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Co-produced transformative knowledge to accelerate change for biodiversity

Food and biomass production systems are among the most prominent drivers of biodiversity loss worldwide. Halting and reversing the loss of biodiversity therefore requires transformative change of food and biomass systems, addressing the nexus of agricultural production, processing and transport, retailing, consumer preferences and diets, as well as investment, climate action and ecosystem conservation and restoration. The RAINFOREST project will contribute to enabling, upscaling and accelerating transformative change to reduce biodiversity impacts of major food and biomass value chains. Together with stakeholders, we will co-develop and evaluate just and viable transformative change pathways and interventions. We will identify stakeholder preferences for a range of policy and technology-based solutions, as well as governance enablers, for more sustainable food and biomass value chains. We will then evaluate these pathways and solutions using a novel combination of integrated assessment modelling, input-output modelling and life cycle assessment, based on case studies in various stages of the nexus, at different spatial scales and organizational levels. This co-production approach enables the identification and evaluation of just and viable transformative change leverage points, levers and their impacts for conserving biodiversity (SDGs 12, 14-15) that minimize trade-offs with targets related to climate (SDG13) and socioeconomic developments (SDGs 1-3). We will elucidate leverage points, impacts, and obstacles for transformative change and provide concrete and actionable recommendations for transformative change for consumers, producers, investors, and policymakers.

EXECUTIVE SUMMARY

The purpose of this scientific report is to provide stakeholders and policy actors with scientific evidence about policies, policy mixes and their interrelations with technologies to enable transformative change for biodiversity conservation. We focus our analyses and discussions on biodiversity conservation policies of the European Union (EU), using the recent European Regulation on Deforestation-free Products (EUDR) as a case study. Our approach includes a review of scientific literature and policy documents, quantitative analyses of survey data from a public consultation of the EUDR development process, interviews with business associations of affected industries and insights from position papers and press releases.

The first part of the report is dedicated to the challenges of designing policies for biodiversity. We discuss biodiversity loss, for example through deforestation, as a global externality and emphasize the role of trade as an important underlying driver. Given the unequal distribution of the societal costs and benefits of trade across the globe, environmental justice represents a key challenge in the design of international governance frameworks for biodiversity conservation. Past endeavours to create and implement such international frameworks and related policies are often criticized for being relatively ineffective. Opposing national economic interests are discussed as one main reason for that circumstance. We also discuss categorisations and assessment criteria and identified *economic feasibility*, *technological feasibility*, and *political feasibility* as especially useful criteria for the selection, design, and assessment of individual biodiversity policies as well as policy mixes.

Considering the political economy of biodiversity conservation and deforestation, we have a closer look at the role and influence of stakeholder groups on policy development processes and how diverging interests among such groups can lead to inefficient policies. We develop a theoretical model of stakeholder preferences and assess the position of different stakeholder groups towards 14 different anti-deforestation policies that were considered in development process of the EUDR. Although just some of our assumptions are confirmed by principal component analyses (PCA) and regression models, it becomes apparent that stakeholder groups differ in their interests and therefore positions towards different types of instruments. Given the relative power and coalition formation between stakeholder groups, their influence on the policy process can lead to inefficient outcomes in the sense that final policy proposals can become compromise solutions that rather cater to individual (economic) interests than to environmental goals. For example, interviews with business associations and analyses of position papers reveal opposition towards the EUDR, as the policy is assumed to lead to market distortions, high individual cost for technological developments, bureaucracy and further factors that cater protectionist interests and contribute to inefficiency.

The second part of the report focuses on the role of technology in the context of biodiversity policies. We analyse promising technological trends that can contribute to the monitoring and assessment of biodiversity and enable the effective implementation of policies. These technologies include digital data collection and survey tools, remote sensing, blockchain, data analysis and other enabling technologies. Remote sensing and technologies associated with supply chain transparency are especially relevant in the context of the EUDR, since companies must use and invest in these technologies in order to be EUDR compliant. We also discuss the role of policies as a driver of technological innovation, as assumed in the Porter hypothesis. Given the cost associated with the EUDR and its limited effect on innovation as reported in our interviews, it remains questionable if the EUDR will be a driver of innovation beyond merely enabling policy compliance.

We conclude that new technologies can serve as enablers of biodiversity-relevant sustainability transformations, which are complex, multi-faceted processes, involving long time frames and multiple actors. This complexity makes it necessary to apply a broad portfolio of synergetic instruments in a balanced policy mix rather than introducing single interventions. Different stakeholder positions but also technological developments should be carefully considered by policy makers in order to develop policy mixes that are both technologically feasible and acceptable by society. In the context of policy mixes for biodiversity, previous research suggests a five-step approach for developing effective and efficient policy mixes: 1) clarify the goals, 2) carefully evaluate existing programs, 3) be sensitive to the context, 4) monitor policy implementation and its results, 5) maintain flexibility so that policies can be changed in response to new information.

1 THE CHALLENGE OF DESIGNING POLICIES FOR BIODIVERSITY CONSERVATION

Developing policy solutions that address complex environmental issues is a challenging process. The complexity involved in the interrelations between species, ecosystems and human activity exceeds even the global challenge of climate change. In this chapter, we want to have a closer look at the underlying reasons that make it so difficult to develop feasible policies for biodiversity, using the European approach to combat deforestation as a policy case study. We first discuss the phenomenon of biodiversity loss as a global externality by elaborating global trade as a main driver, addressing environmental justice aspects and pointing out international policy endeavours to halt biodiversity loss that have been put in place so far. In the second chapter, we will discuss criteria for assessing and classifying biodiversity policies. The third chapter is dedicated to the political economy of biodiversity conservation and deforestation, emphasizing the role of stakeholders and stakeholder preferences in the process of designing socially feasible policies to prevent deforestation and associated biodiversity loss.

1.1 Biodiversity loss as a global externality

1.1.1 Global biodiversity loss and the role of trade

Biodiversity refers to the variety of life on Earth, including species, genetic diversity, ecosystems, and ecological processes (Mace, Norris, & Fitter, 2012). It is an essential component of nature and provides numerous benefits to humanity. The accelerated loss of biodiversity is often referred to as the ‘‘Sixth Mass Extinction’’, emphasizing the global extent of this phenomenon (Pievani, 2014). Indeed, about one million species around the world are estimated to be at risk of extinction due to human activities (IPBES, 2019). Meanwhile, previous international goals to stop the ongoing loss of biodiversity have not been met. Although being a global phenomenon, biodiversity and the risk of its loss are not equally distributed, and ecosystems vary strongly in the number of species they inhabit (Habel et al., 2013). While in areas of the Global North, such as Western Europe, with its dense population and history of industrialisation, many ecosystems have already been dramatically modified or degraded. Areas with the highest amount of species richness are often located along the equator, of which most belong to developing or emerging countries of the Global South. These regions are often home to so called “biodiversity hotspots” (Reid, 1998) that are particularly rich in a large number of endemic species, such as Madagascar or the Amazon rainforest. While still accounting for most of the world´s biodiversity, these regions are especially affected by drivers of biodiversity loss, in particular land use change for agricultural purposes, that is spurred by consumption in developed countries (IPBES, 2019).

Indeed, research suggests that global trade is a strong driver of biodiversity loss, accounting for about 30% of species extinction (Irwin et al., 2022; Lenzen et al., 2012). Consumption in developed countries is a major cause of this loss. The study of Wilting, Schipper, Bakkenes, Meijer, and Huijbregts (2017) shows that there is a large variation in biodiversity loss per citizen among countries, with increasing values as per-capita income increases. The study also found that more than 50% of the biodiversity loss associated with consumption in developed countries occurs outside their national borders. Irwin et al. (2022) developed an “extinction-risk footprint” that incorporates exported, imported and domestic risk of species extinction as a result of country-level consumption. Of 188 surveyed countries, 76 turned out to be importers of extinction risk, including countries like USA, Japan, Germany, France or United Kingdom. Sixteen countries were identified as net exporters of extinction risk. Those countries were predominantly located in Africa and included for example Madagascar, Côte d'Ivoire and Sri Lanka. For 96 countries, domestic consumption accounted for the largest component of the extinction-risk footprint, including emerging countries like Brazil, Indonesia and Mexico. The findings of the above-mentioned studies emphasize the need to approach biodiversity loss as a global systemic phenomenon and that there is often a geographical displacement between cause and effect of biodiversity loss between producing developing countries of the Global South and consuming developed countries of the Global North.

1.1.2 Deforestation associated biodiversity loss and international trade - The case of the EUDR

Forest ecosystems are home to a significant amount of the world's biodiversity. They harbour most of the terrestrial biodiversity, including 60,000 different tree species, 80 percent of amphibian species, 75 percent of bird species, and 68 percent of all mammal species (FAO and UNEP, 2020). Given that 10 million ha of forests are lost each year (Clancy et al., 2024), deforestation and forest degradation are key factors in the global loss of biodiversity. Trade with the EU is estimated to be associated with almost 250.000 ha of global deforestation each year (European Commission, 2021a). Similar to biodiversity loss as a global phenomenon, global deforestation is subject to international trade. It can be assumed that improved access to international markets increases demand for agricultural products which in turn increases local prices of agricultural products (Clancy et al., 2024). This price increase incentivizes more agricultural production, which is correlated with an increase in deforestation. This is especially the case for countries with a comparative advantage in producing such products. Examples of countries in which increases in agricultural and timber prices have led to increases in deforestation include Mexico, Tanzania, Thailand, Brazil, Costa Rica, Australia and Brazil (Robalino & Herrera, 2010).

The EU has committed to several international agreements and initiatives to counteract deforestation, including the UN sustainable development goal 15, the New York Declaration on Forests, the UN Convention on Biological Diversity, the Paris Agreement on climate change as well as the Glasgow leaders' declaration on forests and land use. Several EU policy instruments have been implemented to address deforestation and forest degradation directly and indirectly. These include the EU Timber Regulation (EUTR), as part of the forest law enforcement, governance and trade (FLEGT) action plan and the Renewable Energy Directive (RED). However, these policies are limited towards illegal logging (EUTR) as well as biofuels and bioenergy sources (RED) (Halleux, 2023). On 17 November 2021, the European Commission tabled the proposal of the EU Deforestation Regulation (EUDR). The goal of the final legislative text is to decrease deforestation and forest degradation caused by EU consumption and the associated expansion of agricultural land used to produce cattle, cocoa, coffee, palm oil, soy, wood and some derivate products thereof. It is based on a European Parliament resolution from 2020, which called for regulatory action to act upon global deforestation caused by the EU. In essence, the EUDR imposes mandatory due diligence requirements on operators and traders who intend to place the above-mentioned commodities and products thereof on the EU market or export them from the EU. Requirements include the collection of relevant information such as geolocations of commodity origin, a risk assessment and, in case a non-neglectable risk has been identified, a risk mitigation plan. In addition, affected companies are obliged to report annually on their due diligence obligations (European Commission, 2021c). Member States are responsible for enforcing the policy, including penalties for non-compliance. A benchmarking system will be introduced to classify producer countries according to whether they have a low, standard or high risk of producing non-compliant commodities or products. Associated obligations vary depending on the assigned risk level. The EUDR is related to the European Green Deal, the EU biodiversity strategy for 2030 and the farm to fork strategy (European Commission, 2021c). Due to its recency and relevance for both industry and biodiversity protection, the EUDR is used as a case study in this report and the focus of our empirical analyses.

