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Seaweed cultivation in the Faroe Islands: Analyzing the potential for forward and fiscal linkages

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ABSTRACT

Seaweed has been coined the ultimate sustainable crop for a green transition. The European Union considers seaweed an important tool for mitigating CO_2 emissions and making EU self-sufficient in proteins for feed purposes, but cultivation is still nascent outside South-East Asia. This paper studies seaweed cultivation in the Faroe Islands, which could provide the EU with large amounts of macroalgae due to promising geo-biophysical conditions, and asks whether seaweed cultivation is beneficial for the Faroe Islands too. According to staples theory, this depends on whether resource-extracting industries are embedded in society through *forward linkages* (local processing) and *fiscal linkages* (tools for rent collection). The analysis suggests the potential for developing forward and fiscal linkages is negligible. Thus, if expansion challenges are successfully addressed, the findings serve as an early warning for policy makers: they must consider ways to circumvent market volatility if seaweed cultivation is to benefit the Faroese society.

1. Is seaweed the ultimate sustainable crop?

Extraction of fossil resources contributes to climate change, and high-intensive agriculture and forestry contribute to losses of habitats, biodiversity and carbon storage potential. Switching to greener resources and new techniques for extraction, cultivation and processing might mitigate these problems and generate economic development. However, this paper argues that problems connected to resource dependency persist regardless of the resource or extraction technology in question. Take seaweed as an example. It can replace many fossil and agricultural resources. We can eat it or process it into value-added products such as fertilizers, biofuels, pharmaceuticals, nutraceuticals and cosmetics [1]. [2] coined seaweed *the ultimate sustainable crop* for several reasons. It grows extremely fast compared to terrestrial crops and needs no freshwater or arable land. Furthermore, seaweed consumes CO2, nitrogen and nutrients, hereby mitigating greenhouse gas emissions, acidification and eutrophication of oceans [3]. Two factors might send seaweed prices skyrocketing in the near future, making cultivation economically sustainable too. First, the European Union has agreed on a strategy for making Europe more self-sufficient in proteins, especially for feed purposes. [4]. This ambition could create a very strong demand for seaweed [5]. Second, using seaweed for feed purposes might help European countries reduce greenhouse gas emissions. For instance, studies by [6], [7] and [8] show very large reductions in methane emissions when even small fractions of conventional cattle feed is replaced with seaweed.

The question is whether seaweed is an attractive resource for those communities that have favorable conditions for cultivation. A historical example illustrates that reliance on seaweed may put coastal communities in a vulnerable position. Seaweed used to be an important source of income in Ireland, Wales, Scotland and Canada. In the 18th and 19th century, the Orkney Islands became wealthy by extracting potassium-rich ash from kelp and supplying it to manufacturers of pottery, glass, textile and soap. In the 20th century, Canadian East-coast fishing communities tapped into the global market for food additives by harvesting *Irish Moss* for its high contents of carrageenan. In both cases, the market for North Atlantic seaweed collapsed when cheaper supplies emerged elsewhere [9,10]. This wrecked the coastal communities; jobs and income were lost and population declined drastically. However, Canadian coastal communities which relied on other species, e.g. *Ascophyllum nodosum*, did not experience the same kind of market collapse [11]. Given the renewed interest in seaweed, the historical experience serves as a reminder that all markets – even markets for “ultimately sustainable crops” – may enrich, devastate or simply sustain those communities that depend on them for income and employment opportunities. This paper explores whether the Faroe Islands are likely to face challenges similar to those which devastated some North Atlantic coastal communities in the past.

Although seaweed cultivation is still nascent in the North Atlantic, it might not be so for long. Globally, seaweed cultivation is burgeoning. In the period from 2001–2016, global seaweed output almost tripled from

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approximately 11 mill. tonnes (wet weight) in 2001 to 32 mill. tonnes in 2016 [2]. Today, seaweed is mostly cultivated in South-East Asia [12]. Outside this region, the Faroe Islands are seaweed front-runners. We should expect that future growth in seaweed cultivation will take place in the North Atlantic in general and around the Faroe Islands in particular because conditions for seaweed farming here are very favorable, for example salinity levels, temperature and currents [13]. The single largest seaweed cultivator in Europe and North America (*Ocean Rainforest*) is located in the Faroe Islands. Ocean Rainforest has the world's biggest cultivation sites deployed in a deep open-sea environment [14]. The species *Saccharina latissima* (sugar kelp) has received much attention in the Faroe Islands. Its properties are very similar to *Saccharina japonica* (Japanese Kombu), which is the most commonly cultivated macroalgae globally [15]. Cultivation of *S. latissima* is therefore a promising supplement for the Faroese economy, whose export earnings come mainly from fisheries and salmon farming [16].

