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To facilitate a fair bioeconomy transition, stronger regional-level linkages are needed

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Abstract: The great hopes in Brussels that a circular bioeconomy will help bridge the growing divide between urban and rural areas and allow the hinterlands to prosper from 'green growth' are addressed in this article, which reflects on insights from three Nordic case studies of brown, green and blue biomass use at different levels of technology readiness. A closer examination of the forward, backward, fiscal and final demand linkages at regional level from increased biomass utilization, from eastern Finland and northern Sweden to Jutland and North Atlantic islands, suggests that linkages are and will remain relatively weak, predominantly dashing the expectations. As suppliers and exporters of natural resources, disadvantaged regions may all too easily get locked into a 'staples trap', where the value

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creation evaporates owing in part to the steep start-up costs and the associated boom-and-bust cycles, which place them in a weak position vis-à-vis the resource manufacturers and consumers. To make the prospects of development, employment and prosperity in the hinterlands materialize, measures are needed to strengthen the regional-level economic linkages. Regional-level revolving funds based on benefit-sharing instruments related to natural resources can be used to bolster economic development, as reflected in such schemes present in both China and Canada. We call for further research into whether and how such approaches can be replicated successfully by channeling revenues from biomass cultivation to regional-scale revolving funds, with mandates to strengthen long-term economic linkages and prosperity within the hinterlands. © 2022 The Authors. Biofuels, Bioproducts and Biorefining published by Society of Industrial Chemistry and John Wiley & Sons Ltd

Key words: green growth; biomass; natural resources; disadvantaged regions; staples trap; Hartwick's rule

Introduction

As the European Union is embarking on its ambitious green deal,[1] funded from a multi-billion euro 'Recovery and Resilience Fund', a question is hovering in the sky: is the social dimension inherently pinned against a green recovery? The transformation of production and consumption aimed for will inevitably create losers as well as winners, with regions hosting traditional fossil-fuel based industries and businesses facing uncertain prospects. Still, bioeconomy approaches – for some time now recognized as part and parcel of the green economy – are providing leeway for substitutions of conventional fuels and resource inputs, while offering potential for new jobs and revitalized economic development in the hinterlands, so goes at least the mainstream argument.[2,3] The European Green Deal purports to 'leave no one behind', being 'just and inclusive' while obtaining climate neutrality by means of a 'circular economy (that) offers great potential for new activities and jobs' based on 'deeper cooperation across value chains'. By 'promoting the circular bio-economy' and a 'sustainable blue economy' the European Union has set sails for creating a 'fair and prosperous society', it is claimed.[1]

In this context this article addresses the regional disparities, which remain significant within the European Union, not only among Member States in the north and west vs. those in the east and south, but between urban centers and rural peripheries within virtually all Member States. The highest level of regional gross domestic product (GDP) per capita compared with the lowest shows differences at NUTS3 level [The regional classification for EU subdivides each Member State into three different levels, covering levels 1, 2 and 3 from larger to smaller areas. The disaggregation at NUTS3 level comprises 1169 regions of EU27] exceeding 5:1 in, for instance, Poland and Romania as well as in Germany and France.[4,5] The gap in GDP per capita between the richest and the poorest Member States is roughly 5:1 too. Considering the European Union as a whole, the 10 poorest regions produce less than one-third of the average GDP per capita, while the 10 best-performing can boast a GDP per capita three times the EU average – and more than 10 times the poorest.

Despite modest convergence trends at the overall Member State level, the intra-Member State regional differences have in fact deepened since 2010 and the financial crisis.[5] Processes of Europeanization and globalization have reinforced industrial decline in traditional sectors, including forestry and pulp and paper production. These processes have therefore triggered a weakening of regional centers and rural areas, while the hotspots of economic activity in urban agglomerations have barely compensated for the slow-down, as reflected in relatively modest rates of overall economic growth.[6]

The disadvantaged regions are frequently lacking the financial and human resources that would allow them to bet on green growth and are often reluctant toward challenging transformations.[7] A recent study shows how regions located in Member States and regions with poor economic performance are among the least bioeconomically mature, with an absence of innovation capacities and relevant business clusters.[8] The emergence of the *gilets jaunes* (yellow jackets) movement in rural areas of France reflects, besides despair over declining living standards, a hostility to the government's policies for a green transformation, which is perceived to offer limited opportunities. The hostility is disruptive to the envisioned low-carbon economy, where the active participation of farmers and foresters is very much needed for adjusting crops and increasing harvesting to spur the yields of the biomass resources needed.