1.1.3 Environmental justice aspects of global biodiversity loss

The previously mentioned geographical displacement and different historic developments of ecosystem exploitation in a globalized economy also raise normative questions of environmental justice between developed and developing countries. Do developed nations have a historic responsibility to account for the cost of environmental destruction caused by globalization and international trade? Is it just to sacrifice certain parts of the global environment (which often happen to be especially rich in biodiversity) for economic development in other parts? And, should the benefits and burdens of economic development be equally shared? Amodu (2019) concludes that it is not economically fair if the majority of profits and benefits emerging from biodiversity exploitation accrue in developed nations, if they do not use appropriate and available means to curb environmental degradation in affected developing countries. In addition, developing countries should not be expected to bear the environmental costs of global trade without receiving a fair share of the benefits and must not be expected to respect international treaties by which their environmental rights are threatened. In normative terms it is also questionable whether environmental policy always fulfils its primary purpose of protecting the environment and to what extent economic or other potentially conflicting objectives are included in the final policy design. Regarding EU politics, Berning and Sotirov (2024, p. 12) claim that there is an "underlying normative conflict of pursuing environmental and social sustainability leadership by seeking to mainly address the unsustainability of production practices in third countries through environmental trade policies, resulting in de-facto improvements in economic opportunities within the EU." From a social justice perspective, this normative conflict also emphasises the necessity to apply justice criteria to policy measures in order to internalize the cost of biodiversity loss as a global externality caused by trade. Doing so requires explicit accounting of all private and social costs and benefits of trade as well as measures to compensate for the distributional impacts of policy intervention.

1.1.4 International biodiversity policies, frameworks and conservation endeavours

With the intention to end the loss of biodiversity and promote a fair use and distribution of the benefits of environmental services, the global community implemented different policies and frameworks. In 2010, the world's nations agreed to a Strategic Plan to support the effective implementation of the Convention on Biological Diversity. The plan included the 20 Aichi Targets, of which none has been fully achieved on a global level until 2020 (IPBES, 2019; Kumar, 2020). In 2019, the Global Assessment Report on Biodiversity and Ecosystem Services (IPBS) emphasized the continuing dramatic deterioration of global biodiversity and the need for a significant increase in international action in light of the failure of achieving the Aichi targets (IPBES, 2019). The global agreement that followed post 2020 was The Kunming-Montreal Global Biodiversity Framework (GBF). It was adopted during the 15th Conference of Parties (COP15) of the UN CBD on December 2022. It consists of four goals and 23 targets for halting and reversing biodiversity loss, the fair use of biodiversity and implementations. The targets are supposed to be achieved by 2030 founding the basis of the convention's vision of ''living in harmony with nature'' by 2050. Innovative aspects of the GBF include a focus on IPLC`s rights and the targets 14 to 23, which propose "tools and solutions for implementation and mainstreaming”. However, it remains to be seen whether this time the global community will go beyond promises and ensure quality and effectiveness in tackling the main causes of biodiversity loss. Besides these policies and frameworks that have a clear focus on biodiversity, there are further global sustainability policies that take biodiversity as one of many different aspects into account, such as the sustainable development goals (SDG) 14 and 15 of the Paris Agreement. Moreover, there are international biodiversity policies of the European Union (EU) like the EU Natura 2000 and policies focusing on the protection of specific ecosystems, such as the already mentioned EUTR and EUDR of the European Union, which have been implemented to tackle deforestation in producer countries. National initiatives from countries that play a key role regarding the production or consumption of certain biodiversity-related commodities can also have a great effect on biodiversity, such as Brazil´s Soy Moratorium.

1.1.5 National interests in opposition to international conservation endeavours

A precondition for such international agreements to turn into effective policies is that they are adequately transferred into national law and that these laws are implemented and enforced. In case of the Aichi targets, however, the study of Buchanan, Butchart, Chandler, and Gregory (2020) suggests that on country level, most of the assessed member states appeared to make rather no or little progress, with more than a fifth estimated to be even moving away from certain targets and target elements. Apparently, national interests could conflict with the agreed demands of international biodiversity policy, which represents a national policy dilemma. The introduction of environmental policies can often be associated with additional costs for a country. For example, there is some evidence that countries refuse to raise environmental standards because of the fear of capital flight (Neumayer, 2001). This effect is referred to as ‘regulatory chill’ or ‘stuck in the mud’ (Mabey & McNally, 1999; G. Porter, 1999; Zarsky, 1997). In EU policymaking, coalitions of member states (among other interest groups) can occur, advocating for different policy designs (Sotirov, Winkel, & Eckerberg, 2021). In this policy making process, a member state might be obliged to implement an environmental policy it actually opposes. The member state might then lack commitment in the practical implementation of a policy or try to mitigate its impact on the ground (Winkel et al., 2015). The leeway that member states have in such a case is limited and at a certain point in this power game, EU institutions might intervene (Borrass, Sotirov, & Winkel, 2015). With biodiversity being a global common, it is also subject to the tragedy of commons (Hardin, 1968; Rankin, Bargum, & Kokko, 2007). It is therefore necessary that the benefits of implementing biodiversity policies are shared with all or at least a lot of other countries.

1.2 Categorisations and assessment criteria for policies and policy mixes

1.2.1 Classifications of biodiversity policies

Within the field of environmental policy, several classifications of policy instruments exist. For example, two major distinctions can be made between 'old' instruments, which are usually 'command-and-control' regulations, and so called 'new' environmental policy instruments (NEPIs) (Gunningham, Grabosky, & Sinclair, 1998; Jordan, Wurzel, & Zito, 2005; Wurzel, Zito, & Jordan, 2014; Wurzel, Zito, & Jordan, 2019). NEPIs can be further structured into informational (e.g., eco-labels and environmental management schemes), voluntary (e.g., voluntary agreements), and market-based instruments (e.g., eco-taxes and emissions trading (Wurzel et al., 2019). When focusing on the positions and preferences of stakeholders for policy solutions, the framework suggested by Börner and Vosti (2013) provides a valuable classification scheme. This classification structures environmental policy instruments into three basic mechanisms, based on how they are intended to influence human behaviour (Börner & Vosti, 2013):

1) Enabling Measures
2) Incentive-Based Instruments
3) Disincentive-Based Instruments

Enabling measures like improved technologies, environmental education, or credits are instruments, which foster general conditions that allow actors to behave in a way that environmental goals can be reached. *Incentive-based instruments*, such as subsidies, tax exemptions, and certifications as well as *disincentive-based* *instruments* like taxes/user fees, regulations, and fines encourage or discourage certain behaviours of actors so that environmental goals can be reached (Börner & Vosti, 2013).

In practice, so called *policy mixes* usually encompass a portfolio of instruments from multiple categories (Ring & Schröter-Schlaack, 2011). Some instruments may have the purpose of enhancing other instruments, such as the introduction of educational instruments to provide stakeholders with the necessary knowledge to enhance the outcome of a regulation. In other cases, incentivizing instruments are introduced to compensate for the cost of disincentivizing instruments, and some instruments might just jeopardize the objectives of other instruments (Ring & Schröter-Schlaack, 2011).

1.2.2 Selection and assessment criteria

For the evaluation and selection of policy instruments and mixes, aspects of feasibility need to be considered. However, different concepts of feasibility exist, and the term and the specific concepts applied need to be specified more precisely. For the purpose of this report, the concepts of *economic feasibility*, *technological feasibility*, as well as *political feasibility* are especially relevant. *Economic feasibility* refers to costs and cost-effectiveness criteria, i.e., the implementation and opportunity costs of policy action in relation to the environmental benefits achieved by an intervention (e.g., Euro per ton of CO2 emissions reduced or per river km restored) (Görlach, Interwies, Newcombe, & Johns, 2005). Considering the economic feasibility of policy instruments in specific contexts therefore helps to determine whether they are financially and economically viable in the short and long run. *Technological feasibility* is about whether an intervention can be technically realised and refers to the extent to which the required technology to implement a particular solution is actually available and competitive (Skodvin, 2007). As an example, a policy that requires companies to avoid activities that are harmful to biodiversity hinges on available technologies for biodiversity monitoring in order to be technologically feasible. *Political feasibility* can be defined as "the relative likelihood that a policy proposal or alternative, and a variety of modifications to that alternative, could be adopted in such a way that a policy problem is solved or mitigated" (Webber, 1986, p. 547). In the context of environmental policy, Skodvin

(2007) defines political feasibility as a function of three main categories of constraint, which are i) the distribution of costs and benefits associated with environmental regulation among target groups ii) the distribution of power among and between target groups and decision-makers; and iii) the institutional setting within which decision-making takes place. We also see behavioural change as an important aspect of political feasibility, since policy measures can only be effective if actors, no matter on which level (policy maker, industry, consumer etc.) can and are willing to actually implement them.

Doremus (2003) suggests metrics for explicitly evaluating biodiversity policy mixes. Those metrics are *feasibility*, *effectiveness*, *fairness*, and *effects on the future*. The *feasibility* metric asks whether the policy or policy mix can be adopted and implemented by taking political barriers, costs, and informational requirements into account. *Effectiveness* is given when the desired conservation benefits are achieved. It is difficult to predict and just as it is the case for feasibility, information is crucial to evaluate effectiveness. The necessary biological information is often a limitation factor. Information is as crucial to effectiveness as it is to feasibility. *Fairness* is closely related to feasibility. Policies that are perceived as fair by stakeholders are more likely to be easily accepted and implemented. It is a quite vague concept that is highly dependent on context. A major aspect of fairness is the distribution of costs and benefits among affected actors. *Effects on the future* are the final factor that needs to be considered. Temporal durability is an important factor since biodiversity conservation is a long-term endeavour that implies the goal of future generations being able to benefit from the values of biodiversity such as ecosystem services. undertaken in the hope that future generations can enjoy the option and existence values of biodiversity, the experience of nature, and the benefit of ecosystem services. However, policies and policy mixes should still be flexible enough to respond adequately to unexpected developments. Doremus (2003) also provides some general guidelines for developing a successful and feasible policy portfolio in form of a five step approach:

1) Clarify the goals: Effective biodiversity policies require clear goals. It should be defined what is meant by *biodiversity*, what exactly to protect and on which aspects to focus on (species, specific types of ecosystem etc.). In a policy outline, it should be addressed how much protection is desired and how to achieve that (e.g., is preventing the extinction of a species a sufficient conservation effort?). In addition, societal goals besides mere conservation goals need to be considered. Especially the distribution of wealth needs to addressed since the costs will be distributed differently depending on the respective policy mix.

2) Carefully evaluate existing programs: In many cases, a certain set of policy measures is already in place. An assessment of these measures, e.g., via a survey regarding their stated purposes and their extent should be used to evaluate a policy mix in terms of risk of failure, uncertainties, and consistency with the goals defined in the first step. Gaps in the portfolio should be identified and highlighted and most valuable instruments to fill these gaps should be selected. The evaluation should not be limited to conservation purposes, but also consider related aspects such as tax and development policies or subsidies for habitat destruction as part of agricultural or public land policies. Government efforts should be surveyed as well as initiatives of NGOs and private societal actors.

3) Be sensitive to the context: The feasibility, effectiveness, and perceived fairness of a policy mix is highly context dependent. Context-specific aspects to consider include existing legal and political institutions (e.g., tax breaks will not be attractive incentives if taxes are already low), informational asymmetries between market actors, local and national attitudes toward government agencies, regulation, property rights, and conservation goals. In addition, the extent to which conservation requires restoration or positive management actions, rather than just control negative actions, should be carefully considered when deciding on a set of policy instruments.

4) Monitor policy implementation and its results: Monitoring the policy mix is crucial to its success. It should go beyond number tracking like enforcement actions, fines imposed, or land acquired, and also take into account conservation results, indicating whether and to what extent the selected policy portfolio contributes to achieving the conservation goals. This requires the goals defined in the first step to be both explicit and measurable. Ecological indicators can be used as proxies for monitoring general conservation objectives such as biodiversity or ecosystem health. Besides monitoring, the effectiveness of implementation efforts should be tracked and assessed.

5) Maintain flexibility so that policies can be changed in response to new information: Our limited knowledge about the biological and social prerequisites for conservation efforts to be effective leads inevitably to the failure of certain biodiversity policies. A policy mix with a broad portfolio of different instruments can reduce the risk of mistakes by single instruments. Policymakers should re-evaluate policy mixes on a regular base and in the light of most recent information. Finally, policy mixes should be designed flexible in order to respond to changes and new information.

When assessing policy mixes for biodiversity, two different pathways of analysis can generally be followed: i) Ex post analysis, where an already existing mix is analysed at a specific point in time and in a specific context, ii) Ex ante analysis, in where a new instrument is supposed to be introduced to an already existing portfolio of instruments (Ring & Schröter-Schlaack, 2011). In both cases the focus of the analysis can either be on a single (new) instrument using single instrument criteria or the overall mix with its policy interrelations using assessment criteria for policy mix analysis. Having discussed some of the classifications and evaluation criteria for policies and policy mixes for biodiversity, in the next chapter we will have a closer look at the policy options for biodiversity and forest protection with a focus on policy mix applied by the EU.