According to [12], price trends in the seaweed market are very cyclical and largely affected by harvests in China, the world's largest producer. Staples theory identifies challenges caused by such volatile markets and offers guidance on how to mitigate these challenges. According to staples theory, resource dependency may subdue economic development if linkages fail to evolve. Linkages connect a resource industry to the surrounding society in different ways. *Backward* linkages means that inputs such as investments, expertise, machinery, infrastructure and labor are sourced locally. *Forward* linkages means that the natural resource is processed into value-added goods locally. *Fiscal* linkages means that local authorities can collect resource rents and reinvest them locally. Finally, *final-demand* linkages means that regional demand for goods and services increases when income from the staples sector starts to flow. [17] argues that regions which extract and export natural resources become more robust if backward, forward, fiscal and final-demand linkages are present. If they are absent, regions might get caught in a *staples trap*. A staples trap is a situation characterized by economic vulnerability, decreasing employment and out-migration [18]. In short, a situation very similar to the Orkney Islands' seaweed experience. Staples scholars often look at the *longue durée* and analyze how linkages develop over time. However, inspired by [19] and Gunton [20, in], this paper argues that staples theory can also help us reach important insights about nascent and emerging staples. In order to achieve such insights, this paper presents a detailed, qualitative case study employing a Bayesian methodology for foresight analysis. The following research question guides the analysis:

What is the potential for developing linkages around Faroese seaweed cultivation?

This paper contributes to the staples literature in three important ways. First, it uses staples theory to examine one of the most promising natural resources of the green transition. To the best of this author's knowledge, this has not been done before, most likely because cultivated seaweed only recently has sparked commercial interest in the West. Second, it shows how staples theory can be used prospectively rather than retrospectively. And third, it discusses policy implications of the findings. Section 1.1 presents the history and current status of seaweed cultivation in the Faroe Islands. Section 2 introduces staples theory in more detail, while Section 3 presents the research design. The empirical findings are presented in Section 4. Section 5 discusses their significance, and Section 6 offers conclusions.

1.1. Background: Seaweed cultivation in the Faroe Islands

Harvest of wild seaweed has occurred throughout the Faroe Islands' history, but processing was only attempted in the early 1980s. In 1980, a factory was established to extract alginate from brown macroalgae, but it closed down after only a few years because satisfactory levels of alginate could not be extracted [21]. In 2010, cultivation has been

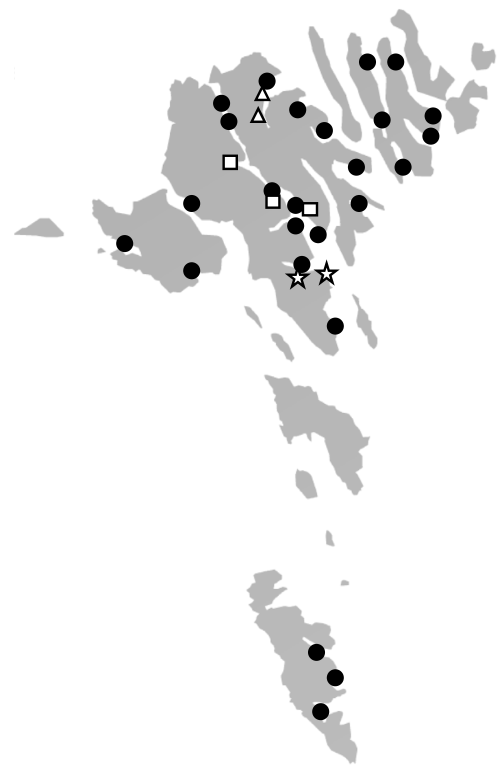

Fig. 1. Aquaculture locations in the Faroe Islands, 2019. Map of salmon cultivation sites (circles) adapted from [27]; Squares: seaweed cultivation sites of commercial actor TARI Faroese Seaweed; [28]; Triangles: seaweed cultivation sites of commercial actor Ocean Rainforest [15]; Stars: seaweed cultivation sites of research institution Fiskaaling [29]. To the best of this author's knowledge, the map is complete.

