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Evidence of Absolute Decoupling from Real World Policy Mixes in Europe

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Abstract: In resource economics, decoupling from environmental impacts is assumed to be beneficial. However, the success of efforts to increase resource productivity should be placed within the context of the earth's resources and ecosystems as theoretically finite and contingent on a number of threshold values. Thus far relatively few analyses exist of policies which have successfully implemented strategies for decoupling within these limits. Through ex-post evaluation of a number of real world policy mixes from European Union member states, this paper further develops definitions of the concept of decoupling. Beyond absolute (and relative) decoupling, "*absolute decoupling within limits*" is proposed as an appropriate term for defining resource-productivity at any scale which respects the existing real world limits on resources and ecosystems and as such, contributes to meeting sustainability objectives. Policy mixes presented here cover a range of resources such as fish stocks, fertilizers, aggregates and fossil based materials (plastics). Policy mixes demonstrating absolute decoupling and at least one where absolute decoupling within limits has occurred, provide insights on developing resource efficiency policies in Europe and beyond.

Keywords: absolute decoupling; aggregates; European Union; ex-post; fertilizers; fish stocks; plastics; policy mixes; productivity; resource efficiency

1. Introduction

Earth Overshoot Day, the 13 August 2015 was the day upon which humanity's annual demand for resources exceeded the Earth's ecosystem ability to regenerate within a year. It was argued that for the remainder of 2015, the use of natural resources contributed to a depletion of natural capital and degradation of the natural environment [1]. The consequences of the "overshoot" amongst other indicators of unsustainable resource consumption are increasingly well understood, for example in climate change, biodiversity loss and water stress as well as related societal and economic pressures. This kind of analysis gives a powerful motivation to better understand the relationship between human development, our planet's resources and related environmental impacts. Decoupling provides one of the lenses through which we can both examine this relationship and start to consider how human development can proceed whilst preserving the ecosystems upon which we depend.

Although decoupling is increasingly being applied across the science policy interface [2–4] and arguably benefits from established academic work particularly in environmental economics [5–8], a diversity of definitions and a number of nuances distract from its clarity, as well as effective application.

Furthermore, analyses of decoupling which truly respect planetary and ecosystem limits are difficult to find.

This article draws upon the results of the DYNAMIX—DYNAmic policy MIXes for absolute decoupling of the environmental impact of EU resource use from economic growth. This is a European Union-funded research project which included ex-post analysis on a number of policies to further develop the conceptualisation of decoupling and to contribute valuable insights based on existing policies. Firstly, the need for decoupling with reference to the over-use of our planet's resources is summarised. Secondly, building on existing literature a three part conceptualisation of decoupling is proposed, based on *relative*, *absolute* and *absolute within limits*. Thirdly, the methodology and results of ex-post analyses of six real world policy mixes insights on decoupling in practice are presented:

- Sustainable levels of fishing in Iceland
- Reducing fertiliser use in Denmark
- Increasing efficiency in aggregate use in the UK
- Reducing plastic bag use in Ireland
- Improving industrial energy efficiency in Portugal
- Sustainable use of forests and wood in Finland.

Building on the above examples, elements to support absolute decoupling within planetary boundaries are identified. In the final section, future needs are considered to support academic and policy development in the application of decoupling.

2. The Need for Absolute Decoupling within Planetary Boundaries

2.1. Existing Research in the Field of Decoupling

This paper contributes to the literature on the assessment of policies aimed at decoupling. As policies to support decoupling and resource efficiency become increasingly visible in European and international legislation, there is a growing demand for analyses of these policies with a range of scales and diverse foci.

Existing evaluations examine single instruments such as environmental fiscal reform [9] and emissions trading schemes, or policy mixes comprised of several instruments [10,11]. Policy analyses often focus on progress towards specific objectives such as reducing energy consumption [12], municipal waste [13], carbon emissions [14,15] and fresh water use [16,17]. The scale of decoupling analyses varies, some focusing on a sector [18,19], while others look at city [20], regional/provincial [21] and national [11,13–15,22] levels, including cross comparisons [12,23,24].

Some research has attempted to categorize the level of decoupling as a response to a particular policy intervention. Tapio's [19] presentation of a theoretical framework for degrees of decoupling applied to a case study of the transport sector in the EU, has been widely cited and applied [25]. A meta-analysis of research on decoupling suggests that there are at least eight approaches for measuring decoupling, although no definitive approach is identified in the study [26].

Luken and Piras [23] review decoupling of energy use and industrial output for six Asian countries and conclude that China and Thailand have been successful in achieving long term relative decoupling. Sorrell *et al.* [27] examine road freight in the UK between 1989 and 2004; they argue that although relative decoupling has been achieved, absolute decoupling has not. Zhang *et al.* [20] provide an interesting analysis integrating well-being and emergy into decoupling analysis at the scale of Shenyang city, China.

While these papers often demonstrate the limitations of decoupling which is not absolute, they do not explicitly acknowledge that even absolute decoupling might be insufficient if it does not respect planetary limits. Zhang *et al.* [22] rightly indicate that decoupling does not explicitly account for environmental externalities and therefore it is appropriate to combine decoupling with wider concepts. Jorgenson and Clark [12] carried out a cross national panel analysis of the relationship between CO_2 emissions and economic growth in 86 countries. They use the data to assess the contradictory *ecological modernization* and *treadmill of production* theories. The final paragraphs of the analysis acknowledge that any decoupling of growth from emissions observed was relative, rather than absolute and as such does not reduce the ecological challenge.

Acknowledging the real world limits which exist on resources and ecosystems, this paper builds on the existing literature to examine the extent to which the various decoupling policies respect these limits. Integrating planetary limits into both the definition of decoupling and its application will help to develop effective and sustainable development policies.

2.2. Absolute Decoupling within Planetary Boundaries

As the extent of humanity's over-consumption of natural resources is scientifically understood and proven and as impacts on ecosystems, the wider environment and health become more evident on a wider scale, there has been growing recognition of the need to change our production and consumption behaviours.

Literature on environmental and resource economics describe the complex relationship between human development and resource use. Decoupling is supported by a number of premises which are gaining growing recognition: firstly, that humanity is dependent on goods and services drawn from the earth's natural capital (including natural resources and ecosystem services) [5,28]; secondly, that the availability of natural capital is finite as defined by the earth as a closed system [5,6,29]; thirdly, that the over exploitation of natural capital deteriorates the resource base as well as ecosystem services [28]; fourthly, environmental indicators suggest that in a number of areas, key environmental thresholds (or planetary boundaries) have either been surpassed or are threatened by predominant approaches to human development which have largely disregarded all these premises [7,29].

These premises are reflected across policies dealing with a wide range of resources. For example, the use of phosphorus as a synthetic fertiliser has played a pivotal role in human development. Yet, the extensive mining of the finite phosphate rock, its industrial agricultural application of the fertiliser and the disruption to natural phosphorus cycles have resulted in detrimental impacts on the aquatic environment due to farm run off and consequential eutrophication. Due to this, phosphorus extraction is closely linked to agricultural output and also to some forms of environmental degradation [30,31].

Bearing this in mind, decoupling provides a framework for potential solutions by focusing on varying degrees of resource productivity, or the return of services or goods which can be obtained through a unit of resource. Within the literature, different definitions of decoupling have been developed proposing varying degrees of resource productivity, with varying degrees of focus on their environmental impacts [4]. Some possible definitions are outlined in the Table 1 below. It should be noted that the definitions are not necessarily mutually exclusive. In the early stages of a policy mix, it might be difficult to determine the level of decoupling which has occurred, as shown in Figure 1.