The objective of the present article is to explore and analyze the regional-social dimension of the green transformation with the experiences of Nordic countries providing insights from bioeconomic innovations at different levels

of technology-readiness, covering brown, green and blue biomass uses.

In Europe, among the regions with the highest levels of maturity for bioeconomy innovations, about two-thirds are found in Nordic countries.[8] Finland and Sweden, in particular, provide significant capabilities for the emergence of domestic biobased industries, given their abundant forests and the associated industries. Denmark eyes potential with cascading uses of biomass from farming with its intensive livestock industry, while Norway and the north-Atlantic jurisdictions are exploring what further uses marine biomass is offering.

Thus, we find here a micro-cosmos of the European Green Deal, considering the pioneering role in environmental policies and innovations of the Nordic states, as well as the explicit strategy of the Nordic Council over the past decade to promote green growth and a bioeconomy, paired with ambitions to address social sustainability and welfare concerns in an era of skewed economic development.[9] Still, in recent years economic growth has been lagging in most of the Nordic area, especially outside the capitals and a few larger cities (Figure 1). We observe here that stronger regional-level linkages, especially of a fiscal nature, are required to escape some detrimental dynamics frequently at play in the resource-endowed territories.

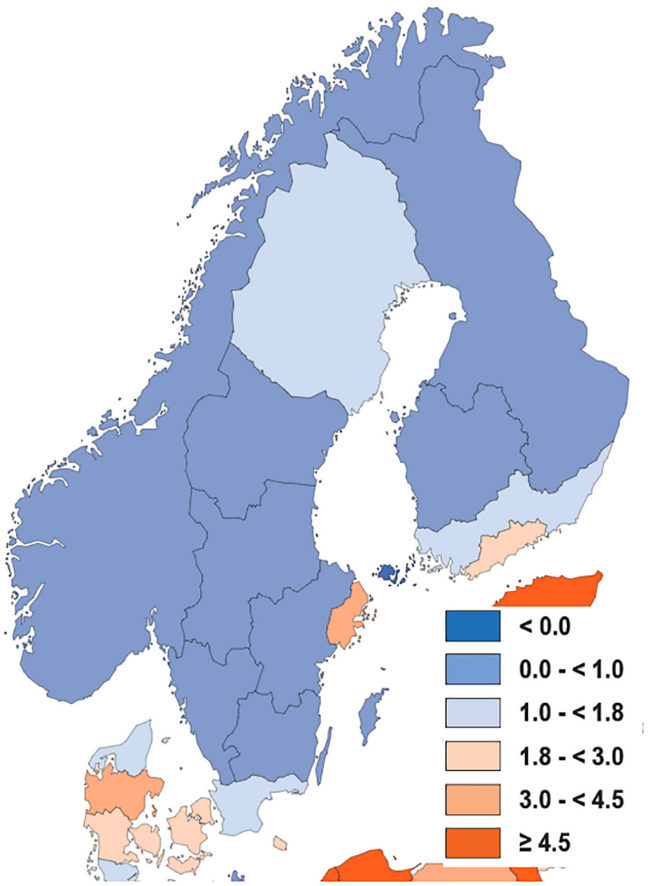

Figure 1. Average annual rate of change of gross value added, 2017–2019 (% per year; NUTS2 regions). Source: Eurostat.

The challenge of inclusive green growth

Biological resources are less 'pointy' than fossil fuels, as they tend to be owned and managed by a wide spectrum of people, communities and entities. This has led some scholars to optimistically conclude that a circular bioeconomy offers the 'possibility to generate a more equitable distribution of income, jobs, infrastructure and prosperity across a wider geography', even if they caution that the role of local populations should not be confined to simply harvesting and supplying bio-resources.[10]

Historical experiences show how resource-rich regions and territories, rather than thriving on the comparative advantage predicted by Ricardian theory, may frequently be captured and locked into a 'staples trap'.[11] Staples are un- or semi-processed raw materials destined for sale and export. A staples trap maintains certain territories as relatively passive suppliers of raw materials, with limited ability to capture the full market value of their natural resources. The inherent price volatility of raw material markets and the associated boom-and-bust characteristics of resource abundance, with a hollowing out of the market power of suppliers, is orchestrating the staples trap, where exports destined for processing elsewhere come to dominate the economy.