1.3 Policy mixes for biodiversity

1.3.1 The role of policy mixes for transformative change

European policymaking can be described as a multi-actor, multi-level governance arrangement in which various EU, national and regional authorities and stakeholders are involved in the design, implementation and evaluation of policies (Piattoni, 2010). Besides instrument-specific characteristics, the policies considered in this process must be assessed in the context of other policies that can have a reciprocal influence. In the context of economic transitions, a mixture of different instruments rather than single instruments is required to address not only traditional market failures like negative environmental externalities, but also structural and transformational system failures, like institutional failures or failures associated with steering the transformation process (Weber & Rohracher, 2012). The benefits of policy mixes for conservation efforts are that they allow to address divergent policy goals, to profit from synergies among different policy approaches and to reduce the risk of failure and pervasive uncertainty often associated with selecting the right policy instruments (Doremus, 2003). Especially environmental problems such as biodiversity conservation justify the application of policy mixes because of their *multi aspect character* (Braathen, 2007), which means that several aspects of the problem need to be tackled simultaneously. This makes it difficult to apply just a single instrument that is able to address the problem in a holistic way. However, developing suitable policy mixes for sustainable transformations is also challenging for various reasons: They usually span across multiple policy domains (e.g. innovation, market regulation or taxation), a lot of uncertainty about future developments is involved (e.g. technical, political, cultural), and the change process is highly complex (e.g., require changes in technology, infrastructure, social practices and market structures) (Kern, Rogge, & Howlett, 2019). Policy mixes that support sustainable transitions usually develop over time and it is necessary that new policies are compatible and add value in a productive way to those policies that are already in place (Schot & Steinmueller, 2018). Although a policy mix is beneficial in almost any context, the exact specifications for an optimal mix vary from case to case, given that they are highly context sensitive. The design of the mix must therefore carefully take into account the specific conservation goals, already existing programs and the local context (Doremus, 2003).

1.3.2 Options for biodiversity policies

With regards to policy mixes for biodiversity protection, Doremus (2003) points out the following spectrum of policy options, which are primarily based on examples for the USA. However, insights for policy options can also be derived for the EU context.

- *Educational programs:* Maintain and enhance societal commitments to conservation, increase capacity and the willingness of landowners to conserve.
- *Government acquisition of land or resource rights:* Purchase of land or purchase of a conservation easement by the government to either acquire all rights or tailoring the acquisition to the specific conservation goals, allowing owners to keep on using the land in a compatible way.

- *Direct incentives for private conservation action:* Encourage and reward positive conservation measures above the baseline set by regulation.
- *Market creation and improvement:* Useful adjuncts to either incentives or regulation, contribute to economic feasibility of conservation efforts or to take consumer preferences into account.
- *Regulatory prohibitions and requirements:* Prohibition of certain activities or limitation of the manner in which a certain activity is carried out. Enforcement of sanctions in case of non-compliance, regulations can therefore be equated to financial disincentives.

These options provide a general reference for policy measures that can be applied in the context of biodiversity conservation. A balanced policy mix should consider multiple of these options for the reasons discussed in previous chapters. The individual design and specifications of each measure needs to be in line with context specific factors. In the next section we give a brief overview of the policy mix applied by the EU to protect biodiversity with a focus on anti-deforestation policies.

1.3.3 The EU policy mix for biodiversity and forest protection

In the EU a biodiversity strategy has been adopted in 2020, which aims to protect ecosystems, halt biodiversity loss, and restore damaged ecosystems. The strategy includes a package of targets and measures for ecosystem restoration. These include the expansion of protected areas to 30% of the EU's land and sea, to ensure the sustainable management of nature across all sectors and ecosystems, to strengthen the EU biodiversity governance framework, knowledge, research, financing and investments as well as developing EU external actions to raise the level of ambition for biodiversity worldwide and to reduce the impact of trade and support biodiversity outside Europe (European Commission, 2021b).

The EU has two main nature conservation directives: The Birds Directive (2009/147/EC) and the Habitats Directive (92/43/EEC). These directives are central parts of EU biodiversity policy, establishing a network of protected areas known as Natura 2000, which is supposed to provide legal protection for species and habitats across Europe (European Commission, 2024e). Biodiversity conservation is also supported through programs like the LIFE program, which funds projects related to nature conservation, biodiversity, and climate action. Additionally, biodiversity considerations are integrated into agricultural and rural development policies through funding mechanisms like in the Common Agricultural Policy (CAP). The CAP is designed to integrate biodiversity considerations into agricultural practices and rural development. It includes measures such as agri-environmental schemes, sustainable farming practices, and support for biodiversity-friendly farming (European Commission, 2024a). Research and innovation in biodiversity conservation is fostered via programs like Horizon Europe. These programs support scientific research, technology development, and knowledge sharing to address biodiversity challenges. The EU also engages in international cooperation on biodiversity issues through platforms such as the Convention on Biological Diversity (CBD) and the United Nations Sustainable Development Goals (SDGs).

Within the EU´s broader biodiversity and environmental strategies, deforestation policies play a crucial role. A Forest Strategy that includes measures for sustainable forest management, forest protection, and combating illegal logging has been developed and the EU Forest Action Plan outlines specific actions to promote biodiversity conservation and sustainable forestry practices (European Commission, 2024c).

The new EU Regulation on Deforestation-free Products (EUDR) is used as a case study in this report due to its high current relevance for the EU and its trading partners' agricultural sector, its importance for the EU's endeavours in forest protection and associated biodiversity conservation as well as its high dependence on enabling technologies. With implementation of the EUDR, the EU intended to address deforestation associated with EU consumption of agricultural commodities like soy, palm oil, beef, cocoa, coffee, rubber, timber and associated products. It requires companies exporting, importing or offering these products on the EU market to ensure via a due diligence process to ensure their supply chains are deforestation free and comply with the law of the country of production. The EUDR replaces the EU Timber Regulation (EUTR), which was supposed to prohibit the placement of illegally harvested timber and timber products on the EU market (European Commission, 2021c). The EU's approach also involves the action plan Forest Law Enforcement, Governance and Trade (FLEGT) It aims to ensure that only legally harvested timber and timber products are imported into the EU. The aforementioned EU Biodiversity Strategy for 2030 also includes domestic and global targets related to increasing forest coverage, improving forest health and resilience, and promoting sustainable forest management practices. By supporting initiatives such as the Tropical Forest Alliance (TFA), the Paris Agreement and the Convention on Biological Diversity (CBD), the EU tries to leverage global cooperation to address deforestation and biodiversity loss on a broader scale and collaborates with partner countries to promote sustainable land use practices and combat illegal deforestation. The EU also invests in research, monitoring, and data collection related to deforestation and forest conservation. This scientific approach is supposed to help inform policy decisions and implementation strategies aimed at reducing deforestation and promoting sustainable forest management.

1.3.4 An assessment of the EU policy mix for biodiversity and forest protection

A thorough assessment of the EU´s biodiversity and anti-deforestation policy mix would be beyond the scope of this report. However, considering some of the assessment criteria from Chapter 1.2, such as economic feasibility, technological feasibility, and political feasibility as well as our discussions of the global challenges associated with biodiversity loss, certain key aspects become apparent. With its measures, the EU has made significant efforts in raising public awareness and support for biodiversity conservation. Initiatives like the European Biodiversity Strategy 2030 have contributed to heightened awareness of biodiversity loss and the urgency of conservation efforts. However, while there is support in general, and also partial support for some specific measures (Berning & Sotirov, 2024), we see challenges in translating awareness into concrete actions at the individual and community levels. Behavioural change remains a significant hurdle, necessitating targeted and impactful outreach strategies. Stakeholder engagement has been an integral part of the development process of EU biodiversity policies, involving diverse actors such as environmental NGOs, businesses, academia, and local communities. Public consultations like in the case of the EUDR development showcase that. However, ensuring meaningful engagement and participation from all stakeholders, especially marginalized groups or stakeholders in third countries, remains a challenge. Not considering aspects of social justice sufficiently and involving producer countries in the process can be seen as one major shortcoming of the EUDR. Enhancing transparency, accessibility, and inclusivity in decision-making processes is essential to strengthen societal support and therefore political feasibility.

EU biodiversity policy development considers scientific evidence and technological advancements. Scientific research and data from organizations like the European Environment Agency (EEA) provide valuable insights into biodiversity trends and inform policy decisions. However, gaps persist in translating scientific knowledge into actionable policies and on-the-ground conservation efforts. Bridging the science-policy gap requires enhanced collaboration, knowledge exchange, and capacity building across sectors. Technological innovation plays a crucial role in biodiversity monitoring, assessment, and management. Programs such as Horizon Europe and Copernicus contribute to advancements in remote sensing, data analytics, and ecosystem modelling. Yet, there are challenges in ensuring widespread adoption and accessibility of these technologies, particularly among smaller organizations and stakeholders. This challenge becomes noticeable in the current implementation process of the EUDR, where affected companies face high cost for identifying or developing and implementing technologies in time to ensure compliance (Chapter 1.4). Overcoming technological barriers and promoting innovation diffusion are key priorities.

EU biodiversity policies demonstrate an emphasis on policy coherence and integration across various sectors. The Common Agricultural Policy (CAP) and directives like the Birds Directive and Habitats Directive reflect this integrated approach. However, challenges persist in aligning national policies and practices with EU-level objectives, leading to implementation gaps and inconsistencies. The regulatory framework for biodiversity conservation within the EU can be seen as robust, with clear directives and enforcement mechanisms. Yet, enforcement at the member state level may be uneven, leading to compliance challenges.

We conclude that policy mixes are often not efficient, as it is the case for the EU biodiversity and anti-deforestation mix. As a focus of this report, we will further discuss and examine the role of stakeholder positions as a potential cause of these inefficiencies in the next chapter. This also includes our analyses of EU consultation data, position papers and interviews with business associations, using the EUDR as a case study.

1.4 The political economy of biodiversity conservation and deforestation

1.4.1 The influence of stakeholder groups on environmental policy processes

The complex and diffuse nature of environmental issues like biodiversity and the heterogeneity of agricultural systems cause policies for sustainability transformations in agriculture to often affect a great variety of stakeholder groups (Santos, Antunes, Baptista, Mateus, & Madruga, 2006; van den Hove, 2000). The involvement of these different stakeholders in the policy process is not just in the self-interest of these stakeholders, but actively supported by policy makers with the goal to create policies that are more accepted and socially feasible (van den Hove, 2000). In EU politics, the regular involvement of stakeholders through instruments like public consultations, workshops, hearings or surveys has been promoted by the Commission's Better Regulation Agenda and became an essential part of the political process. The influence of these groups can be correspondingly large, especially when stakeholder groups with similar interests join together to form coalitions in order to exert a targeted influence on the political process with pooled resources and efforts (Heaney & Lorenz, 2013; Junk, 2019; Sabatier, 1988; Victor, Montgomery, & Lubell, 2018).

1.4.2 Opposing coalitions and stakeholder interests as a source of policy inefficiencies

While on the one hand, the involvement of stakeholders in the development process might lead to more feasible policy solutions (van den Hove, 2000), on the other hand, the impact of competing coalitions on the policy process might cause inefficiencies. For example, in the case of the EUDR, the study of Berning and Sotirov (2024) concluded that the final legislative text is a compromise solution, reflecting a mixture of pro- and contra regulatory policy beliefs and interests of different state and non-state actors. Two powerful coalitions of actors in favour of political change were successful in incorporating their position in the EUDR. If the outcome of an environmental policy process is subject to the power dynamics between coalitions of stakeholder groups with different or even opposing positions, interests and values, it is questionable that these outcomes fully represent an effective political contribution to an environmental challenge. Depending on the most successful coalitions, it might rather reflect individual economic interests, such as to maintain the regulatory status quo, maximise corporate profits, developing new markets or foster free trade. Such economic interests might potentially be achieved in synergy with environmental goals, but also bear the risk of jeopardizing sustainability endeavours. The latter was the case for the EUTR, which was strongly influenced by the strategic support of stakeholders from the forest and retail industry (Sotirov et al., 2021; Sotirov, Stelter, & Winkel, 2017), similar to the EUDR case. The incorporation of these stakeholders´ interests into the finally adopted policy design led to implementation and enforcement issues, limiting the EUTR´s regulatory effectiveness to achieve the intended sustainability goals such as reducing illegal deforestation (Leipold, Sotirov, Frei, & Winkel, 2016; McDermott & Sotirov, 2018; Moser & Leipold, 2021). However, when it comes to EU deforestation policies, coalitions in favour of environmental protection have, overall, been more successful in influencing the policy process during recent decades (Sotirov et al., 2021).