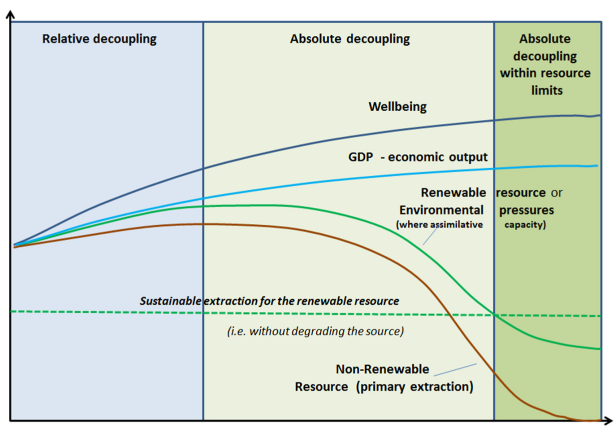

Figure 1. Decoupling concepts. (Source: Own representation, Institute for European Environmental Policy.)

Table 1. Definitions of decoupling, drawing on [4].

Term	Definition	Necessary Indicators
Relative decoupling	The rate of resource use is lower than the growth rate of economic output	Economic indicator (e.g., agricultural output) and environmental indicator (e.g., fertiliser use)
Absolute decoupling	Resource use declines irrespective of the growth rate of economic drivers	Economic indicator (e.g., agricultural output) and environmental indicator (e.g., fertiliser use)
Impact decoupling	Increasing the economic output while reducing negative environmental impacts. (Can be both relative or absolute)	Economic indicator (e.g., agricultural output) and environmental indicators (e.g., fertiliser use, Biological Oxygen Demand of a waterway)
Resource decoupling	Reducing the rate of use of primary resources per unit of economic activity (dematerialisation). (Can be both relative or absolute)	Economic indicator (e.g., agricultural output) and environmental indicator (e.g., fertiliser use)
Absolute decoupling within limits	Resource use and its impacts decline in absolute terms, respecting earth as a closed system	Economic indicator (e.g., agricultural output) and environmental indicator (e.g., fertiliser use, Biological Oxygen Demand of a waterway + limit value ppm)

While all forms of decoupling are potentially beneficial in terms of economic benefits and resource use, because they represent an increase in resource productivity, the differences between them are significant and consequently decoupling as a term, needs further elaboration.

Figure 1 demonstrates that *relative decoupling* can occur even while the rate of resource extractions increase, as well as environmental degradation. This is the basis of Jevon's Paradox, which postulates that resource efficiencies contribute to increased economic output, rather than a reduction in absolute resource consumption. Per capita, waste production provides a good example of this, while rates of recycling may increase in real terms, per capita consumption has simultaneously increased. The result is that net waste production has also increased, negating the benefits of efficiencies. The rebound effect is that while efficiencies may be achieved, net environmental degradation increases. In the case of municipal waste production this means absolute limits on total material throughput [32].

For *absolute decoupling* to be achieved if economic output increases, resource efficiencies must increase at least at the same rate. Therefore while absolute decoupling contributes more to environmental objectives than relative decoupling, examples of absolute decoupling are significantly less common [33,34]. As Figure 1 further illustrates, even absolute decoupling does not address ecological considerations or the real limits which exist on resources, or the function of ecosystems. Just as non-renewable resources are finite, it is increasingly understood that many renewable ecosystem services are in practice finite because of the requirements of the ecological systems which they are dependent on. At a macro scale the concept of planetary boundaries helps to explain this by identifying crucial bio-geochemical cycles (and thresholds) for supporting life [29]. The sustainability of human development therefore depends on a resource use that respects planetary limits on resources and ecosystems and incorporates this idea into the decoupling concept, increasing its salience. While impact decoupling begins to account for ecological considerations, it does so in a non-specific way.

Supported by the analysis presented here, *absolute decoupling within limits* is proposed as a conceptually superior elaboration of decoupling: with resource use and environmental impacts declining in absolute terms irrespective of economic growth and respecting the earth as a closed system. Limits can refer to:

(1) Resource limits relating to the finite availability of non-renewable resources (e.g., availability of bauxite);
(2) Resource limits relating to ecological limits, defined by the generative capacity of ecosystems (e.g., provision of fish or clean water) or absorptive capacity (e.g., capacity of a river for biological oxygen demand loadings);
(3) Ecological limits relating to ecological thresholds such as pollution pressures (e.g., atmospheric ozone);

(4) Environmental limits defined by health impacts on species (e.g., ambient air quality for respiratory health).

Within this definition it should be stated that the limits are determined by the spatial and temporal scale of analysis. This is to avoid a risk of efficiencies being presented as decoupling but in the wider context, remaining insufficiently efficient to meet sustainability pre-requisites, either because they represent increasing environmental degradation in absolute terms or because the absolute reduction in resource use is insufficient to meet an environmental limit. For example, if examining decoupling of bauxite mining and the aluminium sector's output in Australia, while there are global estimates on reserves of bauxite, more appropriate national limits based on practical accessibility and availability might be applied. Similar considerations could be made for the functionality of ecosystems, for instance when examining biomes, habitats or even specific functional groups, rather than biodiversity as whole. The scales of analyses interact and influence their respective contribution to resource efficiencies. As a result of the interconnection of an earth system, processes decoupling at a macro (particularly global) scale is an aggregate of efforts at lower levels. This means that varying degrees of decoupling at micro and individual levels (national, regional, sectoral, installation) can be hidden within higher levels, thus potentially masking inefficiencies on the macro scale. Furthermore, practices at micro levels may represent absolute decoupling yet still be insufficient when scaled to the global level. For instance, decoupling could be taking place in terms of decarbonisation across the United Nations Framework Convention on Climate Change (UNFCCC) member states, through practices that continue to be inefficient, with respect to global climate targets.

Decoupling is increasingly being applied in policy contexts but does not always acknowledge the definitions which have been outlined above. In many areas, indicator and reporting initiatives focusing on environmental sustainability continue to highlight unsustainable resource exploitation. This includes for example, research on climate change [35], biodiversity loss [36] and cross cutting issues such as the foot-printing initiatives mentioned above [1].

Notably, EU legislation on resource efficiency has acknowledged the need for resource consumption within limits. In 2002, the Sixth Environment Action Programme referred to decoupling environmental pressures from economic growth, alongside specifying decoupling of economic growth from the use of resources and waste generation and aiming "to ensure that the consumption of renewable and non-renewable resources does not exceed the carrying capacity of the environment" [36,37]. Most recently, the 2010 EU economic strategy, Europe 2020 [38], ensures that decoupling enters into economic policy through an aim to "decouple economic growth from the use of resources ... " [39] (p. 6). The 2012 Seventh Environment Action Programme (7EAP) entitled "Living well, within the limits of our planet" echoes the Europe 2020 strategy objective and calls for "an absolute decoupling of economic growth and environmental degradation" [39]. On a more international level, decoupling features in the OECD's 2011 Environmental Strategy which includes an objective of "decoupling environmental pressures from economic growth" [40] recognises that particular attention needs to be paid to the areas of agriculture, transport and energy.

3. Collecting Real World Policy Mix Evidence of Absolute Decoupling

3.1. Methodology

The case studies presented in this paper were analysed in the context the DYNAMIX project. Ex-post evaluations were carried out on 15 real world policy mixes addressing a range of natural resources. Resources were prioritised according to the United Nations' International Resource Panel work [41] and supplemented by policies considered to be critical, from the perspective of EU resource efficiency, notably land, soil and waste.

3.1.1. Case Study Selection

A screening exercise led to the identification of existing policy mixes which could be included in the ex-post assessment. Initially, a long list of policies was developed across a number of resource types. A priority was given to policy packages (*i.e.*, several instruments introduced in one policy package) however groups of policies which developed over time (also including several instruments) were also included. A detailed database or long list, including more than 60 policy mixes was developed. The aim of the long list was not to carry out an exhaustive review of decoupling policies but to identify relevant policy mixes within established screening criteria. The screening criteria aimed to maximise the relevance of the policy mixes to the project objectives and was based on seven factors (see Table 2).