The volatility fundamentally stems from the steep start-up costs and the long lead times for cultivating or extracting resources, creating rapid market cycles as markets saturate and prices decline – with the vicious cycles frequently being underpinned and exacerbated by financial speculation. The volatility may feed a series of mechanisms and negative feedbacks, as when declining raw material prices lower demand for local labor that in turn seeks opportunities elsewhere, while the pressure on company finances triggers a quest for automation and rationalization, reducing the long-run employment potential.[12] Although resource-rich regions may be part of globalized production networks, they are frequently not to their advantage. The specifics of the resource-rich hinterlands have, however, not received much attention in the literature on regional development.[13]

According to staple theory[14] it is rather diversification and the development of linkages, backward and forward, to the local economy that are required to escape or diminish a

| *Biofuels, Bioprod. Bioref.* **16:**929–941 (2022); DOI: 10.1002/bbb.2363

staples trap (Table 1). Forward linkage refers to the processing of natural resources into semi-manufacture or final consumer products, whereas backward linkage refers to the sourcing of know-how, inputs and machinery from local suppliers. When there are also effective fiscal linkages available in terms of rent collection via royalties or harvesting fees, more funds will become available for the local economy's savings and investments. In turn final demand linkages will be strengthened, with more stable general employment and improved personal incomes.

Still, there are certain mechanisms at play that frequently hinder the formation of robust linkages in resource-endowed regions. Owing to the high start-up costs, primary producers are susceptible to indebtedness, and the servicing of capital from outside causes leakage of the revenues accruing from their raw material sales. With the pressure on earnings there is a propensity to employ low-skilled labor, possibly migrant workers, whose wages flow to their place of origin (fly-in fly-out practices), weakening any final demand linkages. A further key factor is the technical and marketing skills required for entrepreneurship, which often is sourced from outside and thus circumvents exploitation of local capacities and opportunities.[15] While more diversified regional economies may be able to meet some of the new demands for skills, goods and services, especially small or remote regions may find it difficult to uphold such diversification. For this reason, exports may be regarded as the safe option, as markets are better organized and more familiar. Finally, as long as earnings remain reasonable, raw materials producers are not likely to engage with the transaction costs of upgrading – it frequently takes a crisis to trigger processing or innovations in cultivation and extraction, as seen in the Swedish forestry sector in the mid-1970s with the shortage of timber.[16]

Table 1. Economic linkages with special reference to staple theory[13,15]

	Definition	Indicator
Backward linkage	A measure of the inducement to invest in the home-production of inputs, including capital goods, for the expanding export sector	Domestic production of machinery and semi-finished products as a share of exports
Forward linkage	A measure of the inducement to invest in industries using the output otherwise destined for export as an input	The further processing of natural resources and semi-finished products as a share of exports
Final demand linkage	A measure of the inducement to invest in domestic industries producing consumer goods for factors in the export sector	The size of the domestic market, in turn dependent on the level of income and its distribution
Fiscal linkage	The propensity of the state to stake a claim, for purposes of reinvestment elsewhere in the economy, on the resources that are being exploited in its territory	The presence and economic value of taxation, royalties and impact–benefit agreements with local stakeholders

Hirschman early on questioned the assumption of a trickling-down effect from richer regions to poorer ones.[17] Regions with economic progress will tend to attract the best skilled technicians and managers, who would be poorly remunerated by staying in the hinterlands. The remote areas are furthermore often not sufficiently attractive for highly educated people (with families demanding leisure activities, cultural experiences, good infrastructure such as international airport, etc.). If confronted with higher prices on raw materials from depressed areas, the best performing areas may opt to source their primary products from elsewhere or simply to develop novel primary production, possibly as synthetic production.

As noted by D'Amato and Korhonen,[18] the bioeconomy as currently conceived offers no concrete solutions on how to shorten the distance between the resource-providers and the resource manufacturers and consumers in urban areas. The bioeconomy holds prospects of employment and development in rural areas through regional bioclusters but remains timid in addressing regional and global inequalities. Since the labor requirements are the same for growing food crops and energy crops, the added employment from bioeconomy transformations is expected to stem either from the processing of bio-resources or from the cultivation of fallow land not previously in use for human needs.[19] Still, the technical skills and scientific knowledge required for the bioeconomy are not readily available in the hinterlands, from where calls for vocational training for future entrepreneurs and mechanical engineers are heard.[8,20] Altogether these circumstances seem to dampen expectations as to what might be achieved from the bioeconomy in terms of regional development in the hinterlands, complicating their nexus with and gains from EU's Smart Specialization Strategy, as clearly reflected in the recent official evaluation of bioeconomy developments in EU regions.[8]