1.4.3 Stakeholders and stakeholder theory in the context of environmental policy

As a consumption-oriented deforestation policy, the EUDR affects a wide variety of actors which can be referred to as *stakeholders*. Stakeholder theory is an approach that emphasizes the importance of stakeholder´s interests and concerns in organisational decision-making processes (Freeman, 1984). It originated in the field of business management, but has also become very popular in the context of policy development within the last decades (Brugha & Varvasovszky, 2000). The theory recognizes that stakeholders have diverse and sometimes conflicting interests, values, and preferences (Freeman, 1984). This diversity among stakeholders is reflected in different positions towards policy development and can influence decision-making in policy development processes (Brugha & Varvasovszky, 2000; Kassinis & Vafeas, 2006). Besides stakeholders´ *positions* (level of support for or opposition to a policy), *interest* (concerns about how a particular policy will affect a stakeholder) and *power* (ability to affect policies via resource mobilisation) are characteristics that are commonly analysed in stakeholder analyses within the context of policy implementation research (Balane, Palafox, Palileo-Villanueva, McKee, & Balabanova, 2020; Gilson et al., 2012; Schmeer, 2000). As a participatory method, the stakeholder analysis is widely recognized as an important tool for improving the development and implementation of environmental policies (Lienert, Schnetzer, & Ingold, 2013). It can help policy makers and practitioners to better understand the interests, needs, and perspectives of different interest groups and individuals who may be affected by certain policy instruments. Analysing stakeholders also allows policy makers to gain a deeper understanding of the affected actors as well as potential societal impacts of selected policies or certain policy designs (Brugha & Varvasovszky, 2000). In the context of environmental resource management, Reed et al. (2009) define stakeholder analysis "as a process that: i) defines aspects of a social and natural phenomenon affected by a decision or action; ii) identifies individuals, groups and organisations who are affected by or can affect those parts of the phenomenon (this may include nonhuman and non-living entities and future generations); and iii) prioritises these individuals and groups for involvement in the decision-making process." A stakeholder analysis is usually done to identify and understand the involved actors. After this step, a social network analysis can be useful to further analyse the underlying relational patterns as well as the overall process structure (Lienert et al., 2013). Since a network analysis can be seen as an integral part of a stakeholder analysis, some authors do not even distinguish between these two approaches (e.g. Hermans & Thissen, 2009; Reed et al., 2009).

1.4.4 Relevant stakeholder groups of the EUDR

The policy process of the EUDR encompassed several stakeholder consultation initiatives as part of the impact assessment of demand-side measures to address deforestation and forest degradation. The primary purpose of these initiatives was to gain insights from different affected groups to follow a holistic approach in the policy design process and to get a good understanding of the effects that a new policy might have on actors from industries, society and politics. As part of the European Commission`s consultation strategy, relevant stakeholder groups have been identified (Wood Group, 2021). The results are summarized in Table 1.

Table 1: Stakeholder groups identified in the context of the European Commission´s impact assessment of demand-side measures to address deforestation and forest degradation as well as the respective roles and relation to EU deforestation policies of those stakeholder groups.

Stakeholder Group	Role/Relation to EU Deforestation Policies
EU Member State authorities	Responsible for implementing EU measures
Third-country stakeholders	Public authorities from these countries may be concerned with and/or affected by deforestation; they might be highly affected by new deforestation related EU policies
Farmers, both large-scale agri-businesses and small-scale local producers, including livestock producers, both large and small	Activities of this group sometimes contribute to deforestation by clearing forests for agricultural purposes; they can therefore be highly affected by new deforestation related EU policies
Logging, wood-processing companies and forest owners	This group may contribute to deforestation, even if legally, and therefore be affected by new deforestation related EU policies
Businesses operating with commodities associated with deforestation and forest degradation	Businesses might contribute to deforestation along their supply chains; businesses and their operations can therefore be affected by new deforestation related EU policies; can provide insides on potential economic effects of respective policies
Traders working with supply chains potentially associated with deforestation	Business operations in relevant industries (e.g. food products, timber products, mining products, etc.) of this group would be affected by new deforestation related EU policies
Citizens	Citizens from the EU and from third countries may be concerned with and/or affected by deforestation in their respective countries and have first-hand knowledge of current impacts; might have special interest with regards to social/environmental impacts

Consumers and consumer organisations	Would especially be affected by consumption-oriented deforestation policies
Civil society organisations and non-governmental organisations	Have a high interest in the issue of deforestation and in a broader sense the environmental and social effects that new EU deforestation policies might entail; can provide insides on potential environmental and social effects of respective policies
International organisations	Stakeholder in this group monitor deforestation and forest degradation on an international scale, which can contribute to a better understanding of the overall impact of EU consumption in a variety of countries, as well as how the situation has evolved over time
Research institutions	Provide scientific expertise in different areas associated with deforestation and deforestation policy, including environmental, social, economic and legal aspects

To ensure an effective implementation of the EUDR, the European Commission established a “Multi-Stakeholder Platform on Protecting and Restoring the World’s Forests”. This tool is supposed to facilitate the dialogue between stakeholder groups and regular meetings are used to present and discuss the main strands of work and identify best practices (European Commission, 2024b).

1.4.5 A theoretical model of stakeholder preferences and positions towards EU anti-deforestation policies

In this section we develop a theoretical framework on how stakeholder interests shape their position towards different types of deforestation policy. At the basis of our model, we expect stakeholders to prefer those instruments that do not restrict them, that allow them to gain control or contribute to their individual goals and interests. Stakeholder groups with an intrinsic motivation to attain policy goals and therefore influencing the policy process can be referred to as interest groups (Leifeld & Schneider, 2012). The groups we focus on in our framework and further analyses are Businesses, NGOs, Citizens and Research Organisations, which are summarized groups of actors considered in the EUDR consultation process. The two most prominent stakeholder- or interest groups are businesses (business associations and companies) and non-governmental or civil society organizations (NGO, CSO). These groups have been researched most extensively, including their lobbying behaviour, cooperation as well as differences and similarities between them in terms of policy preferences in the nexus of conflicting interests between economic competitiveness and stricter regulation (Abel & Mertens, 2023; Ingold, 2011; Ingold & Fischer, 2014; Ingold, Fischer, & Cairney, 2017). Table 2 provides a summary of our model assumptions of stakeholder preferences regarding mandatory and voluntary biodiversity policy instruments, as the most prominent instrument types.

Table 2: Summary of framework assumptions of stakeholder preferences for mandatory and voluntary biodiversity policy instruments.

Stakeholder Group	Mandatory Instruments	Voluntary Instruments
Business	Rejecting position, restricting businesses in their freedom to operate and increases cost of operation. Potentially supporting if economic benefits emerge along environmental goals	Supporting position, businesses are free to comply and decide on their investment
NGOs	Supporting position due to high effectiveness to achieve environmental goals	Rejecting position due to low effectiveness to achieve environmental goals
Citizens	Rejecting position if societal groups are targeted, supporting position if companies are targeted and measures are predominantly considered "fair" in society	Supporting position if societal groups are targeted
Science	Neutral, based on scientific evidence	Neutral, based on scientific evidence

For businesses in the forest industry, research indicates a general preference for “softer” instruments with little or no state involvement like voluntary and informational instruments (Dür, Bernhagen, & Marshall, 2015; Ohmura & Creutzburg, 2021). Compared to NGOs, they are also more in favour of keeping the status quo rather than supporting political change (Dür et al., 2015). However, regulatory instruments are still seen as important when they do not restrict businesses directly, but rather protect forests from further external demand from other sectors (Danley, 2019; Ohmura & Creutzburg, 2021). This is in line with the findings from Leipold et al. (2016), where in the context of EU timber legislation industry stakeholders tended to support regulations when they protect them from international competition. In the case of the EUTR, businesses valued the regulation with regards to fostering the "green image" of products and establishing a "level-playing-field", protecting sustainably operating companies from those who might generate a cost advantage by not complying with environmental standards (Leipold et al., 2016; Schwer & Sotirov, 2014). In some cases, businesses and (environmental) NGOs form strategic alliances to achieve common policy goals. These alliances are referred to as "strange bedfellowships" (Abel & Mertens, 2023; Beyers & Bruycker, 2018). Research associated with the Advocacy Coalition Framework indicates that economically motivated organizations (e.g., businesses) are more driven by self-interest than organizations motivated by an ideological position (e.g., NGOs) and that some actors appear to trade policy core beliefs for strategic short-term interests (Jenkins-Smith & St Clair, 1993; Nohrstedt, 2005). Considering the above-mentioned studies, it appears that business stakeholders' favour soft or no policy instruments at all, unless they benefit from those policies in terms of realizing competitive advantages, such as market protection from international competitors. This can nonetheless lead to business stakeholders supporting environmental policies if they happen to also contribute to these competitive advantages.

Environmental NGOs more often support policy change with the aim of harmonizing regulatory standards across Europe (Dür et al., 2015). They tend to promote stricter policies that are seen as contributing to achieving environmental goals effectively and protect forests from further exploitation (Leipold et al., 2016). In the context of EU forest-risk commodities legislations, civil society organisations have supported more comprehensive and stringent regulation, while businesses have pushed for less stringency and enforceability (Schilling-Vacaflor & Lenschow, 2023). In the context of the European Union Emissions Trading Scheme, environmental advocacy groups (consisting of both businesses and NGOs,) were in favour of mitigation measures, but mostly lobbied for stricter regulation with respect to target sectors, allocation modalities, and policy ambitiousness (Abel & Mertens, 2023). Since environmental NGOs are not primarily driven by economic interests, but rather ideals to protect nature and fulfil their members and donors expectations in contributing successfully to that mission (Beyers & Bruycker, 2018), they are in favour of strict and effective environmental policies.

For civil society actors, research indicates that private forest owners are more in favour of soft instruments like voluntary measures (Danley, 2019; Ohmura & Creutzburg, 2021). However, non-industrial private forest owners only make up a very specific subgroup of civil society, who economically benefit from forests directly, therefore showing similar preferences like business groups. Citizens may support protectionist measures for sectors they consider as 'weak', in order to protect them from international competition (Lü, Scheve, & Slaughter, 2012; Naoi & Kume, 2015). Land users reject to bear a burden of which they think should be shared with society at large. They demand to be compensated for their conservation efforts and want autonomy in how and how much to conserve (Doremus, 2003). Studies in the field of climate policy also suggest that citizens highly support voluntary and supply-focused policies that set requirements for industry, while market-based instruments like carbon taxes and cap-and-trade are opposed (Lam, 2015; Rhodes, Axsen, & Jaccard, 2017; Tobler, Visschers, & Siegrist, 2012). Citizens are a very heterogeneous stakeholder group and tend to reject policies that affect themselves, while being supportive regarding policies that put the burden on businesses and policies that benefit disadvantaged groups. In general, the preference for certain policy types is driven by societal awareness and support of environmental conservation.

Scientific organizations (universities and non-university research institutions) are presumably neutral in the sense that they do not have an intrinsic motivation to attain specific policy goals, making it questionable to even classify them as interest groups (Leifeld & Schneider, 2012). Despite the general neutrality of research, different research fields and schools of thinking within research fields can have diverging focal points and perspectives on the same issue, which might lead to diverging policy recommendations. This can especially be an issue for interdisciplinary research fields such as environmental policy research, in which, for example, environmental researchers predominantly focus on how policy can achieve environmental goals effectively, whereas economists rather focus on policy efficiency. Often scientific policy analyses are used to justify policy beliefs (Sabatier,

1988) and a well-balanced perspective across scientific disciplines is necessary to inform policy decisions. Given the relative objectivity and despite discipline-bias, we expect no universal preferences for or against certain policy instruments in this stakeholder group. Instead, we expect the science-base to most likely support policy mixes that balance environmental effectiveness with socio-economic factors in a specific situation.