Table 2. Summary of screening guidance for policy mix selection.

Criteria	Objective	Priority
1. Objective of policy mix	Propose policy mixes to achieve absolute decoupling of resource use and its environmental impacts from economic growth	Prioritise policy mixes which include absolute decoupling as an explicit objective
2. Geographical coverage	Focus on the EU member states. Although interesting third country policies can be included	A good coverage of EU member states
3. Success/failure	The project should cover successful and failed policy mixes	Successful and ambitious policy mixes
4. Level of focus	Screening should cover supranational, national and sub-national policy mixes. As well as a range of instruments (MBIs, regulation, information-based, and voluntary tools)	National policy mixes in the EU covering a range of instruments
5. Timeline/age of policy mix	Identify resource input-, impact- and output-focused policy mixes	Policy mixes which cover a long time period providing evidence of impacts
6. Data availability	Policy mixes should have sufficient data to carry out the study. But also focus on mixes which have already been assessed should be avoided.	Evaluate innovative policy mixes, with good data availability. Where necessary support with stakeholder interviews.
7. Replicability to the EU	Identify policy mixes which can reduce resource use and its impacts across the EU	Prioritise policy mixes which can be developed in other EU member states.

Based on the priorities of the case study selection criteria 15 case studies were promoted to a short list. Ex-post analyses where carried out for all of the case studies in the short list, the results of which are summarised in Table 3 below.

Table 3. Summary of case studies analysis.

Case Study	Issue to Address	Ecological Limits	Policy Mix	Type of Decoupling/Outcomes
Sustainable levels of fish catch in Iceland	Over-exploitation of fisheries in Iceland, leading to a collapse of fish stocks	Rate of biodiversity loss (fish stock)	• Total allowable catches (TACs) quota • Individual tradable quotas (ITQs) • Resource tax	*Absolute (impact and resource) decoupling within limits* • Steadily growing and profitable fishing industry • Reduction of over-fishing to a stabilised level
Reducing fertiliser use in Denmark	Use of synthetic fertilisers disrupted marine ecosystems leading to lower levels of oxygen and the death of many fishes and other aquatic species	Interference with nitrogen cycle and phosphorus flows; Marine biodiversity loss	• Action Plans (on fertiliser use, aquatic environment and sustainable agriculture) • Regulatory tools (bans, limits and requirements) • Financial tools (mineral phosphorus tax on feed, subsidies) • Information mechanisms • Monitoring and review	*Absolute decoupling from resource use, not from impacts* • Decreasing use of fertilisers • Slight increase in national agricultural output • Damaged waterways (*i.e.*, oxygen levels remain too low for the healthy development of marine ecosystems)
More efficient use of aggregates in the UK	Wasteful extraction of aggregates used in the construction sector disrupts ecosystems	Land and water resource use; Biodiversity loss	• Taxes (both incrementally increased): • Landfill tax • Aggregates levy • Aggregates levy sustainability fund	*Absolute decoupling from resource use and impacts, but not within limits* • Decreasing use of aggregates • Independent evolution of construction output • Impacts of remaining aggregates in use difficult to ascertain
Reducing plastic bag use in Ireland	Single use plastic bags not effectively collected accumulate and threaten notably marine life, and other ecosystems	Ocean pollution; Marine biodiversity loss	• Plastic bag tax (incrementally increased since its introduction) • Public awareness campaign (to accompany policy introduction) • Environment fund from tax revenue	*Absolute decoupling from resource use and impacts, but without specific attention to limits* • Significant drop in plastic bag use • Independent economic growth • Impacts of pollution from remaining plastic bag use difficult to ascertain and so far not taken into account
Improving industrial energy efficiency in Portugal	The inefficient use of fossil-based energy in the industrial sector lead to high levels of CO_2 emissions	Atmospheric CO_2 concentration (climate change)	• Industry Efficiency System, including binding: energy audits and energy consumption rationalisation plans • Green fiscal instruments (taxes and incentives to purchase efficient electric equipment) • Energy Efficiency Fund	*No decoupling* • Decreasing industrial production • Decreasing final national energy use • But slight increase of energy use in industry per unit of value added
Sustainable use of forests and wood in Finland	The mismanagement of forests and wood in Finland caused excessive deforestation, biodiversity loss, carbon emissions and soil degradation	Forests and land-use thresholds at national and global scales	• Felling, regeneration and conservation requirements (Finnish Forest Act, Nature Conservation Act) • National Forest Programmes and Management Plans (with targets) • Voluntary Partnership Agreements (with other producing and exporting countries), voluntary Certification and Labelling schemes • Green public procurement, subsidies for more sustainable forestry practices, funding for innovation projects	*Decoupling of forestry sector's economic growth from wood removal within national, not planetary limits* • Reduced use of domestic forestry products and increased forest stock/standing forest biomass • But increased imports of wood products offsetting domestic progress • And continued decline in forest biodiversity and habitats

3.1.2. Case Study Evaluation

For the short listed policy mixes, an in-depth evaluation was carried out based on a common evaluation framework. The evaluation focused on the *effect* of the policy mix, *i.e.*, the results of a measure that can be attributed to its implementation (which implies a causal link between the policy action and its intended impacts on human behaviour and the environment) and its *effectiveness*, *i.e.*, whether or not the intended objectives and targets have been achieved. Additionally, the project identified the policy mixes' *efficiency—i.e.*, the achieved level of resource and impact decoupling with the monetary (or other) resources applied to achieve the outcome.

The policy evaluation framework was based on a series of 45 questions with the analysis of the effect, effectiveness and efficiency of the policy mix considered across factors of environmental, economic and social sustainability. Factors of environmental and economic sustainability were considered from a global perspective (where data was available), while social sustainability was considered only at the scale of the European Union, in order to reduce complexity.

While the presentation of the case studies here draws on the complete results of the project, it focuses specifically on a number of questions within the policy evaluation framework:

- Does/did the policy mix result in a positive environmental outcome?
- Were its stated objective(s) met? Were the instruments used sufficient to meet the objectives?
- Were these objectives set at a level to meet environmental needs such as avoiding crossing environmental thresholds/tipping points or achieve more sustainable levels of resource use/extraction (e.g., maximum sustainable yield (MSY) in fisheries)?
- What has been the level of impact on resource use of the policy mix (the effect)?
- How was relative/absolute decoupling achieved?
- Were resource limits or other thresholds taken into account and how were they addressed?

From the 15 case studies this paper draws on, the results of six case studies in total were presented: four case studies which demonstrated decoupling successfully, as well as two which failed to achieve decoupling. More detailed discussion of the methods can be found on the Dynamix project results webpage [42].

3.2. Case Studies—Real World Policy Mixes in Europe

3.2.1. Evidence of Success

Five of the selected case studies were evaluated as having achieved absolute decoupling. Only four of these are considered in detail in this paper due to difficulties in assessing the performance of one of the policy mixes in relation to a specific sub-set of resources addressed. Of the four case studies, only one is considered to have achieved absolute decoupling *within limits.*

Case Study 1: Sustainable Levels of Fish Catch in Iceland

Fish stocks represent a renewable resource if effectively managed. Nevertheless, healthy fish populations have a number of ecological requirements in order to survive and over fishing amongst other pressures can exhaust this valuable resource. Policies to address the sustainability of Icelandic fish stocks represent an example of successful absolute decoupling within limits, distinguishing the evolution of gross economic output of fishing activities, to levels of fish stocks on the other.