In the following, we consider the possible bioeconomy transformations via three case studies, while applying the conceptual framework of staple theory to analyze them. The cases comprise a brown value chain of forest biorefineries (Sweden and Finland), a green value chain of grass biorefining (Denmark), and a blue value chain of algae biomass (the North Atlantic Faroe Islands) [As a self-governing jurisdiction within the Danish Realm, the islands have many commonalities with Norway's distant coastline

regions as well as with Iceland in terms of the main value chains with the significance of fishery and the sea, and also have fishery, research and trade agreements with EU without being part of it.]. These cases correspond to the three most advanced and non-food biorefinery concepts based on lignocellulosic, wet and marine biomass, respectively (see Table 2).[21] They are all reported in greater detail elsewhere, as part of the New Nordic Ways to Green Growth research project.[22,23,24]

The brown value chain: Lignocellulosic biomass from forestry for advanced biofuels

Nordic hinterland regions with their vast forest areas and declining pulp and paper industries are venturing into a bioeconomic transformation, where forest industries have ambitions to supply raw materials for bioenergy and biobased products. For instance, with demand-pull from motor fuel blending requirements and some financial support from government, several large companies have pioneered biodiesel production based on biomass. While the industry that produces hydrogenated vegetable oil (HVO) tends to rely mostly on imported oils, e.g. from vegetables or food processing, one domestic plant is relying on forest-industrial side streams.[24] Other companies that so far have relied mostly on grain based bioethanol and rapeseed Fatty Acid Methyl Esters (FAME) to contribute to blending requirements, are however turning toward HVO (Hydrogenated Vegetable Oil) using, for instance, crude tall oil (Anglicization of the Swedish *tallolja* i.e. 'pine oil'; rosin) – a byproduct of pulp factories – as feedstock for the production of renewable biodiesel. HVO can readily be utilized in mixtures of fossil diesel of up to 70–100% and in conventional diesel motors. With the EU restrictions on palm oil and food-based feedstock, forest industries see a market opportunity in advanced HVO biodiesel, which allows for high blending levels and under EU state aid rules benefits from reduced motor fuel taxation.[25]

The key entrepreneurs have been large companies such as Neste, St1 and UPM with some production infrastructure in several Nordic regions. While UPM has established a dedicated HVO plant at their facilities in Lappeenranta in rural Finland, SunPine has opened an HVO plant in northern and rural Piteå in Sweden. However, it will be relying on existing refinery infrastructure in Gothenburg, the country's second largest city, where also their next HVO plant will be established. Hence, forward linkages at the regional level of Sweden's hinterlands are absent.[24]

Maintaining activity in the forest industry can help counteract population outflow from the more remote areas.[26] However, the optimistic job estimates frequently presented tend to stem from bottom-up assessments of plants

Table 2. Comparison of three bioeconomy value chains implemented in Nordic hinterland regions

Value chain	Brown	Green	Blue
Bioeconomy resource	Lignocellulosic biomass	Wet biomass	Marine biomass
Productive sector(s)	Forestry; biofuels	Agriculture; food	Fisheries and aquaculture
Products	Advanced biodiesel (HVO)	Green proteins	Raw seaweed for alginate
Technology	Forest biorefineries	Grass biorefining	Algae biomass harvesting
Technology readiness level (TRL)*	TRL9; commercial	TRL7–8; demonstration	TRL6–7; pilot
Innovation type	Substitute product	Substitute product; new processes	New and substitute products
Operator(s)	Industries co-owned by government	Landowner with government support	Private fish farm entrepreneurs
Hinterland regions	Lappeenranta, South Karelia (Finland); Piteå, north Bothnia (Sweden)	Struer, West Jutland (Denmark)	Faroe Islands (North Atlantic; realm of Denmark)
Backward linkages	Wood sourced from forest owners	Grass sourced from farmers	Integrates multi-trophic aquaculture with fish farming
Forward linkages	Basic processing; use of existing refinery structure elsewhere	Cascading use of residuals for biogas plant and non-GMO fodder	Valuable extracts with operation at larger scale
Final demand linkages	Limited	Limited	Limited
Fiscal linkages	Weak despite tree harvest royalties (in Finland only)	Weak despite land value taxation	Weak despite small turnover tax on aquaculture

*TRL definitions of NASA: (6) technology demonstrated in relevant environment; (7) system prototype demonstration in operational environment; (8) system complete and qualified; and (9) actual system proven in operational environment.

| *Biofuels, Bioprod. Bioref.* **16:**929–941 (2022); DOI: 10.1002/bbb.2363

or technologies, whereas macro-economic assessments emphasize how forest resource use will be diverted from other sectors,[27,28] i.e. as increased wood prices curb biomass use in district heating. Hence employment impacts are projected to be neutral, or with only small gains, as the labor-intensive sectors that gain are offset by other sectors losing production.[29] Moreover, Neste has decided to place its HVO production facilities in Rotterdam and Singapore, avoiding forest residues as feedstock. This approach should be a disappointment to the Finnish government, which owns 44% of Neste and had hoped that biorefineries would strengthen backward linkages and bring jobs and income taxes.[30]