1.4.6 Empirical research on stakeholder preferences towards EU anti-deforestation policies

Our quantitative analyses are based on a survey conducted by the European Commission as part of the public consultation process of the EUDR (European Commission, 2020). In addition, we analysed position papers of affected business associations and conducted interviews with German business associations representing the industries affected by the EUDR.

The public consultation survey used for the quantitative analyses was conducted from September 03, 2020 until December 10, 2020. The purpose of the consultation was to include stakeholders in the policy process and to consider their inputs on potential EU policy instruments to tackle deforestation and forest degradation associated with EU consumption. The results of the public consultation contributed to an impact assessment and to the subsequent development process of the EUDR. The questionnaire was open to the general public and 1148 participants responded to it (European Commission, 2021d). These participants comprised a broad variety of different stakeholders, including 816 (71%) EU citizens, 81 (7%) non-governmental organisations, 67 (6%) company/business organisations, 49 (4%) business associations, 42 (4%) non-EU citizens, 37 (3%) academic/research institutions, 12 (1%) public authorities, 11 (1%) environmental organisations, 4 (<1%) as trade unions and 31 (3%) other.

The questionnaire contained several stakeholder-related questions such as country of origin, organization size, industry sector, knowledge level on deforestation and private commitments to tackle deforestation. Other questions related to the role and contribution of different sectors, commodities and driving factors of deforestation as well as the kind of forests to prioritise and the obstacles faced by companies to effectively implement deforestation-free supply chains. In terms of possible policy options, 14 instruments were to be rated on a 5-point-Likert-scale in terms of their suitability to address the issue of deforestation and forest degradation associated with EU consumption, their effect on companies' and public authorities' cost of operation and implementation respectively, their impact on the participant's country of origin, and their effectiveness in terms of halting and reversing EU and global deforestation. The following instruments have been evaluated in the survey:

1) A deforestation-free requirement or standard that commodities or products in their product category must comply with to be placed on the EU market (and consequently a prohibition, in line with EU international commitments, of the placing on the market of commodities that do not comply with those standards)
2) Voluntary labelling (e.g. similar to organic labels for organic products)
3) Mandatory labelling (e.g. similar to nutritional information labels on food products)
4) Public national legality verification schemes, prohibited operators list, country carding system and export ban to the EU (a replication, with the necessary adaptations, of the EU legislation in place for illegal, unreported and unregulated (IUU) fishing)
5) Voluntary due diligence
6) Mandatory due diligence
7) Mandatory public certification system
8) Private certification systems, new and the ones already in place in the EU market
9) Build benchmarking or country assessments (e.g. index) showing which countries are exposed to and effectively combat deforestation or forest degradation for information purposes
10) Promotion through trade and investment agreements of trade in legal and sustainable products
11) Mandatory disclosure of information (including corporate non-financial reporting)
12) Development and cooperation assistance to producing countries
13) Consumer information campaigns in the EU

14) Green diplomacy

We used the question related to the suitability evaluation of an instrument as a proxy for the position of a stakeholder towards that particular instrument. Participants were asked as follows:

From the list below, which measures are the most suitable to address the issue of deforestation and forest degradation associated with EU consumption? Note that some of the measures presented below are complementary and could be combined. Please rate each measure on a scale of 1 to 5, 1 representing not suitable at all, 2 representing somewhat not suitable, 3 representing neutral, 4 representing somewhat suitable, 5 representing completely suitable.

We first conducted a principal component analysis (PCA) to test for evaluation patterns that separate groups of instruments which were distinct in how stakeholders evaluate their suitability. We used the 14 instruments as items and applied oblique rotation (oblim). All necessary assumptions and conditions for conducting a PCA were met: The Kaiser-Meyer-Olkin measure verified the sampling adequacy of the analysis KMO = 0.85 ("meritorious" according to Kaiser (1974)), and all individual KMO values were >0.72 for each item, which is well above the acceptable limit of .5. Barlett´s test of sphericity, χ^2 (91) = 5,840, $p < 0.001$, indicated that correlations between items were sufficiently large for PCA. An initial analysis was run to obtain eigenvalues for each component in the data. Three components had eigenvalues over Kaiser's criterion of 1 and four had eigenvalues over Jolliffe's criterion of 0.7, explaining 59% respectively 65% of the variance. The scree plot showed an inflection that rather justified the extraction of four factors, hence considering Jolliffe's criterion and the graphical analysis, four components were retained in the final analysis. Table 3 shows the factor loadings after rotation above the cut-off value of 0.3, which represent the relationship between the policy instruments and the four components. The items that cluster on the same components suggest that the first component represents mainly *mandatory policy instruments* e.g., mandatory labelling and mandatory public certification systems, the second component representing mainly *international policies* e.g., green diplomacy and development and cooperation assistance, the third component representing *voluntary policies* e.g. voluntary due diligence and voluntary labelling, and the fourth component representing instruments close to the *EUDR solution*, comprising of mandatory due diligence together with deforestation-free requirement and mandatory disclosure of information loading for this factor.

The results suggest that certain instruments are evaluated by stakeholders in a distinct way and can be grouped based on this evaluation. Differences in the nature of instrument types and stakeholder positions towards mandatory and voluntary types of instruments have been discussed in the NEPI literature, distinguishing between 'command-and-control' regulations and 'new' environmental policy instruments (Gunningham et al., 1998; Jordan et al., 2005; Wurzel et al., 2014; Wurzel et al., 2019). Differences in the suitability assessment of instrument types in these two categories might be based on differences in expected effectiveness and coerciveness for certain stakeholder groups. Whereas these two policy types affect stakeholders more directly, international policies can be distinct from them in the sense that they effect stakeholder just indirectly and on a higher level. Consumer information campaigns load on both Mandatory Instruments and International Instruments but not on Voluntary Instruments, which might be an indicator for the supporting role of consumer information campaigns for other policy measures, rather than being a stand-alone intervention. A special case is the component representing instruments close to the EUDR Solution, which also consists entirely of mandatory instruments loading on that component, with "deforestation free requirement or standard" loading on both EUDR Solution and Mandatory Instruments. This might be a result of the policy process and the context in which the consultation process took place. A mandatory due diligence solution might have already emerged as a likely or prioritized solution, leading to a distinct evaluation pattern among stakeholders for these particular instruments under discussion.

Taking our framework of stakeholder preferences into account, we can now derive assumptions on how different stakeholder groups position themselves towards these groups of instruments in relation to other groups. It is assumed that businesses will rather reject mandatory instruments, including the EUDR solution, contrary to NGOs who might favour these instruments due to their expected effectiveness. Since the instruments within these groups primarily target companies and given a rather environmentally aware society in Europe, citizens are assumed to be in favour of these instruments, too. The research group might also diverge from the business position, since the evaluation should not be biased by self-interest, as it might be the case for businesses. The opposite is assumed for voluntary instruments, where businesses are expected to be more in favour compared to all other stakeholder groups. The international instrument group is an interesting case, since these instruments do not affect the actors directly but hold potential for being effective. Here, a high level of agreement could be present among stakeholder groups.

Table 3: Summary of exploratory factor analysis results for the suitability evaluation of 14 policy instrument alternatives to tackle deforestation and forest degradation associated with EU consumption (N=1148). Factor loadings represent the relationship between the policy instruments and the four components. Instruments can be grouped based on the components on which they load together.

	Oblim rotated factor loadings			
Item	Mandatory policies	International policies	Voluntary policies	EUDR solution
Mandatory labelling	0.79			
Public national legality verification schemes	0.76			
Mandatory public certification system	0.75			
Deforestation-free requirement or standard	0.61			0.38
Development and cooperation assistance		0.76		
Green diplomacy		0.75		
Promotion through trade and investment agreements		0.66		
Consumer information campaigns	0.41	0.56		
Build benchmarking or country assessments		0.46		
Voluntary due diligence			0.88	
Voluntary labelling			0.82	
Private certification systems			0.82	
Mandatory due diligence				0.79
Mandatory disclosure of information		0.37		0.44
Eigenvalues	2.89	2.54	2.34	1.40
Variance	21%	18%	17%	10%

Factor scores from the PCA have been extracted to further analyse our assumptions regarding differences in the relationship between stakeholder groups and components. For that purpose, a new variable “stakeholder group” has been created, summarizing different stakeholders that answered the questionnaire: i) *Business*, including companies, business organisations, trade unions and business associations, ii) *NGO*, including non-governmental organisations and environmental organisations, iii) *Research*, including academia and research institutions, iv) *Citizen*, including EU and non-EU citizen, and v) *Other*, including stakeholders that classified themselves as “Other”. In addition to stakeholder group, control variables have been added to the analysis. *Policy core belief* represents a participant’s belief that an EU-level intervention on EU consumption of goods would reduce global deforestation and forest degradation, measured on a 5-point scale from “very little” to “very much”. *Knowledge level* indicates participants’ self-assessment on how they rate their level of knowledge of deforestation and forest degradation and associated trade, measured on a 5-point scale from “I have not heard from it” to “I am recognised as an expert”. Furthermore, the *main sector* and *country* of origin most represented in the survey have been included.

Linear regressions have been conducted for each component. Variables were added stepwise based on importance. Given the high number of missing values in some of the variables, only complete cases (n = 198) were included to prevent biases. The results of these regressions are summarized in Tables 4 to 7. Figure 1 shows a plot of the coefficients for all four components (full models) with standardized coefficients and robust standard errors.

For our analyses we focus on model five, which encompasses all variables and explains more than 51% of variance. First, we look at differences between stakeholder groups, using the *Business* group as a reference. In general, the results show that our model assumptions are just partly confirmed.

Regarding mandatory policies (Table 4), research organizations ($\beta = 0.917$, $p < 0.01$) and citizens ($\beta = 0.849$, $p < 0.01$) are significantly more in favour of this instrument category than businesses. Surprisingly, this is not the case for NGOs ($\beta = 0.026$, $p > 0.1$). A possible explanation for this result could be the emergence of pro-environment alliances between NGOs and businesses in the development process of the EUDR, as analysed by Berning and Sotirov (2024). While NGOs advocate mandatory instruments for their effectiveness in reaching environmental goals, certain mandatory instruments are also supported by business as these policies can also lead to de-facto improvements in economic opportunities in the EU and have positive implications for EU firms such as preventing competition from outside the EU to enter the market.

As for international policies (Table 5), NGOs ($\beta = -0.711$, $p < .05$) and "other" stakeholders ($\beta = -1.064$, $p < .05$) evaluate them significantly less suitable compared to businesses. Businesses might prefer international policies since it shifts away the responsibilities from single companies to governments and restrict them to a lesser degree and less direct. This is also in line with findings from our interviews, where associations point out international policies like development and cooperation assistance to producing countries as more adequate measures than the EUDR in its current form.

Regarding voluntary policies (Table 6), both citizens ($\beta = -0.952$, $p < .01$) and NGOs ($\beta = -0.549$, $p < .05$) are significantly less in favour of this instrument type than businesses. This appears plausible since these instruments do not put any burdens on businesses unless they decide voluntarily to comply. Since these measures are often rather ineffective, they appear less suitable for environmentally conscious stakeholder groups like environmental NGOs.

In case of the EUDR solution (Table 7), all other stakeholder groups evaluate them more suitable than businesses, but the result is only slightly significant for research organisations ($\beta = 0.582$, $p < .1$), indicating a rather broad consent among stakeholders regarding the instruments in this category. The broad support of the EUDR as a mandatory due diligence regulation was reflected in strong supportive coalitions of businesses and NGOs, with only weak opposition. Berning and Sotirov (2024) explain this circumstance with the Baptist & Bootlegger Theory, which holds that coalitions between policy actors with different but practically aligning moral values and economic interests can enable policy change (Yandle, Rotondi, Morriss, & Dorchak, 2007). In the development process of the EUDR "specific business actors, such as multinational and EU companies from the agricultural and food sectors and their associations ('Bootleggers'), pursued strategic business-oriented interests.

