97)
ICLV 3	9.89***	10.43***	0.70	−2.55	3.88	5.79
	(2.68)	(2.93)	(2.75)	(2.72)	(2.73)	(2.98)
ICLV 4	9.85***	10.52***	0.72	−2.62	4.00	5.92*
	(2.67)	(2.93)	(2.74)	(2.71)	(2.72)	(2.97)
Sweden						
RE	9.82***	13.49***	6.00***	4.86**	7.56***	6.29***
	(1.50)	(1.74)	(1.67)	(1.67)	(1.72)	(1.76)
ICLV 1	9.83***	13.73***	6.27***	5.01**	7.68***	6.39***
	(1.50)	(1.74)	(1.66)	(1.66)	(1.72)	(1.76)
ICLV 2	9.81***	13.54***	5.79**	4.59**	7.62***	6.43***
	(1.52)	(1.74)	(1.67)	(1.67)	(1.72)	(1.76)
ICLV 3	9.73***	13.52***	6.01***	4.77**	7.68***	6.43***
	(1.50)	(1.74)	(1.66)	(1.66)	(1.72)	(1.76)
ICLV 4	9.80***	13.71***	6.25***	4.96**	7.70***	6.42***
	(1.50)	(1.74)	(1.66)	(1.66)	(1.72)	(1.76)

Unit: Euro/month; 1 Euro (€) = 0.086 NOK = 0.084 SEK.
Standard errors in parantheses.
Estimates were obtained by δ-method.
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

forest area from the *status quo* of 5%. MWTP for increasing set aside area to 10% and 20% were 9.65– 9.89€/month and 10.24– 10.52€/month among Norwegian respondents, and 9.73– 9.83€/month and 13.49–13.73€/month among Swedish respondents, respectively. MWTP of Norwegian respondents for adopting one more broadleaved species was 5.88– 6.01€/month, but the estimate was not significant in ICLV 3. MWTP for adjusting the proportion of uneven-aged stands were only statistically significant ($p < 0.01$) in the Swedish sample. On average, Swedish respondents were willing to pay 5.79– 6.27€/month and 4.77–5.01€/month to increase the proportion of uneven-aged tree stands by 10% and 20%, respectively; and 7.56– 7.70€/month and 6.29– 6.43€/month for adding one more coniferous species and one more broadleaved species, respectively. We cannot say mean Norwegian and Swedish public's MWTPs were statistically different since Chow-like test of equality of coefficients were not significant (section **4.3,** *Integrated choice and latent variable model*).

5. Discussion

5.1. Public preferences and marginal willingness-to-pay for selected forest management attributes

Our results show that both Norwegian and Swedish public seemed willing to accept less intensive area management practices that could increase biodiversity. Both the Norwegian and Swedish public showed the strongest preference for increasing set-aside areas compared to prevalent *status quo* levels. This may reflect on common public perceptions in Nordic countries (Gundersen and Frivold, 2008) toward reducing the footprint of forest operations (e.g. tailoring the size of clear cuts without infringing public accessibility and visual enjoyment of forest structures).

Average MWTP values for set-aside attributes showed that increasing it to 10% provided a similar gain in utility and the higher category (i.e. increasing set-aside to 20%) elicited a higher degree of utility to Norwegians and Swedish participants (Table 7). In the Swedish sample, increasing set-aside area provided the highest utility among all attributes, followed by adjusting tree species composition and proportion of uneven-aged tree stands. This might suggest that the Swedish public places greater importance on species diversity than diversification of stand age structures. This finding seems congruent with those of Nordén et al. (2017), which reported that Swedish citizens were more willing to pay to diversify tree species than for changing forest stand age and structures through a DCE.

5.2. Measurement and structural equations for psychological distances to climate change

Our data provides a three-dimensional structure of psychological distances to climate change (Table 4). While such a structure is not identical to the conceptual four-dimensional structure of PDs to climate change (Liberman and Trope, 2014), it does not necessarily deviate from the conceptual structure since a degree of direct correlation among the dimensions of PDs to climate change exists (Spence et al., 2012). The loading of all the items constructing PDs to climate change onto a single latent variable (Ov-P, **Tables 5** and **6**) supports the argument that these multiple dimensions appear to be intertwined (Keller et al., 2022).