Some observers see advanced HVO-biodiesel as an interim technology owing to concerns related to land use changes and biodiversity from logging.[31] Biological resources are valuable and the forest resources that can be harvested sustainably could become subject to more advanced processing for biobased products. In particular, tall oil is scarce (3–5% of pulp production volume), with potentials for other uses in the chemical industry. Government support to advance biodiesel may obstruct the market for such value creation, limiting local forward linkages of forest industries. So far, innovations have mostly been incremental, as the incumbent industries prioritize innovations that do not conflict with core skills and practices, whereby more advanced biorefinery trajectories, based on byproducts with favorable sustainability performance, are being forfeited.[32] Despite royalty payments from tree harvesting in Finland, the overall fiscal linkages are weak at the regional level. Tax revenues are collected by the central government and the regional administrations have no own-source incomes.

The green value chain: Wet biomass of grass for biorefining

Switching agricultural land use from crops to perennial grasses allows for a value chain where green proteins are extracted from grasses to replace some of the imported livestock feed with proteins sourced from soy, with the biomass residuals (juice and fiber) cascading into co-feeding biogas generation, providing combined heat and power production for a protein plant while supplying surplus gas upgraded for the grid. The digestate from the biogas plant in turn holds potentials as fertilizer, allowing for substitution of GHG-intensive mineral fertilizer imports.[33,34]

As the proteins can only be extracted from the grasses while still wet, the protein plant needs to be in the vicinity of the harvested fields, providing a case for forward linkage from the raw materials to harvesting. However, as the input needs to be sourced during the growing season, a protein plant will not be operating all year round, and so the otherwise limited labor demand might be covered by non-resident temporary staff. Low-skilled labor is required for the harvesting itself, while just one or two technicians are needed for operating the protein plant.[22]

In terms of backward linkage, the technical equipment for the protein plant is not sourced locally but from specialized suppliers. Investment in the first land-owner managed demonstration plant is with 50% public financial support, while for upscaling mortgage lending from national level credit agencies or investors will be required. The main backward linkage is the supply of wet biomass, which however does not increase the return to the farmers, as compared with crop growing, despite the farmers switching from a market with numerous buyers to one of, at best, an oligopoly.[35] The absence of higher returns is due to the high costs of honoring the investment capital, making the protein plant commercially viable only when farmers abstain from price and risk premiums. To grow the grasses efficiently, higher inputs of fertilizers are required as compared with crops, adding costs and limiting the scope for higher returns.[34]

The fiscal linkages are hence relatively weak, as an absence of higher returns would leave land prices as they are, thus forfeiting land value tax increases. A positive revenue stream stems from the labor salaries, to the extent that labor is sourced from the region itself and in vicinity to the plant. There are no requirements in Denmark for royalty payments or any harvesting fees to the benefit of the region of the landowners. The biogas plant, if expanded to accommodate the wet biomass revenues, will be able to attract higher subsidies from the national support scheme for renewables, but similar to the protein plant most of the financial flows will benefit the specialized providers of technical equipment for biogas production, servicing profitable returns to the investors. As a result, the final demand linkages to the region must be considered modest, even if the region sustains higher external costs from the more frequent lorry transports of the voluminous wet grasses and digestates.

The blue value chain: Marine biomass from algae cultivation

Cultivation and harvesting of seaweed to supply alginate in demand from a range of industries, including textiles, food, pharmaceuticals and paper, has been reinvigorated and offers prospects of specific valuable extracts useful for cosmetics, food additives and chemicals, for instance. Seaweed cultivation jointly with fish farming as integrated multi-trophic aquaculture involves circular loops among species at different trophic levels. As an infant business, seaweed cultivation competes for space and licenses with fish farming,

and with limited spatial opportunities left in many coastal fjords of the North Atlantic, exploiting synergies is considered the way forward.

With only a few small-scale producers the raw seaweed is destined for export; apart from washing, drying, ensiling and milling, further processing takes place elsewhere. The industries that can make use of seaweed are not situated in the coastal communities, and with their remoteness and small population base, local demand for other seaweed-derived products remains too limited to support a viable business model for processing.[23] It would also require higher market prices for processed seaweed to trigger forward linkages in the region. Despite an innovative method to avoid the costly re-seedling of brown seaweeds (*Saccharina latissima*), the production costs, especially salaries, remain high in comparison with Asia's nearshore and manual labor approach. Even processing into the stream of potential valuable extracts can hardly match the current production cost level and the industry would seem to require operation at larger scale.