Like other industrialised fishing nations in the first half of the twentieth century, Iceland was over-exploiting its fisheries. Numerous international (until 1976) and domestic fishermen competed for shares of the resource, leading to a race to fish, with fishermen over-investing in their equipment in order to compete. This resulted in increased over fishing in the industry when compared to the fish stocks' capacity to reproduce. By 1973 herring stocks had collapsed with a catch of 10,000 tonnes compared to the highest catches in the mid-1960s (2 million tonnes in 1965) [43]. Estimated spawning biomass declined from 14 million tonnes in 1950 to less than 2000 tonnes by 1972 [44]. The collapse was followed by a sharp drop in demersal stock (*i.e.*, fish such as cod or haddock which live and feed in the demersal zone) and catch levels of capelin were seriously threatened by overfishing [43].

The policy mix evaluated involves three instruments introduced over the course of four decades and in a mostly ad-hoc manner (independently of policy analysis). The three instruments are: total allowable catches (TACs), individual tradable quotas (ITQs) and a resource tax.

The first TAC was set for herring in 1975, divided equally among boat owners. The quota shares were initially not transferable, though this was changed in 1979 at the initiative of the boat owners. With evidence of the success of the herring catch quota system, TAC shares were introduced for capelin in 1980 (with transferability introduced in 1986). Application of the TACs and ITQs to demersal fisheries was more gradual beginning with the introduction of effort quotas in 1977 which lead to harvesting of a maximum number of fish allowable during fishing days, to over-investment in the fleet and overfishing. The system continued until 1983 when the Fisheries Minister was given discretionary power, through a revised Fisheries Act, to issue individual quotas for each vessel in the demersal fisheries. Each vessel was issued a TAC share based on its catch history, quotas were partly transferable and small boats were exempt. A partial redesign in 1985 was replaced in 1990 when effort quotas were abandoned and replaced with a fully transferable system of ITQs, as per other fish stock types.

In 1991, a small "service fee" was introduced on quota holders (fishers) to allay criticisms that the public was not receiving any benefits from the privatisation of the resource and the revenue was used to aid the reduction of the fleet.

In 2002, a resource tax (applying to all species) was introduced, replacing previous levies. The tax was calculated based on a fishing firm's quota and its economic performance, both for a reference period of 12 months. Total catch value for the year was calculated and deductions made for fuel, wages and other operating costs. Total tax revenue for the given year was charged at 9.5% of this calculation and the tax calculated based on a "per cod-equivalent", (total tax revenue divided by catch on cod-equivalent kilograms) [45].

This policy mix does not have an explicitly stated objective, but the objective of the Fisheries Management Act is "to promote (exploitable marine stocks') conservation and efficient utilisation, thereby ensuring stable employment and settlement throughout Iceland". TACs and ITQs serve to limit how much fish can be caught (TAC) and to allocate rights to fisheries through a cap-and-trade mechanism (ITQ).

Since the introduction of the ITQ system, a steady improvement in fish stocks has occurred and there has also been a steady increase in the fishable biomass of cod stock, from 550,000 tonnes in 1992 to around 1.2 million tonnes in 2012. The spawning stock of Icelandic cod is increasing and "is higher than has been observed over the last five decades" with fishing mortality (percentage of the fish stock removed each year by fishing) at an historical low [46].

Figure 2 presents the over-exploitation of fisheries resources and the economic performance of the fishing sector (gross output). Over-exploitation is represented by the degree to which Icelandic landings of cod exceed the TAC. The sector's economic performance has steadily grown over the studied period (1997–2011) while over-exploitation has shown an overall downward trend, stabilising over the past decade at less than 10%. Therefore it can be concluded that *absolute decoupling within limits* has been achieved.

The policy mix aimed to improve environmental sustainability as well as to maximise profitability of the exploitation of the resource. Before the introduction of the ITQ system the profitability of the fisheries sector was poor [47,48] and the ITQs increased the sector's efficiency by reducing fishing effort and fishing capital, rebuilding fish stocks, raising the quality of the landed catch and improving coordination between supply of landings and market demand [47]. The introduction of TACs provided fisheries with the right incentives to improve the profitability of their fishing practices and the ITQs allowed transfer of quotas from less efficient firms to more efficient ones. The Icelandic fishing industry has been profitable since the early 1990s and this is mainly due to increased productivity and higher prices.

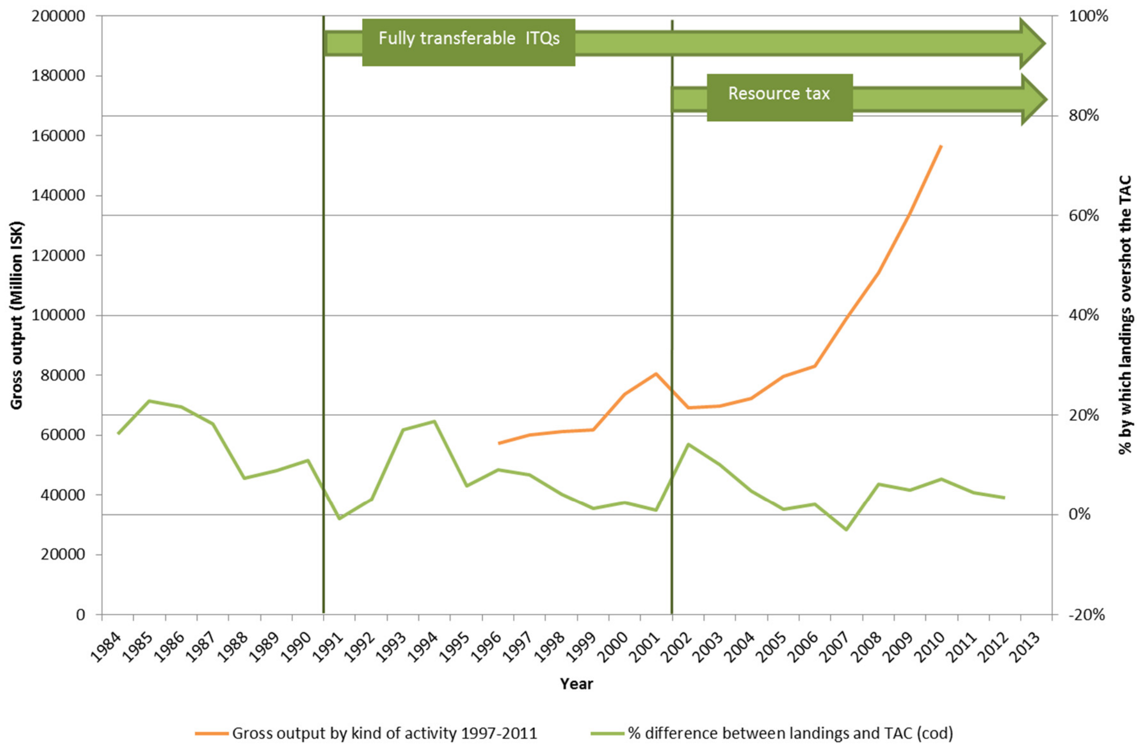

Figure 2. Performance of the Iceland fish policy mix in relation to gross output of fishing activity (millions of Icelandic kroner), 1997–2011 [49].

Case Study 2: Reducing Fertiliser Use in Denmark

Synthetic fertilisers make a considerable contribution to global agricultural output however disruption to biogeochemical cycles, particularly for nitrogen and phosphorus, threatens marine and terrestrial ecosystems. Nitrogen and phosphorus are finite non-renewable resources furthermore, ecological thresholds have been determined for phosphorus and nitrogen flows into oceans [29]. Efforts to reduce fertiliser input into the Danish agricultural system provide an example of *absolute decoupling* between agricultural production and fertiliser use, but ex-post assessment suggests that this was not achieved within limits, due to impacts on Danish waterways.