Associations found between socio-demographic characteristics and PDs to climate change seem country-specific. While we found no significant relationship between age and hypothetical proximity, Milfont et al. (2014) found an inverse association after surveying New Zealanders. The significant and negative association between being male and hypothetical proximity to climate change found by Milfont et al. (2014) was also found in our Swedish sample (Table 5, Hyp-P).

5.3. Psychological distances to climate change and stated choice for forest management strategies

Our results showed that all dimensions of psychological proximity to climate change were correlated with greater support for biodiversity-augmenting changes in forest management in both nations (Table 6). We contextualized our choice tasks in terms of climate strategy in forest management by explicitly explaining to participants that the forest management profiles in our DCE aimed to address climate change. Previous studies conducted in different contexts suggest that psychological proximity to climate change was positively associated with increased support for climate policy (Singh et al., 2017; Spence et al., 2012). Results from past studies and our own DCE point to how the public in both Norway and Sweden might deem biodiversity-augmenting changes in forest management as a more acceptable climate strategy than the *status quo*. Nevertheless, we offer a point of caution that our findings do not equate public preference for biodiversity-augmenting attributes to endorsement for particular climate strategies.

Our findings come from the analyses of cross-sectional data from a survey conducted in the summer of 2022. Nevertheless, PDs to climate change are not constant but subject to change due to new information and events (Keller et al., 2022). Some empirical studies (e.g. Demski et al., 2017; Zanocco et al., 2018) have reported that exposure to extreme weather events has increased perceived proximity to climate change based on samples from the UK and the US, while others studies conducted in Germany and France did not find such statistically significant relationship (Gärtner and Schoen, 2021; Guillard et al., 2019). Given the increasing likelihood of more frequent and impactful climate-induced events (Stott, 2016), and our own empirical estimates denoting the association between dimensions of PDs to climate change and preferences for forest management contextualized as addressing climate change, we posit that biodiversity-increasing changes in forest management attributes will have greater public support in the future.

5.4. Policy recommendations

Among selected attributes and based on corresponding average MWTP estimates, forest management practices expanding set-asides garner a wider public approval than the *status quo* in both countries. Increased adoption of silvicultural methods such as continuous-cover-forestry (Kim et al., 2021; Lundmark et al., 2016) might receive a wider public support in Sweden as the Swedish public showed statistically discernible support for the promotion of mixed species and uneven-aged stand structures. Feasibility of implementing such biodiversity-supporting changes needs to be thoroughly investigated for their net costs and potential socio-ecological barriers that might be spatially variable to some extent. Besides, implementation of these changes should be made at forest owners' volition and be likely combined with technical and financial support.

We note that respondents may have negative connotations to *status-quo* forest management even though our DCE described that production-oriented management and wood products could contribute to climate mitigation. Yet, the latter role of forest management and wood product supply is often neglected by the public and may lead to negative evaluations (Ranacher et al., 2017, 2020). This point might also be reflected in past syntax of public preferences for Nordic forest attributes and management practices (Gundersen and Frivold, 2008). Wood product-oriented management and value-added systems are ingrained in Nordic economies and have a particular role to play in rural regional economies. Communication efforts to inform the public of carbon storage and substitution effects of wood products could help increase public perception and the acceptability of a sector deemed integral to the bioeconomy goals in Nordic nations (Lindner et al., 2017). Nonetheless, we point to any communication effort with caution as scientific evidence, risk and uncertainty on the role of forest products in climate mitigation need to be fully presented, and the interpretation of public messages can be highly sensitive to socio-economic conditions (Johnston and Radeloff, 2019).

We found no evidence that DCE coefficients and MWTP estimates were statistically different between the Norwegian and Swedish samples. But our results do not necessarily imply that preferences for forest management are homogeneous across both countries, nor that the lack of statistical evidence of differences might support a pan-European over national-level forest management approaches - as seems intended by the New EU Forest Strategy (Edwards and Kleinschmit, 2013; Gordeeva et al., 2022; Onida, 2020). While public opinion is an essential input for forest management policy, country-specific contexts such as wood production level and a broad set of other natural and socio-economic conditions are of central considerations. As noted by the European Council, a one-size-fits-all approach without taking country-specific contexts into account can be counterproductive to achieving climate mitigation and adaptation through forest management (European Council, 2021).