By integrating fish farming and seaweed cultivation, higher biomass yield (up to 60%) can be harvested without using more space, while integration can reduce the amount of waste emitted from fish farming. Still, backward linkages in terms of the use of local expertise, equipment and infrastructure for seaweed cultivation have not yet emerged, as cultivation methods are based on rigs and growth lines imported from outside. The scope for integration is further constrained by the seasonal mismatch in the relatively cold waters between peak nutrient uptake of seaweeds and fish farm effluents, limiting its environmental and economic value.

Despite a persistent quest for independence, there is no tradition of extracting rent from marine resources in the Faroe Islands, where algae harvest is pioneered. Although the collapse of the economy in the 1990s led to legislation allowing for the charging of resource rents, the law was soon revoked, a start–stop policy process that repeated itself in 2018–2019, despite fishing licenses being concentrated on still fewer vessel owners. Economic experts assess that a potential royalty income of more than €2 billion could accrue annually from marine resources.[23] Nevertheless, apart from a small turnover tax on aquaculture, political pressures from vessel and fish farm owners indebted to foreign investors have been sufficiently strong to fend off the institutionalization of such fiscal linkages.

Discussion

Controversies on land use changes from increased biomass production have largely overshadowed concerns over the optimistic claims regarding the beneficial impacts on rural areas in terms of increased employment and higher value added.

The Copenhagen declaration for a bioeconomy in action proposed that 'the perceived conflict between food and non-food production from arable land could be overcome by using agricultural crop and forestry residues and biodegradable waste as well as selecting feedstock such as algae and other under-exploited resources from aquatic and marine environments, and by using existing and new knowledge and technologies to increase biomass yield' while reiterating that 'this economic concept (bioeconomy) is composed of numerous new value chains to which farmers, fishermen and forest and aquaculture managers will add significant value' leading to 'social inclusiveness'.[36]

Regarding the employment impacts of a bioeconomy transformation, Copenhagen Economics identified substantial potentials,[3] estimating opportunities for tens of thousands of new jobs to implement and service the bioeconomy, 80% of which would be created in rural areas and involve low-skilled workers and technical staff. Unfortunately, the appendix footnote cautioning that 'the job creation figures do not account for the fact that other jobs elsewhere may disappear, as a result of this job creation' has largely been neglected, thereby contributing to overtly optimistic appraisals of the implications of the bioeconomy to regional development. Specifically, if the factors of production engaged by the bioeconomy ventures are already employed elsewhere in the regional economy, there will be a loss of value-added in this preexisting activity. The increased demand for labor may also bid up wage levels, thus potentially diminishing the competitiveness of other private sectors and/or raise the cost of providing public services. Recognizing such challenges, the Nordic planning agency Nordregio as early as 2008 provided the dry assessment that cultivation of biomass requires no more labor than conventional arable crops, while perennial crops actually will be requiring less labor, so that the net employment effect, if any, is to be found in the advanced processing and cascading uses leading to higher value-added from biomass.[20]

The three cases revisited above are at different levels of technology readiness as regards the processing, with lignocellulosic biomass technologies having reached a higher readiness than most green and marine biomass technologies.[21] Nevertheless, with what we can learn from these cases, the chances that rural areas will truly prosper from their upscaling are, under the current circumstances, not very convincing. Despite the vast Nordic territories of forests, farmland and seas, the difficulties with establishing forward and backward linkages in the proximity of biomass-supplying areas owe much to the occurrence of limiting

| *Biofuels, Bioprod. Bioref.* **16:**929–941 (2022); DOI: 10.1002/bbb.2363

bottlenecks. Most actors in the bioeconomy are locked into the lower levels of value chains and have limited resources and appetite for innovation other than cutting production costs, with especially the poor access to finance and risk capital a pressing issue.[8] They have traditionally been served mostly by a synthetic knowledge base dependent on localized learning and sticky knowledge, whereas the bioeconomy challenge can be seen as requiring a shift into a more analytical and science-based knowledge base.[37,38]

From the wind energy experience, it is well known that the deployment of turbines in rural areas by distant investors meets with local resistance, as the local communities that must sustain the noise and amenity nuisances raise the 'what's-in-it-for-us' question.[39] Despite a legal scheme with compensation for real-estate owners in the immediate proximity of turbines and royalties from the wind power-generated revenues to local communities, local resentment against the siting of wind turbines continues to surface.[40] While there are some regional employment impacts of wind power during construction, they are modest in the subsequent production phase, reflecting the staple trap dynamics at play.[41] It is one thing for value to be created and enhanced in given locations, but it may be something different to capture it for the benefit of those locations.[13]