taken up by *Ocean Rainforest* as an alternative to wild harvest. Ocean Rainforest is a small company with less than a dozen employees. According to their website (www.oceanrainforest.com), Ocean Rainforest operates two vessels and more than 42,000 meters of seeded lines and has a laboratory, a hatchery for seaweed seedlings and capacity for cleaning, storing and pre-processing. Ocean Rainforest sells four kinds of seaweed: *Saccharina latissima, Alaria esculenta, Laminaria digitata* and *Palmaria palmata* mainly as food, but also for cosmetic purposes. From 2014 to 2016 Ocean Rainforest harvested 3.2 tonnes dry weight seaweed from their macroalgae cultivation rigs [13]. Thus, seaweed cultivation is still a very small-scale business. The main export markets are the UK, the Netherlands, Germany, Denmark, Estonia and North America [22]. Apart from Ocean Rainforest, *TARI Faroese Seaweed* and the research institution *Fiskaaling* also cultivate seaweed, but at smaller scales.

Faroese law defines all living marine resources as property of the people. Private actors' access to marine resources are therefore not property rights as such, but licensed user-rights, which may never become permanent private property [23]. Seaweed cultivation is such a novelty that specific legal frameworks do not yet exist, so seaweed cultivators operate on salmon farming licenses [22]. Private actors can trade these licenses, and the 2009 liberalization lets one single actor hold up to 50 per cent of all licenses [24]. The current legislation strictly regulates aquaculture and the locations where it is allowed [25,26]. This proved necessary as aquaculture experienced rapid expansion from its beginnings in 1967 and struggled with disease problems, low prices and bankruptcies. In 1980, there were 63 aquaculture facilities around the country. However, by 1994, this number had dropped to 20. The map in Fig. 1 shows all active salmon farming locations and present and former seaweed cultivation sites.

Expansion of seaweed cultivation runs into one major challenge. According to [23], all locations suitable for aquaculture are already occupied in the Faroe Islands. Thus, as long as seaweed cultivation is restricted by salmon farming licenses, seaweed cultivation can only occur near existing salmon cultivation sites, see Fig. 1. This limits the expansion of nearshore seaweed cultivation. However, techniques for far-offshore cultivation have received much academic interest in recent years [13,30–34, see for instance]. These techniques include stand-alone cultivation rigs and co-production with offshore installations like wind farms and oil rigs, which can withstand rough sea conditions. Depending on the development of these techniques, Faroese seaweed cultivation might be able to expand outside the already crowded fjords. Another option for expansion is integrated multi-trophic aquaculture (IMTA). IMTA is not a new idea; it has been practiced commercially in Asia for a long time [35], and recently also on pilot scale in for instance Canada [36] and Norway [37]. IMTA involves circular flows of nutrients among species at different trophic levels. For instance, particulate waste from fin-fish aquaculture (e.g. uneaten feed and faecal matter) falls down through the water column and serves as a food source for bivalves, while dissolved components (e.g. metabolic waste nitrogen) serve as nutrients for macroalgae production. Harvest of macroalgae and bivalves then becomes feed for the fish, thus closing the loop and reducing the amount of waste that would otherwise enter the wider environment [35]. If salmon farming continues to grow in the Faroe Islands, bio-remediation through IMTA is not only attractive, it might even be necessary. As salmon farming is already a vertically integrated business it seems plausible that salmon farmers can incorporate seaweed farming into their existing business models. The remaining part of this paper explores how an expansion of Faroese seaweed cultivation might affect the surrounding society. This exploration takes staples theory as the point of departure, and focuses on the potential for developing forward and fiscal linkages around seaweed cultivation.

2. Staples theory: Outcomes, causes and mechanisms

In his seminal book “The Fur Trade in Canada”, Innis defines staples as *unprocessed or semi-processed export-oriented raw materials* [38]. Thus, any resource, including seaweed, can become a staple. Staples theory’s founding fathers, Innis 1999[1] and Macintosh 1923,1936, originally used staples theory to describe how economic life played out in Canada’s important trade sectors: fur, cod, wheat and timber. Innis was motivated by the fact that the dominant economic paradigm at the time, i.e. the Ricardian comparative advantage paradigm, seemed inadequate to explain Canadian economic history [41,42]. Canada’s experience seemed to suggest that comparative advantages and competitiveness did not add up to long term economic development. Instead, Innis noticed that Canadian regions relying on their comparative advantages, i.e. their natural resources, often became locked in a staples trap. [18] shows that the same is true outside Canada, because staples markets are often more volatile than markets for processed goods.