5.5. Limitations and future research

Our study is not without caveats. Our empirical measurement for PDs to climate change might be susceptible to measurement errors owing to complexity of the concept and questionnaires in two different languages. For example, omission of Hyp1 in measurement equations in ICLVs compared to CFA in both samples may imply measurement errors in this item in both countries. Measurement error is a common challenge in multilingual survey with self-reported psychometric questions. We also acknowledge that, among others, the precision of our MWTPs is constrained to the specific framing and design of the DCE which are common issues for all empirical applications of DCE (Rakotonarivo et al., 2016; Weng et al., 2021). Hence, we only referred to signs and relative size of our estimated MWTPs when drawing policy recommendations.

We recommend future studies to investigate unobserved heterogeneity in perceived changes in utility arising from the implementation of alternative forest management attributes. Accounting for unobserved heterogeneity provide consistent WTP estimates and distributional effects of resource management decisions (Boxall and Adamowicz, 2002). Behavioral constructs other than PDs to climate change, such as environmental attitudes, have been associated with heterogeneous levels of utility in forest and peatland management (Faccioli et al., 2020; Meldrum, 2015). Similar efforts in the context of climate change and forest management could guide to a more effective and legitimate climate-oriented national forest management.

Several country-specific factors including forest history, wood production levels and public interest on climate change and biodiversity may construct public preferences for forest management in different ways. Hence, future studies are advised to investigate public preferences and their explanatory variables in multiple European countries with different forest and socio-economic conditions and compare similarities and differences with robust methods. Such an effort could manifest Europeans' perception on climate-oriented forest management and provide scholarly inputs on ongoing policy discussions on priority between national-level and European-level forest management.

6. Conclusion

Our study elicited public preferences for biodiversity-augmenting management attributes in family-owned production forests of Norway and Sweden. Forest management was described with three selected attributes: set-aside, tree age variation, tree species composition. Particularly, we investigated how psychological distances to climate change were associated with preferences using integrated choice and latent variable approach. Norwegian respondents showed higher utility for increasing set aside areas to 10% and 20% and introducing one more broadleaved specie. Swedish respondents preferred increase in all attributes. However, there was no evidence that preferences were statistically different between countries.

Psychological proximity to climate change was positively associated with the probability to choose biodiversity-augmenting alternative strategies. Everything else constant, respondents with closer social, temporal and hypothetical distances were more likely to choose alternative strategies. Temporal remoteness was inversely correlated with stated choice for alternative strategies. Our results show that, on average, the Norwegian and Swedish public both seemed to be willing to accept larger set-asides that could increase biodiversity. Our findings suggest that psychological proximity to climate change correlates with greater support for biodiversity-augmenting changes in management of family-owned production forests.

Our findings that greater psychological proximity to climate change was associated with preference for biodiversity-increasing changes may imply that demand for biodiversity in family-owned production forests might increase with exacerbating climate change impacts. Expanding set-aside areas will likely receive a wider public approval in both countries. Communication efforts to inform public of carbon storage and substitution effects of wood-based products could help increase the public's perception and acceptability of wood production as an integral bioeconomy transition in Nordic countries. The indistinguishability of preferences between both countries does not necessarily support a one-size-fits-all European forest policy approach; country-specific forest and socio-economic conditions should be considered when crafting national forest management decisions. Future studies are recommended to investigate unobserved preferential heterogeneity associated with behavioral constructs other than PDs to climate change, and compare similarities and differences in preferences and their explanatory variables among European countries with different forest and socio-economic conditions.

Author statement

This manuscript or a very similar manuscript has not been published, nor is under consideration by any other journal.

CRediT authorship contribution statement

Do-hun Kim: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Hanne K. Sjølie:** Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Investigation, Funding acquisition. **Francisco X. Aguilar:** Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

All data used in this manuscript are available online at the Harvard Dataverse (https://doi.org/10.7910/DVN/ZFNXFR).

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.forpol.2024.103201.

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This Thesis contributes to the growing forest bioeconomy literature by examining public values on wood products and forest management intensity, and by empirically analyzing trade-offs emerging from intensive forest management. It consists of four academic papers of thematic and geographical diversity. Results suggest that increasing wood production to meet forest bioeconomy goals is broadly acceptable, and policy instruments to balance and monitor trade-offs between production and other ecosystem benefits are warranted.

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