These business actors sought opportunities to secure market access, remove or reduce disadvantages from cheaper competitors on the market, secure legal certainty, and reap reputational benefits or level playing fields. Supported by mixed motivation-driven political decisionmakers, certifiers and consultants (‘Televangelists’), they found common ground with environmental protection- and social justice-oriented (E)NGOs and CSOs (‘Baptists’).” (Berning & Sotirov, 2024, p. 12).

Regarding the control variables, it appears that a strong belief in EU interventions is associated with the support of mandatory policies (ß = 0.452, $p < 0.01$) and the EUDR solution (ß = 0.522, $p < 0.01$). Stakeholder claiming to be knowledgeable about deforestation oppose mandatory policies (ß = -0.231, $p < 0.05$) and voluntary policies (ß = -0.208, $p < 0.05$), but support the EUDR solution (ß = 0.522, $p < 0.01$). This again emphasizes the strong support of the EUDR with mandatory due diligence as the central measure to counteract deforestation and forest degradation. With little exceptions, the primary sector plays a minor role. The same holds true for the country of origin, with the exception of Brazil being significantly in opposition to the EUDR solution (ß = -1.125, $p < 0.01$) compared to Germany.

Our interviews with representatives of German business associations and analyses of common position papers regarding the EUDR revealed further insights on the position of business stakeholders. We reached out to nine major associations in Germany, representing the affected industries as well as agricultural trade. Interviews of 45 minutes with seven representatives were conducted between April and May 2024 (see questionnaire in Appendix). Although associations emphasise their commitment to help protecting forests globally, the criticism is focused on details in the design and implementation of the EUDR. As it was phrased in one common position paper in early 2023, “the bureaucracy, effort and costs associated with implementing geolocation, requirements concerning evidence and the segregation of commodity flows within a very short space of time will put a strain not just on the countries of origin outside of Europe, but on farmers and operators within the EU as well.” In more recent position papers and press releases, the criticism of high cost, especially because of necessary technological developments for EUDR compliance as well as the high administrative effort associated with the due diligence statements remain. In addition, the short transition period is criticised as well as the legal uncertainty due to poor communication of the European Commission, as mentioned by business associations. The EUDR is also assumed to cause market distortions, given that substitute products are not covered. There are fears that the flow of commodities associated with deforestation will be diverted to regions of the world other than the EU, as it is assumed that many producers will not be prepared to bear the additional costs of becoming EUDR-compliant. Especially SMEs are assumed to be prone to the additional cost associated with the EUDR compliance as they do not have enough resources to invest in new technologies or hire additional personnel, causing some players to change their business models or leave the market entirely. That is why some associations developed individual solutions for their members. One example includes the *EUDR Coffee Compass* of the German Coffee Association (Deutscher Kaffeeverband e.V., 2024). Interviews also revealed that industries are affected differently depending on the respective commodity. For example, the wood trading industry is already experienced in such regulation given that this industry was already affected by the EUTR. Industries that rely heavily on smallholders such as coffee or cocoa are confronted with a more complex data management as more remote sensing and geolocation data needs to be processed. Also differences in supply chain complexity lead to varying degrees of data management burdens for EUDR compliance.

When asked for policy alternatives, some business associations favoured international policies such as *promotion through trade and investment agreements of trade in legal and sustainable products*. Interestingly, voluntary instruments were approached in a rather mixed way. For example, while some association representatives valued the benefits of private certification, consumer information campaigns were seen as rather ineffective, difficult to assess and too costly. Mandatory instruments were seen as effective, but often evaluated as a too high burden for companies. It became apparent that the individual policy instrument plays a less important role for the degree of support, but the details of how a policy is designed, implemented and costs are distributed among actors can lead to rejection or opposition of a stakeholder group, finally causing a policy to be inefficient. For further insights from interviews regarding the technological feasibility of the EUDR, see chapter 2.2.2.

Table 4: Linear regression results for the Mandatory Policies component.

	Mandatory Policies				
Model:	1	2	3	4	5
Policy core belief	**0.621*** **	**0.588*** **	**0.563*** **	**0.457*** **	**0.452*** **
	(0.113)	(0.100)	(0.097)	(0.102)	(0.106)
Knowledge level		**-0.595*** **	**-0.576*** **	**-0.264*** **	**-0.231** **
		(0.075)	(0.080)	(0.099)	(0.103)
<u>Main sector (reference: Biodiversity and/or environment):</u>					
Climate change			**0.423** **	**0.440* **	**0.404**
			(0.206)	(0.243)	(0.250)
Consumption (general)			**0.139**	**0.202**	**0.137**
			(0.436)	(0.338)	(0.369)
Education			**0.182**	**0.048**	**-0.024**
			(0.239)	(0.177)	(0.198)
Scientific research			**-0.017**	**-0.219**	**-0.327**
			(0.562)	(0.515)	(0.527)
Services (general)			**0.330**	**0.232**	**0.143**
			(0.221)	(0.208)	(0.210)
Other			**-0.185**	**-0.162**	**-0.211**
			(0.148)	(0.156)	(0.161)
<u>Stakeholder group (reference: Business):</u>					
Citizen				**1.003*** **	**0.849*** **
				(0.243)	(0.242)
NGO				**0.085**	**0.026**
				(0.274)	(0.265)
Other				**0.150**	**-0.076**
				(0.328)	(0.345)
Research				**1.086*** **	**0.917*** **
				(0.317)	(0.347)
<u>Country (reference: Germany):</u>					
Belgium					**-0.110**
					(0.380)
Brazil					**0.174**
					(0.398)
France					**-0.008**
					(0.396)
Italy					**0.237**
					(0.313)
Netherlands					**-0.373**
					(0.406)
Sweden					**0.346**
					(0.521)
United Kingdom					**-0.237**
					(0.540)
United States					**-0.349**
					(0.344)
Other					**0.284**
					(0.315)
Constant	**-2.935*** **	**-0.535**	**-0.492**	**-1.838*** **	**-1.914*** **
	(0.512)	(0.584)	(0.600)	(0.593)	(0.679)
Observations	198	198	198	198	198
R^2	0.183	0.375	0.393	0.487	0.513
Note:			*p<0.1;	**p<0.05;	***p<0.01

Table 5: Linear regression results for the International Policies component.

	International Policies				
Model:	1	2	3	4	5
Policy core belief	**0.024**	**0.011**	**0.029**	**0.062**	**0.102**
	(0.109)	(0.110)	(0.108)	(0.105)	(0.114)
Knowledge level		**-0.227*****	**-0.170***	**-0.058**	**-0.013**
		(0.082)	(0.099)	(0.106)	(0.106)
Main sector (reference: Biodiversity and/or environment):					
Climate change			**0.090**	**0.085**	**0.159**
			(0.251)	(0.281)	(0.279)
Consumption (general)			**0.206**	**0.178**	**0.070**
			(0.361)	(0.343)	(0.357)
Education			**0.204**	**0.131**	**0.042**
			(0.230)	(0.229)	(0.262)
Scientific research			**0.029**	**-0.083**	**-0.303**
			(0.642)	(0.642)	(0.612)
Services (general)			**0.548**	**0.473**	**0.245**
			(0.397)	(0.403)	(0.407)
Other			**0.170**	**0.070**	**-0.047**
			(0.190)	(0.200)	(0.195)
Stakeholder group (reference: Business):					
Citizen				**-0.007**	**-0.250**
				(0.214)	(0.232)
NGO				**-0.515***	**-0.711****
				(0.263)	(0.277)
Other				**-0.881**	**-1.064****
				(0.621)	(0.530)
Research				**0.059**	**-0.114**
				(0.239)	(0.309)
Country (reference: Germany):					
Belgium					**-0.373**
					(0.331)
Brazil					**-0.371**
					(0.494)
France					**-0.417**
					(0.399)
Italy					**0.221**
					(0.288)
Netherlands					**-0.724**
					(0.532)
Sweden					**-0.584**
					(0.356)
United Kingdom					**-0.461**
					(0.615)
United States					**-0.010**
					(0.386)
Other					**0.084**
					(0.277)
Constant	**-0.127**	**0.791**	**0.407**	**-0.001**	**-0.054**
	(0.492)	(0.620)	(0.694)	(0.683)	(0.693)
Observations	198	198	198	198	198
R^2	0.0004	0.039	0.049	0.091	0.159
Note:			*p<0.1;	**p<0.05;	***p<0.01

Table 6: Linear regression results for the Voluntary Policies component.

	Voluntary Policies				
Model:	1	2	3	4	5
Policy core belief	**-0.320******	**-0.328******	**-0.265******	**-0.127**	**-0.131**
	(0.085)	(0.084)	(0.083)	(0.089)	(0.090)
Knowledge level		**-0.157****	**-0.048**	**-0.229****	**-0.208****
		(0.076)	(0.082)	(0.091)	(0.095)
<u>Main sector (reference: Biodiversity and/or environment):</u>					
Climate change			**0.501***	**0.573****	**0.664****
			(0.292)	(0.280)	(0.289)
Consumption (general)			**0.177**	**0.190**	**0.129**
			(0.338)	(0.265)	(0.249)
Education			**0.160**	**0.200**	**0.207**
			(0.291)	(0.267)	(0.270)
Scientific research			**-0.484**	**-0.332**	**-0.398**
			(0.487)	(0.512)	(0.557)
Services (general)			**0.784***	**0.875****	**0.850****
			(0.409)	(0.424)	(0.415)
Other			**0.454*****	**0.433*****	**0.419****
			(0.163)	(0.161)	(0.164)
<u>Stakeholder group (reference: Business):</u>					
Citizen				**-0.815*****	**-0.952*****
				(0.188)	(0.216)
NGO				**-0.487****	**-0.549****
				(0.235)	(0.236)
Other				**-0.514**	**-0.705**
				(0.455)	(0.476)
Research				**0.064**	**-0.050**
				(0.385)	(0.397)
<u>Country (reference: Germany):</u>					
Belgium					**-0.335**
					(0.332)
Brazil					**0.031**
					(0.464)
France					**-0.040**
					(0.340)
Italy					**0.068**
					(0.305)
Netherlands					**-0.037**
					(0.414)
Sweden					**-0.055**
					(0.353)
United Kingdom					**-0.447**
					(0.400)
United States					**-0.233**
					(0.373)
Other					**0.269**
					(0.300)
Constant	**1.509*****	**2.142*****	**1.257****	**1.884*****	**1.898*****
	(0.375)	(0.485)	(0.506)	(0.507)	(0.604)
Observations	198	198	198	198	198
R^2	0.071	0.090	0.144	0.220	0.255
Note:			*p<0.1;	**p<0.05;	***p<0.01

Table 7: Linear regression results for the EUDR Solution component.