To break the deadlock of linkage deficits, stronger fiscal linkages allowing the regions their own financial resources to invest in the processing of biomass into high-value bioproducts are needed and deserve consideration. The start–stop policies of the Faroe Islands on the introduction of royalty payments for marine resources owed a great deal to concerns over the possible loss of investments, and the associated decline in job opportunities, involved with royalty payments to the government. However, if the royalty revenues, rather than being spent for public welfare consumption expenditures, were recycled back to regional level revolving funds, providing low-interest investment credit to local stakeholders and entrepreneurs, and infrastructure co-funding, then such concerns could perhaps more easily be dismissed. Rather than opportunistic investors screening for the highest returns on global markets when disposing of the bioeconomy value added, the commitment of a regional-level investor fund dedicated to the opportunities and creation of knowledge-intensive clusters in the hinterlands would help underpin a long-term payback to increase regional prosperity and welfare services. Revolving funds are well known in other sectors, e.g. social housing and environmental protection, not implying public ownership but merely as a de-risking instrument to facilitate investments.

Hartwick's savings rule denotes the amount of investment needed to offset declining stocks of natural capital, so that sufficient physical and human capital is accumulated to substitute and allow a rent that can make up for the shrinking resource stock.[42] Hartwick's rule is devised with exhaustible resources in mind, rather than renewables; nevertheless, as the biomass harvested may gradually deplete the land and sea of carbon, minerals and trace elements, unless skillfully managed, the rule is indeed of some relevance to a future bioeconomy too. Hartwick's rule provides justification for institutionalizing royalty schemes that allow governments to capture the revenues (the surplus over production costs) flowing from the exhaustion of the natural capital base. To ensure a sustainable development where future generations have the same opportunities for consumption as the present, the revenues captured must be reinvested by the government in creating other types of capital offering the potential for an equivalent stream of annual yield.[43] The literature generally points to the need for using the benefits to invest in public infrastructure, health and education, involving also investments that promote economic diversification (or what the European Commission refers to as smart specialization).[44]

However, far too often regions and countries rich in natural resources are deprived of such schemes and appear to be content with the short-term, direct employment opportunities associated with the extraction or mobilization of natural resources, notwithstanding the boom-and-bust cycles of resource price volatility that in the long run will tend to erode the number of jobs created. Whereas governments in developing countries will be pressed to spend any revenues accruing from royalties on resource extraction to mitigate pressing needs for food and health, governments in middle- and high-income countries are better positioned to undertake genuine savings to meet the criteria for a sustainable use of its natural capital. Indeed, Norway's Petroleum Fund provides the conventional best practice example of securing that the revenues from resource extraction are not squandered but are reinvested to provide a stable revenue stream far into the future.[45]

A novel approach to the mitigation of the regional resource disparities was launched recently in China with the revised legal framework for the country's natural resource taxation. To underpin development in its western hinterlands, China allows its provincial governments to retain revenues from resource and coal taxes.[46] The national government has defined the ranges of tax liabilities with ad-valorem rates of resource taxation, leaving it to provincial governments to fix the actual rates applying each year on their territory. The scheme has been demonstrated to have potential to spur economic development in the peripheral provinces.[47] In contrast, most developed and emerging economies channel revenues from resource taxation to the national government, although Canada presents a notable exception with provinces

benefiting. Interestingly, the Canadian scheme targets, besides non-renewable resources, also forestry. Its design resulted from the '1985 Western Accord', a provincial push-back against the fiscal policies of the federal government.[48]

Still, a major factor in the rising rural–urban gap in developed and emerging economies is besides the increased migration into larger cities the higher educational level attained by residents in urban areas. As there are higher economic returns available on educational attainment in urban areas with their knowledge-intensive clusters, there is a self-enforcing cycle at play. Rural and peripheral regions are drained of the most knowledge-intensive businesses, with urban areas attracting the greater share of investments, reinforcing the income gap. Funds of the national government that are committed to seek the highest economic returns on their investment will easily become part of this pattern of development, this unless there are firm obligations for a just spatial distribution.