Several factors contribute to this volatility. Resource extraction is typically characterized by economies of scale and very steep start-up costs, and staples markets respond slowly to price signals because of long lead times, i.e. the time it takes to breed, cultivate or extract resources. These dynamics create cyclical markets: When prices are high, investments increase until the market saturates. Prices decline when markets saturate, but it takes time to adjust production to new price signals. Eventually, production declines, leading to increased demand, rising prices and investments all over again. Recent years have seen more severe and rapid market fluctuations than ever before, and this increases uncertainty for resource dependent regions [43]. Fig. 2 shows that the global seaweed market displays the cyclical price structure that often characterizes staples markets. Dependency on such markets can become self-reinforcing through two mechanisms: Dutch Disease and income leakage.

[1] Originally published in 1930.

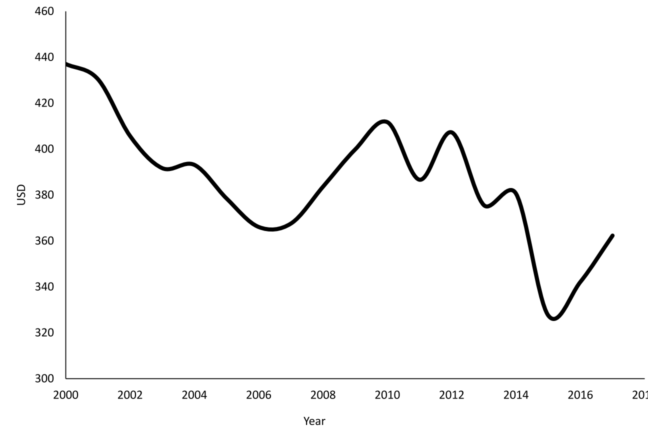

Fig. 2. Value per tonne seaweed (USD/wet weight), 2000–2017. From 2001 to 2017, prices fluctuated between $437 and $328 per tonne wet weight. Based on data from [44].

Dutch Disease occurs when prices for natural resources increase and export soars. In such periods, national currency may increase in value and make other export-oriented sectors less competitive on the global markets. This problem is often solved through outsourcing, potentially resulting in permanent job loss [45]. In short, *Dutch Disease* hollows out manufacturing capacity, and when other export sectors are weakened, resource-extracting industries become even more important for obtaining foreign currency. Consequently, these industries can become more influential, which for [46] raises the concern that they will be able to lobby and affect policy making. When prices decline, *income leakage* can become a problem. At the company level, lower revenues make it harder to service debt. To mitigate this pressure, production might be rationalized and automated leading to decreasing employment potential [43]. A negative spiral might arise in which workers unable to find jobs in the resource sector seek opportunities elsewhere, which strengthens the impetus for automation and further decreases local employment potential. Consequently, capital exits the local economy and tax revenues decrease too. This loss of capital impedes public and private investments, which could have otherwise generated new sources of revenue and employment. As a consequence, the region depends even more on existing resource industries, which may eventually become *too big to fail* [20].

2.1. How economic linkages reduce vulnerability

Together, Dutch Disease and income leakage can reinforce dependence on volatile staples and lock regions into a trap. However, [17] noticed that some developing countries experienced steady development even though they relied heavily on natural resources. [17,47] developed the notion of local economic linkages to explain how staples could be catalysts for development. Watkins argued that traps could be avoided if regions developed local linkages, as these would help regions maximize resource rents and reinvest wealth into other parts of the regional economy thus diversifying economic activities. Contrary to the Ricardian paradigm, Watkins contended that *diversification*, not *specialization*, was the path towards sustainable economic development. A diversified economy would act as a bolster against market fluctuations, leaking income, inequality and resource depletion [20].

So, what do strong linkages look like? According to [17], *backward linkages* are strong when the resource-extracting industry relies on local input sourcing for important factors of production, e.g. expertise, equipment and infrastructure. *Forward linkages* are strong when the resource is processed locally to higher value-added products before export. *Fiscal linkages* are strong when the institutional setup allows for efficient and transparent collection of resource rents. Collection tools include taxation, royalties and impact-benefit agreements with local stakeholders. The presence of strong linkages make resource-extracting regions better equipped to avoid trap trajectories. The benefit of forward linkages is that markets for value-added goods are less volatile than commodity markets. The benefit of backward linkages is that local input sourcing makes currency fluctuations matter less. The benefit of fiscal linkages is that they make more capital available for investments in the local economy. When these three types of linkages are present, strong final-demand linkages may develop too, i.e. increases in income and general employment.