	EUDR Solution				
Model:	1	2	3	4	5
Policy core belief	**0.592*** (0.090)	**0.607*** (0.093)	**0.550*** (0.084)	**0.494*** (0.094)	**0.522*** (0.092)
Knowledge level		**0.266*** (0.066)	**0.199** (0.078)	**0.187** (0.088)	**0.189** (0.090)
<u>Main sector (reference: Biodiversity and/or environment):</u>					
Climate change			**-0.011** (0.241)	**-0.015** (0.234)	**-0.092** (0.212)
Consumption (general)			**-0.353** (0.285)	**-0.331** (0.294)	**-0.195** (0.318)
Education			**-0.174** (0.183)	**-0.146** (0.181)	**-0.201** (0.195)
Scientific research			**-0.286** (0.585)	**-0.239** (0.571)	**-0.277** (0.588)
Services (general)			**0.073** (0.258)	**0.116** (0.253)	**0.089** (0.259)
Other			**-0.410** (0.168)	**-0.341** (0.167)	**-0.374** (0.159)
<u>Stakeholder group (reference: Business):</u>					
Citizen				**0.161** (0.235)	**0.219** (0.245)
NGO				**0.397** (0.247)	**0.345** (0.238)
Other				**0.040** (0.501)	**0.168** (0.388)
Research				**0.153** (0.268)	**0.582*** (0.325)
<u>Country (reference: Germany):</u>					
Belgium					**0.288** (0.255)
Brazil					**-1.125*** (0.421)
France					**-0.046** (0.264)
Italy					**-0.048** (0.210)
Netherlands					**-0.339** (0.342)
Sweden					**-0.012** (0.364)
United Kingdom					**-0.011** (0.206)
United States					**0.440** (0.275)
Other					**0.015** (0.215)
Constant	**-2.588*** (0.412)	**-3.663*** (0.518)	**-3.018*** (0.536)	**-2.923*** (0.551)	**-3.054*** (0.546)
Observations	198	198	198	198	198
R^2	0.221	0.272	0.301	0.312	0.382
Note:			*p<0.1;	**p<0.05;	***p<0.01

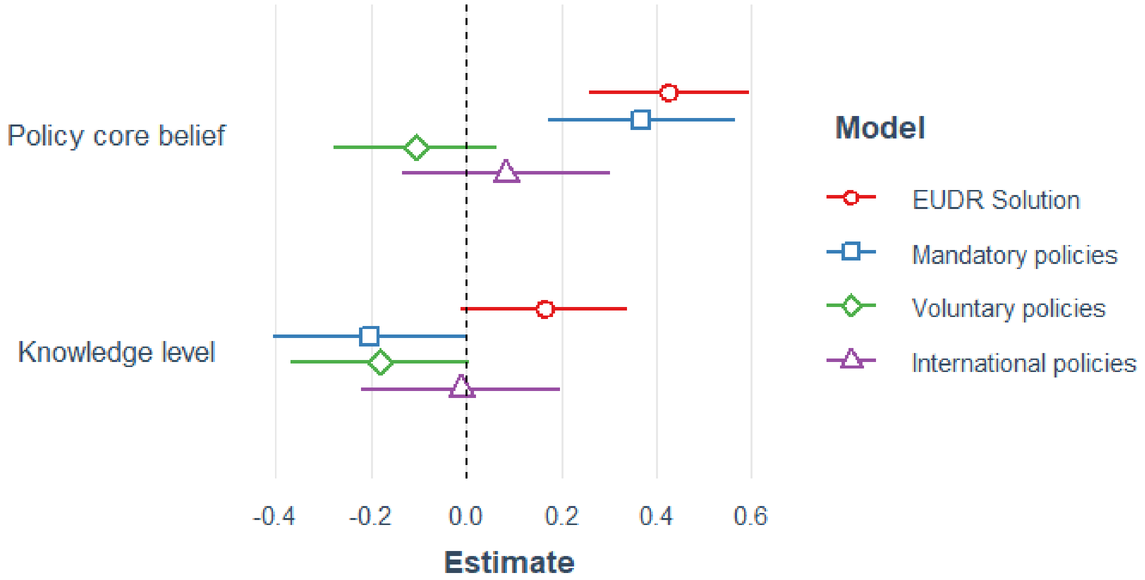

Figure 1: Plot of the coefficients for all four components (full models) with standardized coefficients and robust standard errors.

2 THE ROLE OF TECHNOLOGY

Technological change is an important aspect in the context of environmental policy since it is assumed to not only stimulate economic growth but to also contribute to environmental goals directly, e.g., by reducing emissions (Sterner & Coria, 2013). Technological change is also assumed to be an important driver of innovation and competitiveness (M. Porter & van der Linde, 1995). In this chapter, we first have a closer look at the current trends and technological developments that can enable the effective and cost-efficient implementation of policies for biodiversity conservation. In the second part, we look at the opposite effect and discuss how policies can function as drivers of technological innovation, looking at the scientific literature as well as insights from our interviews with business associations from industries affected by the EUDR.

2.1 Trends and technological enablement for biodiversity policies and conservation

2.1.1 Technology trends for biodiversity

The recent decades have shown how new technologies stimulate innovation, disruption, and change across sectors, including the field of environmental sustainability and biodiversity protection (White, Viana, Campbell, Elverum, & Bennun, 2021). Major advances have especially been made in the field data generation and collection methods (Marvin et al., 2016; Pimm et al., 2015; Snaddon, Petrokofsky, Jepson, & Willis, 2013) and methods to analyse large data sets (Kelling, 2018; Marvin et al., 2016). The increased availability, affordability, and quality of technologies such as satellite imagery, aerial photography, and camera traps significantly improved the possibilities of data collection for ecological survey and monitoring, even for species that used to be difficult to monitor (Marvin et al., 2016; Pimm et al., 2015).

Such advances have led to a shift in attitudes toward the application of technology within the biodiversity conservation community. Initial scepticism and rejection have transformed into widespread enthusiasm and an increasing demand for technological solutions specifically tailored to biodiversity conservation needs (Berger-Tal & Lahoz-Monfort, 2018). However, the full potential of technological solutions for biodiversity conservation has not yet been fully realized (White et al., 2021). Possible reasons include insufficient development of widely applicable tools, e.g., due to lack of commercial incentives, financial support, business models, or markets, and a lack of awareness and technical skills among users, including inappropriate use due to insufficient consideration of constraints or context (Joppa, 2015; Lahoz-Monfort et al., 2019). The insufficient use and application of technologies for biodiversity conservation also applies to the private sector, despite its long history of fostering technological development and in some cases private companies being pioneers in developing and testing new technologies for conservation purposes (White et al., 2021).

In a recent study, White et al. (2021) assessed existing and emerging technologies feasible and relevant to mitigate the loss of biodiversity and enhance biodiversity surveys and monitoring. These technologies have been identified as relevant for private sector operations across sectors and can be applied to all steps of the mitigation hierarchy and project stages (White et al., 2021). Twenty-four technologies were identified within the following six categories:

1) Mobile survey (technologies that collect data through a mobile platform include unmanned aerial vehicles (UAVs), unmanned submersibles, and GPS trackers)
2) Fixed survey (survey technologies where data are collected in a fixed location, including camera traps, eDNA, and passive acoustic monitoring (PAM))
3) Remote sensing (satellite remote sensing imagery of habitats/land, real-time threat data from satellite remote sensing)
4) Blockchain (public digital ledger system that is distributed widely across many computers so that records cannot be altered retroactively without altering all the subsequent units in the chain)
5) Data processing (technologies to store, distribute, and process environmental data to produce and disseminate useful information)
6) Enabling technologies (technologies that facilitate the delivery and functioning of other technologies)

Beyond survey and monitoring tools, White et al. (2021) identified just few technologies that directly influence biodiversity restoration and mitigation. Many of those technologies are not implementation-ready due to high cost and/or underdevelopment. In addition, they may have just a narrow applicability as they are often specific to certain species, sectors, or issues (White et al., 2021).

Public engagement and awareness are also integral to biodiversity policies and sustainable supply chains. Technology offers digital platforms like social media, mobile apps, and interactive websites to engage and educate stakeholders. Citizen science initiatives leverage these platforms to collect data and involve the public in biodiversity monitoring and conservation efforts (Ballard, Dixon, & Harris, 2017). Technological advancements also contribute to creating more biodiversity-friendly supply chains by enhancing traceability and transparency. Blockchain technology enables secure and transparent tracking of products throughout the supply chain, ensuring adherence to sustainability standards (Bai & Sarkis, 2020). Companies and other organisations can also use blockchain technology to track and verify the environmental credentials of products in supply chains to assess the effectiveness of mitigation measures. Devices used in the context of the Internet of Things (IoT), a network of interconnected physical devices that collect and exchange data through the internet, provide real-time monitoring of environmental parameters and supply chain processes, reducing environmental impacts and improving resource efficiency (Gallacher et al., 2021). By integrating these technologies, businesses can ensure traceability of raw materials, identify biodiversity hotspots affected by their operations, and implement conservation measures within their supply chains.

2.1.2 Relevant technologies enabling EUDR compliance

In case of the EUDR, remote sensing is of particular relevance for affected actors. Remote sensing is an indirect observation method and describes the collection of information about objects or phenomena on the earth's surface from a distance. For the EUDR, this applies to evaluating forest cover, deforestation, forest degradation and land use change into agricultural land. Imaging remote sensing systems are a particularly widespread method and, according to Albertz (1991), always consist of the following three elements:

1) Data is recorded by sensors on board satellites, aircraft or drones that detect electromagnetic radiation over various frequency ranges. These sensors can, for example, operate in the visible, infrared, thermal or microwave range, whereby different information about the earth's surface can be obtained. In addition, metadata about the recorded data, such as time of recording, geographical coordinates and sensor parameters, can be recorded.
2) The signals recorded by the sensors during the recording process are digitized, converted into raw data and stored as aerial or satellite images (data storage).
3) Since remote sensing data is often large in volume, its storage often requires specialized systems with high capacity and performance. In addition to pure storage, metadata about the recorded data can be stored. This metadata can have a great influence on later possibilities for data evaluation and corresponding versatility of applicability.
4) Data analysis involves processing and analysing the stored remote sensing data to extract information about the surveyed areas. This can involve a variety of techniques, including image processing, pattern recognition, machine learning and geographic information systems (GIS). The interpretation of this requires a high level of expertise and possibly additional information (e.g. metadata).

To comply with the EUDR, market operators and traders are obliged to check and provide the coordinates of the production site of the relevant commodity or product for not being associated with deforestation before the cut-off date of December 2020. A point coordinate or, if the production area is larger than four hectares, a polygon enclosing the area must be specified. This information and data need to be part of the due diligence statement and handed in via the EU "Information System". This presents market participants and traders with the challenge of tracing their value chain back to the place of production and verifying the absence of deforestation and other factors such as legal compliance in accordance with EUDR. The provision of this geodata and proof via remote sensing (e.g., satellite pictures) is supposed to enable competent national authorities to check whether forest was still present at the specified location on the cut-off date and whether deforestation has occurred as a result of agricultural land use. A forest reference map is required for this check, although the regulation does not yet propose a specific one. Possible options include the open source tool *Global forest cover 2020* provided by the

European Commission (European Commission, 2024d). Furthermore, the regulation stipulates that control authorities must investigate *substantiated third-party concerns*, which means that specific violations of the regulation can be identified and prosecuted using geodata. Besides deforestation, the regulation considers forest degradation, where remote sensing can be of valuable contribution. However, forest degradation is much more difficult to detect via remote sensing because it requires higher-resolution data and advanced classification methods.

Since due diligence requires high amounts of data, adequate tools to analyse this data are also of high relevance. One promising approach in this context is the use of artificial intelligence (AI) technologies like machine learning. According to Ferreira, Iten, and Silva (2020), machine learning based on remote sensing data plays a key role in achieving sustainability goals, while still providing great potential for innovation in the further development of this technology in conjunction with earth observation data. Machine learning and deep learning enable computers to identify patterns and correlations in large data sets and gain insights from them. It enables computers to learn through experience by training algorithms and models to recognize patterns in data and make predictions. By applying machine learning techniques, complex problems can be solved and data-driven decisions can be made. These technologies play a crucial role in automating data processing, predicting trends and making data-driven decisions. AI algorithms are able to analyse data, identify patterns and make predictions with minimal need for human intervention. This approach appears promising for the EUDR, since manual analysis and assessment of provided data by authorities is a high organizational and administrative burden. It also allows the quick and accurate assessment of remote data images in terms of deforestation, forest degradation, land use change and other relevant aspects of policy compliance.

However, digitalization and the application of new innovative methods like machine learning in the public authority environment of Germany, where the research focus for this report lies, is a complex issue. The new requirements arising from the EUDR present authorities with major challenges, particularly with regard to the effective processing and integration of the resulting data. Many of the previous assessment processes, such as those carried out as part of the European Timber Regulation (EUTR), were conducted manually. In order to meet the high requirements of the EUDR, a high degree of automation is required. This not only enables the necessary checks to be carried out efficiently, but also helps to minimize errors and improve the transparency and traceability of the assessments carried out. The digitalisation and automation of assessment processes are therefore essential steps to ensure compliance with the legal requirements under the EUDR and at the same time increase the resource efficiency of the authorities involved.