The EU's Smart Specialization Strategy has been devised to channel large European funds to underpin regional development, rooted in a diversification strategy building on place-based comparative strengths. While aiming to resolve the problem of too standardized one-size-fits-all regional innovation policies, instead focusing on existing structures and strengths, its application in peripheral regions has proved challenging.[49] Studies have identified a regional innovation paradox, i.e. 'the mismatch between the large need for innovation in structurally weak regions and their low absorptive capacity to use innovation funds'. Despite their mature institutional and governance capabilities, the Nordic hinterlands are also complaining that 'In order to advance bioeconomy and smart specialization (…) more attention should be given to decentralized systems and dynamics between centralized and decentralized systems'.[8] In other words, the tedious procedures and strict requirements for obtaining a share in EU funds are leaving the peripheral regions with limited autonomy, locking them into schemes devised by Brussels administrators. Although some relaxation is planned for the 2021–2027 phase of the EU's Smart Specialization Strategy, the unbalanced control over public financial resources will not fundamentally change, with the regional innovation paradox likely to persist.

Conclusions: Policy implications and future challenges

Experiences from Nordic countries with low-carbon bioeconomy innovations, as reviewed here based on three illustrative case studies of brown, green and blue biomass at different levels of technology readiness, indicate that the linkages to spur green economy transformations and green growth in regions rich in natural resources are relatively weak and deserve far more attention. The scope for the upscaling of advanced innovations in circular and cascading biomass uses is seen to be constrained by the presence of staples traps and the absence of appropriate mechanisms for benefit sharing, as the hinterlands may prefer to cling on to business-as-usual rather than embark on risky low-carbon bioeconomy transformations.

An important policy implication is, therefore, that benefit-sharing instruments – e.g. royalties or taxes earmarked for revolving, regional funds – could be necessary to ensure stronger regional-level linkages, especially in regions and communities where existing fiscal linkages are already weak. Taxation is a prerogative of national governments, that could opt to strengthen and further develop the present fiscal instruments (i.e. timber royalties; land value taxes; aquaculture turnover tax) and earmark their revenues for regional-level revolving funds. The European Union could play a role by developing an overall framework in conjunction with its regional policies and in easing the conformity of de-risking instruments with state aid rules. The implementation of such regional funds is, however, not straightforward; previous experiences suggest a need for clearly defined strategic visions, co-funding and collaboration among different actors, transparent practices and sound financial policies.[44]

It is also important to recognize that the design and implementation of such benefit-sharing instruments will involve difficult trade-offs. First, there are trade-offs involved in introducing instruments that can help capture significant bioeconomy benefits but without discouraging further investment in the relevant sectors. Clearly, the introduction of too draconian land value taxation or royalties on biomass or its by-products could see the bio-sector slowly decline owinge to a lack of investment. Nevertheless, this article has argued that the bioeconomy often relies on industrial activities that may be in economic terms relatively detached from the regions in which the resources are harvested, so the benefit-sharing instrument essentially is a redistribution policy. Striking a balance is never easy, and the solutions, which may involve a shifting of the tax burden and/or of the revenue streams managed by industries, will need to be carefully tailor made to circumstances and context.

Second, there is the issue of the allocation of regional funds across different priorities. Rather than current consumption and in line with Hartwick's rule, there is a strong case for prioritizing low-interest loans for productive purposes and infrastructure or expenditures for education and vocational training. Difficult trade-offs remain, though. For instance,

| *Biofuels, Bioprod. Bioref.* **16:**929–941 (2022); DOI: 10.1002/bbb.2363

future infrastructure needs such as roads or electric grids may be difficult to anticipate ex ante and are typically identified as a consequence of productive activities, rather than in advance of them. Another challenge concerns the role of economic diversification. In some regions, support to sectors beyond the bioeconomy could involve risks since the regional economy may lack the capacity to absorb the investments productively. Here the Smart Specialization Strategy can play a constructive role by stimulating how hinterland regions can build on their specific strengths, potentials and opportunities.

Both of the challenges and trade-offs outlined above deserve scrutiny in future research efforts. This includes, for instance, more in-depth empirical work on how regions dominated by the bio-sector have adapted over time and managed to prosper in the presence of changing markets and policies, as well as deeper theoretical attention to the unequal nature of the relationships between resource-endowed regions in the developed world and global markets. Clearly, gaining increased experience of the impacts of various types of benefit-sharing instruments will also be important.

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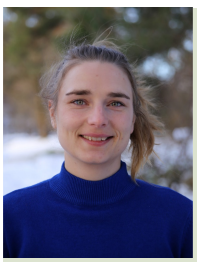

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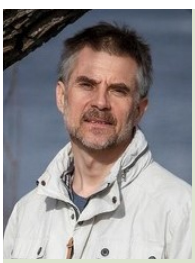

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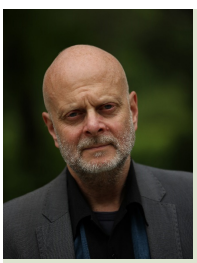

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