Note that staples theory highlights linkages as *necessary*, but *insufficient* conditions for avoiding negative development pathways. Consequently, by emphasizing relations of necessity and sufficiency rather than symmetric, linear causation staples theory relies on a set-theoretic conception of causality: *presence* of linkages does not guarantee economic development, but *absence* of linkages makes it very hard to withstand challenges caused by market volatility.

2.2. Hypotheses on forward and fiscal linkages

Staples analyses often include all four types of linkages. However, analyzing final-demand linkages requires detailed economic modeling beyond the scope of this paper. The analysis also ignores backward linkages because seaweed cultivation is still such a small-scale business that it is unlikely to induce Dutch Disease. Thus, from the perspective of staples theory, the potential for developing forward and fiscal linkages is what crucially matters in the Faroese context. The staples literature considers two factors as important for the development of forward and fiscal linkages: geography appropriability. *Geography* is important for the development of forward linkages. Impenetrable terrain and long distances to export markets create incentives to process the resource in order to off-set extraction and transportation costs. *Appropriability* is the degree to which public administration is able to tap into the income stream accruing from the staple to various actors [48]. The degree to which resource rent is appropriable depends on the spatial distribution of the resource and the institutions that define property rights. *Diffuse resources* are spread out, while *pointy resources* are concentrated either in spatial terms, or in terms of who owns them. [48] argues that rent from pointy resources is more easily appropriable than rent from diffuse resources, because extraction of pointy resources is very visible. Extraction of diffuse resources, or *escape crops*, is much more difficult to monitor, and rent is therefore less appropriable. In short, the pointier the resource, the greater the likelihood that strong fiscal linkages can develop. The two hypotheses below specify the conditions under which forward and fiscal linkages are most likely to emerge:

> **H1**: Forward linkages will emerge or grow stronger in the Faroe Islands if the export price for unprocessed seaweed does not offset extraction costs.

> **H2**: Fiscal linkages will emerge or grow stronger in the Faroe Islands if seaweed becomes more appropriable.

The empirical part of the paper answers the research question by assessing how much confidence we should have in these hypotheses. If H1 is to be credible, it must be true that (1) current technologies make cultivation costly and (2) processed seaweed sells at high enough prices. Forward linkages will otherwise make no sense for local entrepreneurs. If H2 is to be credible, it must be true that (3) seaweed will become pointier both in terms of spatial distribution and ownership structure. Rent will otherwise not become more easily appropriable.

3. A Bayesian research design for foresight analysis

The aim of the empirical analysis is to probe the plausibility of H1 and H2. Whether or not linkages ultimately develop is a counterfactual claim. Counterfactual research designs are common in historical research, where hypothetical reasoning allows researchers to answer "*what if?*" questions [49]. However, [50] and [51] illustrate that counterfactual reasoning is not unique to historical research; it is also applicable to foresight research. In order to ensure alignment between theory and methodology, it is important to choose a research design which is rooted in set-theoretic logic and enables counterfactual inference. *Bayesian updating* offers such a combination. It constitutes a simple, but formalized dialog between theory and evidence, and enables the researcher to revise beliefs on the validity of a hypothesis based on a small number of key observations [52]. This makes Bayesian updating well-suited for single-case qualitative studies. To perform Bayesian updating, the researcher must specify three probabilities, or *prior beliefs* [53]:

1. A probability representing the researcher's initial confidence that the hypothesis (H) is true: p(H). This likelihood ratio is based on the researcher's prior theoretical and empirical knowledge.
2. A probability representing the likelihood of observing the evidence *e* if the hypothesis is true: p(e|H). This likelihood ratio expresses the degree to which certain observations are necessary for the hypothesis. The higher the value, the greater the potential for hypothesis dis-confirmation.
3. A probability representing the likelihood of observing the same evidence *e* if the hypothesis is false: p(e|~H). This likelihood ratio expresses the degree to which linkage development is affected by factors not captured in the hypothesis. The higher the value, the greater the importance of alternative factors and the smaller the potential for hypothesis confirmation.