In the early 1980s dead fish started to wash up in large numbers on Danish shores and waterways, catching media and political attention [50] and leading to higher levels of awareness of the degradation of the country's aquatic environment. As a result, a series of Action Plans were introduced from the mid-1980s starting with the 1985 NPO (Nutrients-Phosphorus-Oxygen) Action Plan, an Aquatic Environment Action Plan launched in 1987 (and revised in 1998 and 2004) and a 1991 Action Plan for Sustainable Development in Agriculture. These Action Plans introduced a series of instruments based primarily on regulatory instruments (e.g., bans, limits and requirements) and supported by financial (including a mineral phosphorus tax on feed and subsidies) and information mechanisms, initially voluntary farm-based fertiliser accounts which became mandatory and linked to tax levels paid [51]. Bans on direct discharges from manure were introduced, alongside government subsidies for investments in animal manure storage capacity.

Monitoring and review feature strongly in this policy mix and amendments to instruments have been made following effectiveness monitoring of the situation on the ground. This includes the strengthening of targets and introduction of further targets (e.g., on nitrogen leaching reduction; areas of forests, organic agriculture and wetlands) and requirements (e.g., mandatory fertiliser accounts, use of nitrogen fertilisers, requirements for low-nitrogen feed, limits on livestock) [19].

Denmark's policy mix aiming to reduce fertiliser use, has evolved since the first national policy document was published in 1985 and has a strong focus on strategic documents that clearly set out detailed policy objectives (targets to be met by a certain date) and announcing policy instruments to meet these objectives.

Fertiliser use in Denmark has decreased considerably since the 1980s while agricultural production has slightly increased. Average apparent consumption of nitrogenous, phosphate and commercial fertilisers per annum from 1980 to 1990 was 1128 thousand tonnes, which by 2005 reduced to 256 thousand tonnes, while agricultural production rose slightly (from a 1995 baseline index of 98, to around 100–102 between 1998 and 2004 [52]; where the index used by the OECD in its 2008 Environmental Data Compendium is based on price-weighted quantities of agricultural commodities produced, after deduction of quantities used as seed and feed.

The agricultural land area in Denmark has remained stable at around 2600 to 2700 thousand hectares (a 1990–1992 average of 2788 thousand hectares and a 2002–2004 average of 2656 thousand hectares) [53]. Figure 3 indicates that Danish fertiliser use has been absolutely decoupled from the agricultural sector's economic performance and that nutrient use and leaching have reduced. Yet, the graph does not depict the oxygen conditions of Denmark's waters, which have not improved to the extent required *i.e.*, the levels of oxygen in water remain too low for the healthy development of the Danish aquatic ecosystem; there was therefore no decoupling from impacts [54]. This is considered to be due to a still relatively high intensity of nutrients used per hectare in Danish agriculture compared with other OECD countries [53], as well as due to increasing temperatures caused by climate change. Hence, despite signs of absolute decoupling of fertiliser use from agricultural production and as temperatures are forecast to increase further, the Danish aquatic environment will continue to degrade if the flow of nutrients is not further reduced to take ecological limits into account.

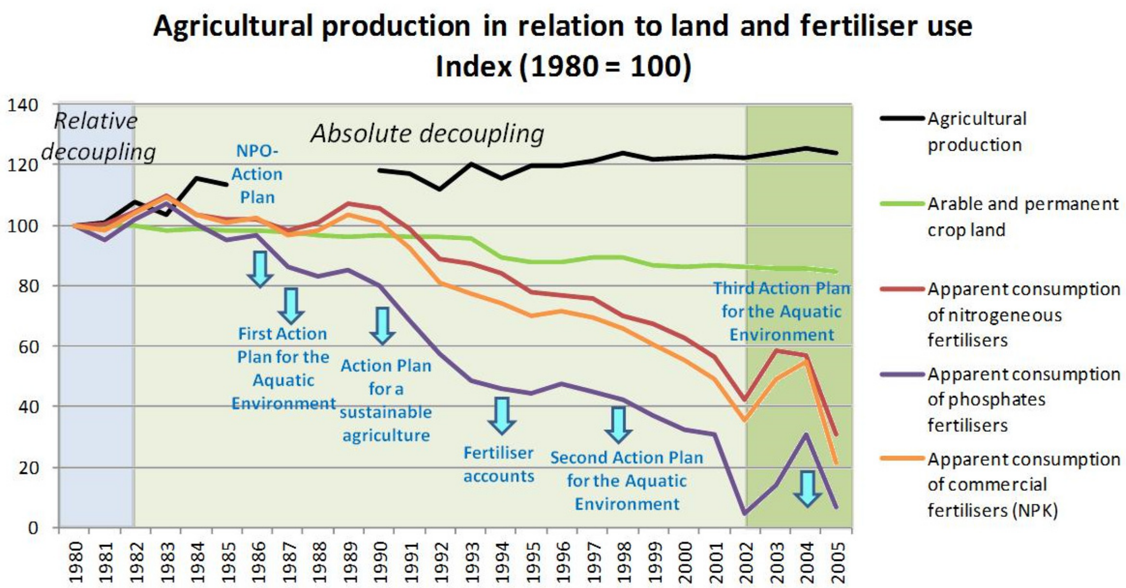

Figure 3. Decoupling trends in the Danish agriculture sector, agricultural production *vs.* apparent consumption of various fertilisers, 1980–2005 [52].

Case Study 3: More Efficient use of Aggregates in the UK

Aggregates are an essential input to the construction sector and whilst readily available they are theoretically finite. Furthermore, the extractive industries linked to their recovery are often characterised as highly wasteful and disruptive to ecosystems [55]. The aggregates tax in the UK represents a policy which has absolutely decoupled aggregates consumption from construction output. However, it is difficult to assess if this decoupling has taken place within limits.

A change of national government in 1997 introduced environmental tax reform efforts to internalise externalities associated with environmentally damaging activities. A landfill tax had been introduced the year before by the previous government (at a standard rate of GBP 7.00 per tonne and a reduced rate of GBP 2.00 per tonne for inert waste) and proposals for a levy on aggregates extraction were announced in 1997. In 1998, the Government announced changes to the landfill tax to make it more environmentally effective, including increasing the standard rate and in 2002, the aggregates levy was introduced at GBP 1.60 per tonne (see below for detail of increases both charges). The UK aggregates tax is a tax on sand, gravel, or rock that has been dug from the ground in the UK, dredged from the sea in UK waters, or imported. Secondary aggregates from building and maintenance of highways and waterways are exempt from the levy.

The policy mix which is the focus of this case study is primarily made up of the two charges (the landfill tax and the aggregates levy), supplemented temporarily by an aggregates levy sustainability fund which recycled levy revenue towards environmental improvements to aggregates production and alternative uses of recycled aggregates (from 2002 until early 2011).

Levels of both charges have increased over the years, with the landfill tax showing the most dynamism (against a backdrop of poor UK performance and based on waste management targets set out in various pieces of EU legislation). In 1999, an annual 'escalator' to the landfill tax (of GBP 1.00) took effect, lasting until 2004 (with an initial raising of the tax level from the original GBP 7.00/tonne to GBP 10.00/tonne in 1999 and increasing by GBP 1.00/tonne annually to reach GBP 15.00/tonne by 2004); and this escalator was increased (to GBP 8.00) from 2011 to 2014, taking the landfill tax to GBP 72.00/tonne. The aggregates levy was also increased in 2008 (from its original GBP 1.60/tonne to GBP 1.95/tonne) and in 2009 (to GBP 2.00/tonne). A further increase to GBP 2.10 was announced for early 2011 but the increase has been delayed by the current Government [56].

Figure 4 illustrates the trend in UK aggregates use against construction output against 1995 baseline levels. Before 1995 these were strongly linked, while from 1995 to 2010 a trend of absolute decoupling can be seen. There is an overall increase in construction output in combination with an overall decrease in aggregates consumption.