Despite the progress of technology solutions for biodiversity, challenges such as data privacy, technological accessibility, and standardization remain. Future efforts from both private and state actors should focus on developing integrated platforms that combine biodiversity data with supply chain information, promoting interoperability and transparency. Collaborative initiatives between governments, businesses, and civil society are crucial to drive sustainable practices and policies that benefit biodiversity and supply chain traceability. Technology plays a multifaceted role in enhancing biodiversity policies while also contributing to more biodiversity-friendly supply chains through improved traceability and transparency. By leveraging technological innovations, policymakers, businesses, and stakeholders can collaborate towards achieving biodiversity conservation goals while ensuring sustainable and transparent supply chains for transformational change.

2.2 Biodiversity policies as a driver of technological innovation

2.2.1 The role of the government

Policies and the government as an actor itself have a key role in the development and diffusion of environmental innovations. Direct measures such as the introduction of regulations and standards that require companies to switch to more sustainable operations and technologies can create incentives for the development of innovative solutions that support environmental protection such as clean energy, resource-efficient production technologies or low-emission logistics (Bergek & Berggren, 2014).

The government can also engage in establishing public-private partnerships to bundle resources and incorporate industry knowledge and foster the financial support of research and development programs aimed at technological innovation for environmental purposes (Dudin, Shakhov, Vysotskaya, & Stepanova, 2020). Information sharing and collaboration between different actors facilitate the development of new ideas and solutions, which in turn promotes innovation. Suitable communication technologies can improve or enable the exchange between these actors. Public procurement also offers potential for sustainable transformation, since it allows the state to create demand for certain technologies and encourages companies to invest in research, development and innovation (Ghisetti, 2017).

2.2.2 The Porter hypothesis

The Porter hypothesis is a theoretical prediction for the relation between (environmental) regulation and innovation. It posits that stringent environmental regulations can stimulate product and process innovation and enhance competitiveness within industries. This concept challenges the view that environmental regulations necessarily impose net costs on businesses, suggesting instead that they can drive positive outcomes such as technological advancements, cost savings, and market differentiation. M. Porter and van der Linde (1995) analysed the relationship between environmental regulations, innovation, and competitiveness in the context of pollution-intensive industries. The authors found that firms subject to stringent environmental standards were more likely to invest in cleaner technologies and processes, leading to improved environmental performance. These investments also translated into cost reductions and enhanced market positions. Further research by Lanoie, Laurent-Lucchetti, Johnstone, and Ambec (2011) explored the impact of environmental regulations on innovation and competitiveness in the pulp and paper industry. The study found evidence supporting the Porter hypothesis, indicating that firms facing stricter environmental regulations were more likely to innovate and develop eco-efficient technologies. These innovations not only reduced pollution but also enhanced productivity and competitiveness in global markets. Moreover, several studies across different industries have consistently shown that environmental regulations can stimulate technological innovation and improve firms' competitiveness (Lanjouw & Mody, 1996; Popp, 2002, 2019).

2.2.3 Insights from interviews with business associations

Our interviews revealed that the EUDR can indeed be a driver of technological innovation, but also influences the innovation activities of companies in a broader sense. Requirements regarding geolocation data and product traceability force companies to find new technological solutions that can foster supply chain transparency. It can contribute to digitalization in both companies and public authorities. In addition, the necessity induced by this regulation incentivizes affected actors to get in contact and exchange ideas, spurring the ideation process. The EUDR might also lead to product innovations and incentivises further investment in research and development for product alternatives, e.g. proteins from insects and substitute crops for animal food in the case of soybeans, or new technologies for safe supply chain traceability such as blockchain. However, a lot of these developments are in an early phase and interviewees assume that the effect of the EUDR on developments and R&D investments beyond mere policy compliance will be rather weak. In addition, some of these product innovations might not contribute to a sustainable development and can rather be seen as a desperate attempt of companies to circumvent the cost and effort associated with the EUDR. Examples include the switch from the renewable raw material wood to less regulated products such as wood polymer composites in the product portfolio of companies. These differences in the regulation of substitute products might further lead to market distortions to the detriment of companies operating with raw materials and products covered by the EUDR, given the additional cost, bureaucracy and necessary price increases for affected companies. The EUDR might also lead to undesired business model innovations in the sense that companies switch from importers to becoming domestic traders in order to not be affected by the EUDR, a trend that already happened in the wood trading industry as a response to the EUTR. Some business association representatives fear that companies might even completely stop trading or importing agricultural resources and products that fall under the EUDR. These challenges are especially problematic for small and medium-sized companies which do not have the necessary resources to invest in new technologies or product innovations, and lack the capacity to alter their business models. Overall, it appears from our interviews that the expected costs of the EUDR for affected companies will not offset the expected benefits in terms of environmental and economically beneficial innovations. In that case, EUDR impacts are not in line with the Porter hypothesis.

3 SUGGESTIONS AND RECOMMENDATIONS ON POLICY-TECHNOLOGY MIXES WITH TRANSFORMATIVE POTENTIAL FOR BIODIVERSITY CONSERVATION

As we outlined at the beginning of this report, global biodiversity loss and deforestation are urgent challenges for humanity and effective and efficient policies need to be set in place to counteract these trends. Global trade is a main driver of biodiversity loss, which also contributes to environmental injustices often associated with consumption in developed countries of the Global North, spurring biodiversity loss in developing countries of the Global South. Therefore, principles of environmental justice need to be considered in the design of biodiversity policies (e.g., by early and active engagement of producer countries and minority groups affected by these policies in the policy development process), offsetting the import and export of biodiversity risk between consumer and producer countries. Another design principle for international policies should be mechanisms to ensure national implementation, being aware that national interests might be causes for opposition the implementation process.

A major factor to consider in the policy process as analysed and discussed in chapter 1.4 is the position of stakeholders. Our research revealed that stakeholder groups can have divergent preferences for policy instruments, reflecting strategic interests such as individual (economic) or idealistic (environmental) goals that stakeholders aspire to be included in policy solutions. Power imbalances among such groups that try to influence the policy process to their advantage can lead to inefficient and ineffective policies. Policy makers should circumvent this potential pitfall by avoiding certain groups to exert too much influence on the policy process and ensure an open participation process, in which concerns and expectations of the whole spectrum of affected stakeholder groups are considered in a balanced way.

Challenges with regards to choosing instruments or instrument mixes are possible trade-offs with other policy objectives, such as economic growth or poverty alleviation and a lack of systematic evidence about the effectiveness and cost efficiency of many candidate instruments (Cole & Grossman, 2002; DeFries & Rosenzweig, 2010; Lee & Barrett, 2001). In addition, contextual factors like a country's political history, compatibility with the legal system, regulatory traditions, and preferences of political parties may play a major role when it comes to selecting policy instruments (Wurzel et al., 2019). Policies are often a reflection of economic interest and the question of who gains and who loses from the implementation of a certain policy might have a stronger effect on the selection process than its actual potential for contributing to solving environmental issues, emphasizing the role of non-state stakeholders and lobbying activities in policy development processes (Hood, 1990; Lascoumes & Le Gales, 2007; Wurzel et al., 2014). Hence, policy instrument selection and specifications of those instruments often vary between jurisdictions (Wurzel et al., 2019).

The specific characteristics of complex environmental issues make it challenging to design adequate policy solutions. They are subject to a high degree of uncertainty (Metz & Ingold, 2014), simultaneously require short- and long-term solutions (Ingold, Driessen, Runhaar, & Widmer, 2019), and they are extensive in the sense that they often touch multiple sectors, levels of decision making, and geographical areas at once (Varone, Nahrath, Aubin, & Gerber, 2013). Literature recommends addressing complex environmental problems with policy mixes rather than single instruments, as they are better suited to meet the challenges mentioned above (Glaus, 2021). Mixes that include multiple types of instruments, which address a variety of actors, challenges, goals, interests, and priorities, can be defined as *balanced policy mixes* (Flanagan, Uyarra, & Laranja, 2011; Kern & Howlett, 2009; Schmidt, Schneider, & Hoffmann, 2012). When designing a balanced policy mix, a good understanding of the differences among the affected and involved actors in terms of norms, values, and interests is necessary, since preferences for instruments to include differ among stakeholder groups, as shown in our analyses. Despite the challenges, research provides some general guidelines for developing a successful and feasible policy portfolio, such as the five step approach suggested by Doremus (2003), which includes 1) clarify the goals, 2) carefully evaluate existing programs, 3) be sensitive to the context, 4) monitor policy implementation and its results, 5) maintain flexibility so that policies can be changed in response to new information.

Given the multitude of challenges and objectives associated with policies for biodiversity, the question is how many instruments should be included in a mix? According to Gunningham and Young (1997, p. 286), "the number of instruments must be sufficient to accommodate each level of biodiversity and the web of institutions acting to conserve it". This means that each threat to biodiversity and each objective should be subject to at least one instrument. However, the question of which particular instruments to select remains difficult to answer (Ring & Schröter-Schlaack, 2011). Due to the diverse nature of biodiversity and biodiversity policies, a wide variety of stakeholders is affected by them. Hence, only instrument mixes developed and implemented with an emphasis on stakeholder involvement will be successful (OECD, 1999).

The technological prerequisites vary depending on the respective policy mix and each policy mix can foster or hinder technological innovation in a different way. Promising technological trends for more effective and cost-efficient biodiversity policies include mobile and fixed survey, remote sensing, blockchain, data analysis and other enabling technologies. The monitoring of biodiversity through remote sensing is of particular relevance to track the effectiveness of conservation efforts. Other technologies like blockchain or data analyses tool are useful to foster supply chain transparency, enabling regulations targeting supply chain sustainability. Suitable technologies can reduce transaction cost of affected actors like companies to comply with policies. The EUDR provides a current example where technologies like remote sensing and data analysis can be of high value. However, the case of the EUDR also highlights the difficulties in the nexus of technological feasibility and policy demands and how a mismatch between both can rather lead to additional cost and inefficiencies than innovation and effective policy implementation. If feasibility can be ensured and the discussed design principles are applied, socially beneficial innovation beyond technological developments to ensure policy compliance can be a valuable outcome of the policy process.

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APPENDIX

Questionnaire used in interviews with representatives of German business associations

Fragebogen

Abfrage Name, Organisation und Positionsbezeichnung: ____________________

1. Für wie **effektiv** halten Sie die EUDR? Sind Sie der Ansicht, dass damit ein Beitrag zur Bekämpfung von Entwaldung durch EU-Konsum geleistet werden kann?

2. Welche **Herausforderungen** ergeben sich durch die EUDR für Unternehmen Ihrer Branche, insbesondere im Hinblick auf dadurch entstehende **Kosten und die technologische Realisierbarkeit**?

- Welche genauen Eigenschaften der EUDR haben zu diesen Herausforderungen geführt?
- Welche Organisationsbereiche und welche Kostenarten sind am stärksten betroffen (Transaktionskosten, Logistik, Verwaltung etc.)?
- Was sind Herausforderungen bei der Entwicklung oder Implementierung geeigneter Technologien?
- Was sind Herausforderungen in Bezug auf Marktsituation und Wettbewerb?

3. Welche **Vorteile** ergeben sich durch die EUDR für Unternehmen Ihrer Branche?

- Kann die EUDR Anreize für die Entwicklung neuer oder verbesserter Technologien schaffen?
- Ergeben sich in bestimmten Bereichen Kosteneinsparungen?
- Hat sie positive Effekte auf den (internationalen) Wettbewerb?
- Leistet sie einen Beitrag zu nachhaltigeren Lieferketten?

(Präsentation der 14 Instrumente zur gedanklichen Unterstützung auf geteiltem Bildschirm)

4. Die EUDR ist im Kern eine Due-Diligence-Maßnahme. Im Entwicklungsprozess der EUDR standen aber noch weitere Instrumente zur Diskussion. Fallen Ihnen **Instrumente** zur Bekämpfung von Entwaldung durch die EU ein, die eher **im Sinne Ihrer Branche** gewesen wären?

- Welche Vor- und Nachteile würden sich für Ihre Branche durch diese Instrumente ergeben?
- Wie bewerten sie die Effektivität dieser Maßnahmen?
- Wie bewerten Sie die technologische Umsetzbarkeit dieser Maßnahmen und die Effekte auf Kosten für Unternehmen?