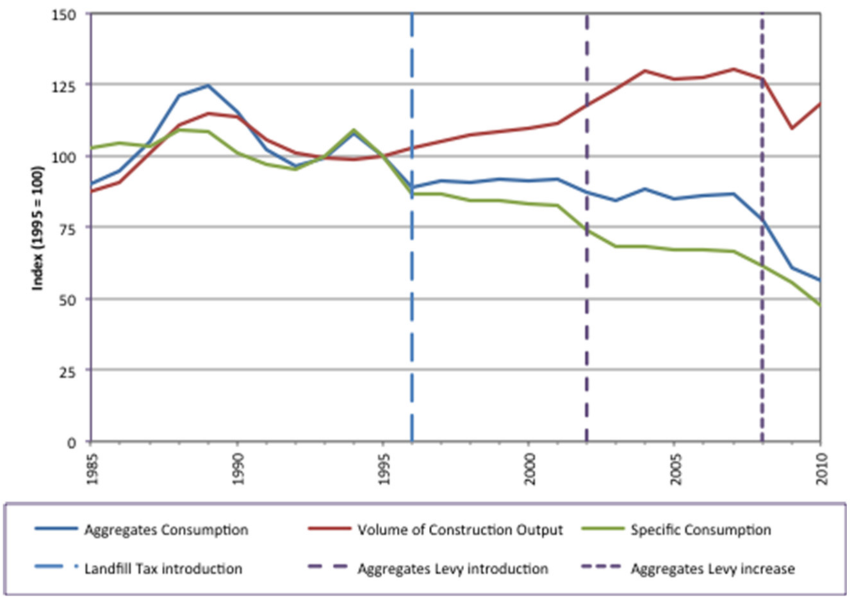

Figure 4. Policies and decoupling of UK aggregates consumption from construction output *against a 1995 baseline* [57].

While evidence of decoupling is clear, it is difficult to assess whether aggregates consumption has been decoupled within limits because the limits are numerous and complex to assess. Firstly, at a macro scale the quantity of aggregates which can reasonably be extracted is finite. However, these pressures may be more acute at smaller scales of observation, for example on small islands, in specific quarries or when considering minerals with specific qualities. Thirdly, environmental impacts are difficult to assess but potentially significant due to the processes used in mining. Dredging can also disrupt marine habitats, for example by destroying benthic organisms or disturbing critical micro water climates. Fourthly, these considerations for potential limits on aggregates are further compounded when considering that aggregates can also be imported (albeit accounting for just 1% of demand in the UK [58]); hence international considerations for those aggregates must also be taken into account. Considering these four dimensions, accurately assessing the sustainability of aggregates at a national level requires substantial assessment based on multiple indicators. Even though the policy mix of taxes and a sustainability fund was successful in almost immediately triggering absolute decoupling of the use of aggregates from construction output, with a minimisation of environmentally harmful waste disposal, it is therefore unclear that this was done within ecological limits.

Case Study 4: Reducing Plastic Bag Usein Ireland

Plastics represent a high utility finite fossil-based resource. Single use bags and other disposable plastic packaging items closely linked with consumption are often coupled with economic growth. Critically however, bags which have not been effectively collected by waste management systems accumulate and persist in terrestrial and marine biospheres, with unnecessary and increasingly well understood damage to marine life, as well as wider socio-economic impacts [59].

In 2002, Ireland introduced a tax on plastic carrier bags as a means of reducing litter through reduced bag use. Although before the introduction of the tax plastic bags made up a relatively small percentage of litter, the bags were seen as a visible and persistent part of litter in the countryside and along the coast [60]. The tax is the only ongoing instrument in this policy mix; it was temporarily complemented by public awareness campaigns around the time of its introduction.

Prior to the introduction of the tax, plastic bag use per capita was at 328 bags per person per year. Following the introduction of the tax at EUR0.15/bag, an extremely rapid and pronounced drop in plastic bag use, a reduction of 95% occurred in the space of five months, bringing per capita use to 21 per year. However, during a period of strong economic growth, this per capita use level gradually increased to 30 by 2006. The tax was therefore increased to EUR0.22/bag in 2007, leading to a reduced per capita use of 26 bags per person in 2008; 18 in 2010 [61]. The aim of the increased rate was to maintain annual per capita use at 21 or fewer bags. It should be noted that the 2008 global financial and economic crisis hit Ireland very hard, so this reduction in plastic bag use cannot be allocated purely to the tax level increase [62]. Nonetheless, this case study like the previous one dealing with aggregates in the UK, illustrates *absolute decoupling* (of plastic bag use from economic growth) achieved through a simple policy mix (mainly a tax and a public awareness campaign).

The more difficult aspect to establish is whether this decoupling addresses ecological limits (notably the levels at which plastic debris pollution poses serious risks for the marine environment). A legal provision was introduced in 2011 to set a ceiling for the tax at EUR0.70 and to allow the tax to be amended once in any financial year. Revenue from the tax is paid into an environment fund to provide funding for recycling centres and other environmental activities, including cleaning up illegal landfill sites; with annual revenues rising from initial figures of EUR 12–14 million to EUR 23.4 million in 2009. This fund could potentially serve the purpose of ensuring that decoupling occurs within limits (e.g., of the levels of plastic pollution which the earth system can tolerate *i.e.*, linked to its impacts on the marine biosphere); however this is as yet not a defined as a policy objective and would require an assessment of multiple national and international indicators.

3.2.2. Learning from Less or Not Yet Successful Experience

A small number of case studies from the DYNAMIX project had not yet shown signs of achieving any decoupling at the time of the ex-post assessment. One of the case studies detailed here addressed carbon dioxide (CO_2) emissions (focusing on industrial energy efficiency in Portugal), while another focused on the sustainable use of forests and wood (in Finland).

Case Study 5: Improving Industrial Energy Efficiency in Portugal

Fossil based energy production is closely coupled with economic output in most countries. In the EU, as part of decarbonisation programmes linked to climate change targets, Member States are undertaking initiatives to increase resource efficiency, including in industrial sectors.

Portugal's industrial energy efficiency policy mix was developed as part of the country's ongoing contribution to reaching the EU climate and energy targets for 2020; based on the national implementation of EU Directive 2006/32/EC on energy end-use efficiency and energy services (the Energy Services Directive) [63], which aims to reduce by at least 9% the final energy consumption of all Member States by 2016 (using 2008 as the baseline). Member States were required to submit their planned activities towards the target to the European Commission through National Energy Efficiency Action Plans (NEEAP). The NEEAP evaluated in the case study dates from 2008 and aimed to increase energy efficiency of total final energy consumption by 9.8% by 2015 (exceeding the EU target by 0.8%). Measures targeted all sectors, with 30% of the projected energy savings coming specifically from industry.

Three different instruments were used in the policy mix: an Industry Efficiency System, aiming to promote energy efficiency through modified production processes, new technologies and behaviour change [64]; green fiscal instruments, particularly taxes and an accelerated depreciation scheme to increase the uptake of energy efficient equipment; and the Energy Efficiency Fund to encourage behavioural change, raise awareness and support energy efficient equipment. Of the three, the Industry Efficiency System was the most constraining, requiring industrial facilities consuming more than 500 tonnes of oil equivalent/year (toe/year) to have regular energy audits [65], and to develop Energy Consumption Rationalisation Plans (PREns), setting individual facility-specific targets for energy and specific energy consumption as well as energy rationalisation measures [65]. Following approval by the national government these became strictly binding Rationalisation Agreements for Energy Consumption (ARCEs), linked to exemptions from excise duties on petroleum and energy products according to certain criteria [64]. The ARCE was also the basis for applying for subsidies for energy audits and investments in energy management and monitoring equipment [64]. Penalties for non-compliance with ARCE targets were also introduced, with a sum paid for each toe/year exceeded.

Despite the focus on industrial energy use and the synergies between the different regulatory and economic policy instruments, Portugal's industrial energy use per unit of value added increased slightly between 2000 and 2010 (see Figure 5). In the same period, Portuguese industrial final energy consumption reduced by 14%. Therefore, apparent energy use reductions appear to be due to a reduction in industrial production, rather than an improvement in energy efficiency. Portugal was amongst the EU countries hardest hit by the international economic and financial crisis and this is likely to explain much of the reduction in energy use. Hence in this case, the economy and energy consumption appear to continue to be coupled.

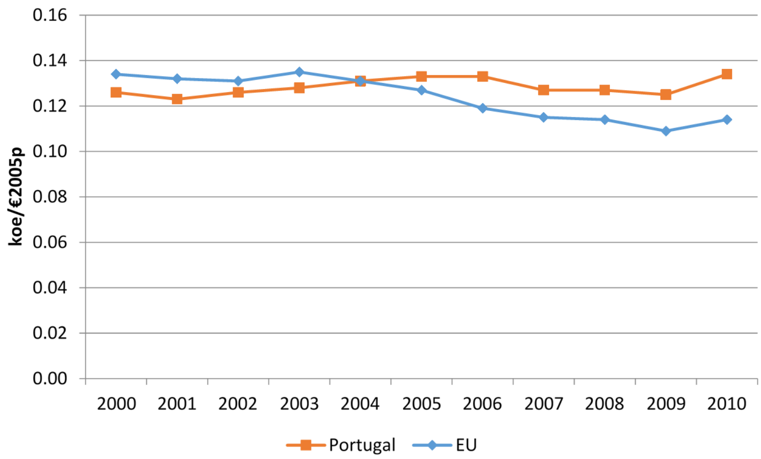

Figure 5. Portuguese and EU average industrial energy consumption per unit of value added (at ppp), toe/€ [66].

Case Study 6: Sustainable Use of Forests and Wood in Finland

Forests provide essential ecosystem services and a renewable resource when effectively managed. Excessive deforestation and mismanagement of forests continues to be a key global driver of biodiversity loss, carbon emissions and soil degradation [67]. In many countries forestry products or land use change contribute significantly to economic output, but the benefits are often coupled with environmental degradation. In Finland, efforts to increase the sustainability of the forestry sector have seemingly failed to decouple the economic performance of the forestry sector from environmental degradation.

The relevant policy mix in Finland aims to enhance and secure the sustainable supply of wood. It was created against a backdrop of international, EU and national efforts at controlling negative environmental impacts of unsustainable forestry management practices and tree-felling levels. This included the Forest Stewardship Council certification scheme at the international level and EU instruments such as the EU Forest Law Enforcement, Governance and Trade (FLEGT), Voluntary Partnership Agreements, the EU Timber Regulation and the Programme for the Endorsement of Forest Certification schemes.

Legislative acts on forestry were developed at the national level, with a strategic programme for the forest sector (2009–2011) and national forest programmes (2010 and 2015). Further voluntary measures were put in place for the certification and labelling of products for example; and financial support was awarded to develop more sustainable forestry practices and innovation projects.

Forests are culturally and economically important in Finland. The forest sector contributes approximately 4% of national GDP and forest industry products represent approximately 20% of Finland's total export of goods [68]. Finnish wood removals appear to be within sustainable resource limits (with removals at lower levels than growth). Domestic wood production has increased, yet remains healthily under the annual growth in growing stock. It also appears to have been stable over the past two decades, even though domestic consumption was steadily increasing until the 2008 global economic and financial crisis, particularly for wood fuel [69].

Absolute decoupling of wood removal from deforestation in the forestry sector can be said to have been achieved within *national* sustainability limits (as defined in the Finnish National Forest Programmes). However, the policy mix in Finland has not to date succeeded in decoupling the forestry industry's economic performance and wood removal, from the global degradation of forests: within planetary limits.

Habitat degradation and biodiversity loss in Finland was reported to continue despite some improvements brought about by the policy mix. This is thought to be due to intensive forestry practices, resulting in reduced ecological integrity and quality of habitats. Furthermore, the policy mix failed to address the substitutability of forestry products with imported goods whose environmental impacts are at least as significant. As wood consumption grew in the country there was a significant increase of imports (a 50% increase from 1990 to 2007), particularly of wood fuel (more than a 400% increase from 1990 to 2007) driven by EU and Finnish renewables targets. Worryingly, much of the wood fuel supply was imported from Russia and there is a suspicion that a large portion of this may be from illegal sources [70]. In order to achieve decoupling within *planetary* boundaries, national measures focusing on internationally traded resources need to address global impacts of resource use, particularly imports.

4. Insights from Real World Policy Mixes—Absolute and Relative Decoupling or Current No Decoupling

Ex-post evaluations of the policy mixes presented here provide examples of varying degrees of decoupling, from which a number of insights were drawn to support the development of the concept and policies in this field.

The resources addressed by the policy mixes ranged from locally produced and sold (aggregates), locally used and having larger geographical impacts (fertilisers), geographically mobile (fish), internationally sold and having local and global impacts (fossil fuels), to specific products (plastic bags, chosen for analysis as they are made from fossil fuel-based materials). Despite the diversity in the characteristics of the natural resources addressed by the policy mixes, a number of horizontal issues were identified in relation to *effectiveness in achieving absolute decoupling*:

- Ecological thresholds and absolute limits on resources are difficult to assess and it may not be evident how they can be applied to specific sectors at a local level. Research on planetary boundaries as the namesake suggests, is a theory for global limits; and disaggregating these to sub-global levels will always be complex and political, as is touched upon in existing research on the subject [71]. The nature of economic practices determines the appropriate thresholds to observe but in many areas these are not easy to define. Decoupling should consider the whole lifecycle of products and economic processes. For example, in relation in the case of plastic bags in Ireland, core issues relate to end-of life inefficiencies and wasted material. Marine litter remains a key impact of single-use bags but research on the subject is relatively underdeveloped and there is a lack of comprehensive understanding of impacts or appropriate limits [59]. Often thresholds will need to be determined indirectly by processes, rather than resources themselves *i.e.*, impact decoupling. This is the case for aggregates, which as a resource are in practice not scarce but the impacts of extraction can be disruptive on multiple levels and thus require limits. In this way, defining limits requires careful consideration of appropriate scales, resources and their impacts which are generally complex and diverse.
- Focusing on a specific resource or sector is more likely to achieve absolute decoupling. Such focus increases the likelihood of the policy mix being effective, particularly by allowing different instruments in the policy mix to provide enhancing support to each other (e.g., recycling revenue from a tax to fund activities to achieve policy mix objectives, cap and trade tools). In Ireland for example, the proceeds from the plastic bags tax were paid into an environmental fund used to finance recycling centres and the cleaning up of illegal landfill sites; also ensuring greater coherence within the policy mix.
- The complexity of the policy mix is highly dependent on the complexity of the resource through the economy. Complexity can be due to different uses of the resource (and therefore potentially numerous market failures needing to be addressed) and/or a high number of users. Hence the UK's aggregates and Ireland's plastic bags policy mixes feature no more than 2–3 instruments (which had more or less immediate positive effects in achieving absolute decoupling), whereas Denmark's fertiliser use policy mix includes more than 15 instruments (and has taken decades to achieve absolute decoupling, yet still not within ecological limits).

- The design of a policy mix needs to reflect the level and type of existing 'lock-in' to achieve transformation. The level of ease of transformation depends upon the level of (inter)dependency of economic and social systems in relation to the resource addressed by the policy mix, including whether substitutes are available or acceptable. Systems thinking can help to understand the range of inter-linkages and to identify which dependencies or market failures need to be addressed. Particularly in the case of economically deeply embedded resources (*i.e.*, where there is a very strong link between the use of a resource and economic performance) which run through the economy in a complex way (e.g., many users, resource forms and uses; wider knock-on effects). It is difficult to isolate specific elements of a wider policy mix to assess effectiveness of efforts on any one given aspect. An example is policy instruments focusing on industrial energy efficiency but which are part of overall CO_2 emission reduction efforts, which can include increased use of renewables and other forms of reducing CO_2. It is worth noting that two of the most progressive countries in the world in CO_2 reduction efforts, Denmark and Sweden, have either only just begun to show trends towards absolute decoupling (Denmark) or have had periods of no, relative or absolute decoupling (Sweden), despite ambitious efforts since the 1960s and 1970s. Fossil fuels and subsequently CO_2 emissions remain strongly correlated to economic performance.
- Absolute decoupling is more effectively achieved if a policy mix is based on identification and integration of limits and thresholds. This was particularly evident in Iceland's fish policy mix where the setting of total allowable catches was central; and in Denmark's fertiliser use policy mix which features clear targets for the estimated contribution of the various instruments.
- The availability of alternatives or substitutes is critical for absolute decoupling. The existence of alternatives to disposable plastic bags (multi-use bags) enabled the decoupling of plastic bag demand in Ireland.
- Policy mixes focusing on internationally traded resources need to address global impacts of resource use, particularly imports. The Finnish wood case study is a very good example of how domestic improvements can 'falsely' present a positive image while hiding potentially more significant negative impacts internationally through imports. Care is needed for domestic products being substituted by imports where these have environmental impacts that are at least as significant.
- Design of policy mixes to include targets and built-in monitoring, review and response mechanisms will better ensure effectiveness. This is particularly the case for more complex policy mixes addressing a higher number of market failures, such as the Danish fertiliser use case. A mid-term review of a central strategic document (Action Plan) resulted in introduction of further measures and revision of existing ones. This could also be the case for the Irish experience with plastic bags, where the tax was raised following analysis of per capita bag use.
- Engagement with affected stakeholders can help build a better balance between effectiveness and acceptance. Engagement depends on the specific stakeholder being addressed. For example, the general public can be better engaged through awareness-raising campaigns (as in the Irish plastic bag case), while industry sectors can be engaged through structured dialogue with industry (as in the UK's aggregates case where studies and dialogue were undertaken for up to five years prior to the introduction of the levy). Information instruments play a key role in the development of natural resources policies, but when used in isolation or as the central instrument in a policy mix, they fail to deliver the change demanded for decoupling. Information-based instruments such as labels can improve company and product transparency, but too strong a focus on information will not address important market failures. Nonetheless information-based activities can help raise awareness of key issues and act as a precursor to more ambitious activities. For resources about which relatively less is known, the role of information plays a vital role in setting the scene for future activities, for example in the area of critical metals.

The analysis of the case studies presented here provides insights which can be integrated into the design of future policy mixes aiming towards decoupling. Existing decoupling policy analyses confirm some of the conclusions which have been made here, including the need to develop explicit targets for decoupling [23], the need for alternative technologies [18,19,27] or the overall complexity of attributing decoupling to specific policies [27]. The need for more comprehensive policy mixes to reflect the many uses and users of certain resources (e.g., water) has also been previously exhibited [22]; as well as the interest of understanding the different factors driving changes in resource use or impacts, possibly beyond the proposed policies [13]. Existing research also demonstrates the limitations of relative decoupling, due to the risk that ecological objectives may not be met [12,13,18,27]. Several papers recognize that the quality of decoupling may evolve over the lifetime of a policy, such as Tapio [19] and Wang *et al.* [25]. Various studies also propose to compare different policy options on the basis of considerations (social for example) that go beyond resource efficiency [9]; echoed in this paper through the proposal to take planetary ecological limits into account. However, little research or indeed policies explicitly identify limits as part of their analysis or objectives respectively. While the qualitative case studies carried out here do not assess the policy mixes in the respective countries against set limit values, acknowledging them in the analysis provides an alternative perspective on the effectiveness of those policies.

5. Discussion and Future Needs

The DYNAMIX project has delivered analysis of existing policy mixes addressing a range of natural resources, evaluated in the context of absolute decoupling of resource use and/or its impacts from economic performance. It provides evidence of actual practice in absolute decoupling, as well as insights into less effective policy mixes that have so far failed to achieve decoupling.

The policy agenda on the sustainable use of natural resources in the EU continues to evolve, building on policies relating to sustainable consumption and production, waste and environmentally performant products. More recently, the resource efficiency agenda has raised issues on sustainable use of natural resources to the highest political level, making natural resources one of seven 'flagship initiatives' in the EU's overarching economic policy, Europe 2020. Horizontal activities since the publication of the Resource Efficient Europe Flagship Initiative [3] have increasingly focused on the circular economy as a tool for increasing resource productivity in the EU [72].

Further work on the EU sustainable use of natural resources policy agenda will need to continue to evolve in detail in the coming years, particularly to set out clearer objectives in relation to specific resources and sectors and to provide overarching political targets to crystallise effort levels and policy instruments to support the targets.

The need remains to strengthen EU natural resource policies through more detailed targets and supporting measures that set out limits and help to correct market and government failures that continue to encourage unsustainable consumption and production patterns. It is important to complement targets by "getting the prices right", for example by reforming environmentally harmful subsidies [73] and by wider environmental tax reform [71,74] Similarly, improved policy coherence, transparency and governance in policy making are all fundamental in enabling progress on decoupling, for example by finding synergies and avoiding trade-offs. Improving understanding and awareness will also be essential for innovation and demand choices that are central to absolute decoupling. Each of these will take considerable effort in itself, especially for a community the size, complexity and diversity of the EU. However, there are already a considerable number of successfully implemented policies that can inform and more systematically feed into and help deliver an overarching EU natural resources policy focused on absolute decoupling and national implementation.

One area needing considerable attention, particularly in light of the ongoing changed economic and financial situation in the EU after the 2008 crisis, relates to the economic performance indicator used to assess decoupling. All the policy mixes evaluated used GDP or production levels as indicators of economic performance, which perpetuates a narrow assessment on monetary valuation rather than looking more broadly at improvements in well-being.

The concept of limits is inherent in the context of policies seeking to achieve absolute reductions in natural resource use and would be better served by the use of indicators that more adequately reflect quality of life and well-being, beyond the historically-used indicator of GDP. In this way, the EU would make more effective steps in truly getting more from less to more well-being, equality and happiness while using fewer resources, staying within resource limits, ecological thresholds and ever less negative impacts on health and the environment.

There is a need for more systematic ex-post assessments of EU and national policies and measures, to learn lessons from successes and failures and inform the next generation of policies and measures. This is an essential part of better regulation, part of a wider science-policy interface and essential for effective policy making and implementation. This approach will support the evolution of environmental policies and other sectoral policies that enable decoupling of the EU economies from resource use and impacts, such that European economies can become resource efficient, low carbon and operate within the planet's limits.

Finally, a better understanding of absolute decoupling is needed through deeper analysis of a wide range of existing policy addressing different natural resources and impacts of their use. Absolute decoupling is not a 'one way process' that once achieved is guaranteed to continue. Apparent absolute decoupling can sometimes simply be accelerated relative decoupling and sometimes decoupling can go from absolute to relative and back, or even return to no decoupling. This is particularly the case for natural resources that are strongly coupled to (most usually) economic performance as illustrated through GDP. The urgent need for a global reduction of natural resource use and its related impacts will necessarily drive the policy agenda towards absolute decoupling. A better understanding of the possibilities and characterisations of policy mixes achieving absolute decoupling would serve to reduce, at least in part, key elements of resistance to the development of policy goals and policy instruments that explicitly aim to achieve such decoupling.

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