Given the observed evidence, the posterior or updated confidence in the hypothesis – P(H|e) – is expressed in Bayes' theorem as:

$$P(H|e) = \frac{p(H) * p(e|H)}{p(H) * p(e|H) + p(\sim H) * p(e| \sim H)} \qquad (1)$$

These likelihood ratios structure the empirical analysis. This paper draws on a broad base of empirical, political and theoretical knowledge when determining whether the likelihood ratios are high or low. Bayesian updating is only meaningful if the empirical evidence is quite conclusive. In order to ensure that, this paper uses a triangulation strategy to identify whether linkages and their necessary scope conditions are present, and collects data from independent sources across different types of evidence as recommended by [54]. Sources include Faroese statistical registers, legislative archival material, journalistic material (e.g. interviews with seaweed cultivators) and a broad range of research papers.

The literature disagrees on how formally Bayes' theorem should be employed [55]. Using it informally as a heuristic tool disciplines our reasoning, but lacks precision [52]. On the other hand, formal numerical specification enhances transparency on how we evaluate evidence in social sciences, although it inevitably suffers from some degree of arbitrariness [56]. This analysis adopts the pragmatic approach suggested by [57]. According to them, the important thing is not the numerical results, but *the direction in which confidence changes*; is the posterior probability greater or smaller than the prior probability? And more importantly, is it *qualitatively* different? The answers to these two questions are much more interesting than the exact numerical values, which merely guide the interpretation. Numerical values are specified as is common practice in set-theoretic analysis [50]: likelihood ratios are set at 0.67 if a statement seems highly probable, improbable statements receive a score of 0.33, and the score of 0.5 constitutes the qualitative threshold between confidence and disbelief in a hypothesis.

Readers may disagree on the assessment of likelihood ratios and the conclusiveness of evidence presented in this paper. Numerical specification makes explicit *how much* and *which elements* readers would need to disagree on in order to question the validity of the findings. As recommended by [57], sensitivity tests are carried out in order to identify the ranges within which each likelihood ratio can vary without changing the direction and qualitative state of the updated probability. All calculations and sensitivity tests are available in the Appendix.

4. Empirical analysis

The empirical analysis deals with forward linkages first and then fiscal linkages. Each analysis starts by defining the three likelihood ratios, and then presents the empirical evidence that shows whether necessary scope conditions are present for developing stronger linkages. The last part presents the updated confidence in each hypothesis.

4.1. Forward linkages: Initial confidence in H1

Initial confidence in H1 is high because the price of processed resources almost always outweigh those of unprocessed resource [43]. Interestingly, this is not true for the Faroe Islands' main export, fish. In 2018, the value of unprocessed Faroese fish for human consumption was 2,359 per tonne [58]. Processed Faroese fish sell at much lower prices; fish oil and mink feed yield merely 284 per tonne [58, calculations based on]. The Faroese home rule government nonetheless supports local fish-processing [59,60]. There is therefore little reason to expect that it should oppose local processing of seaweed even if it is not yet economically profitable.

Faroese seaweed is only sold as food and feed, and some value-adding occurs, such as washing, drying, ensiling and milling. However, seaweed is not processed any further into e.g. chemicals, fuels or pharmaceuticals. Consequently, no forward linkages currently exist. Processed brown seaweed in general and *S. latissima* in particular have many potential market outlets, the largest of which is the market for alginate. This market grows 2–3 per cent per year [12]. Approximately half of all alginate sold at the global level goes to the textile industry, which uses alginates as thickeners in textile printing [61]. The food industry constitutes approximately 20 per cent of the global alginate market. When used as a thickening or gelling agent in the food industry, alginate shares some of the qualities of other seaweed-derived products such as carrageenan and agar agar (ibid). The pharmaceutical industry constitutes another 20 per cent of the alginate market. Here, alginate is used in applications for controlled release of medicinal drugs and chemicals (ibid). The remaining 10 per cent of the alginate market is split between the paper industry (5 per cent), and various smaller markets, e.g. markets for welding rods, binders for fish feed and release agents (5 per cent) (ibid.). Potential market outlets for components other than alginate include cosmetics, nutraceuticals, food additives, bio-fuels, chemicals and fertilizers [62]. Should we expect to see Faroese seaweed tapping into any of these export markets by developing capacities for local upgrading?

4.1.1. H1: Second likelihood ratio

H1 stresses the importance of sales prices; if the raw feedstock sells at low prices, local entrepreneurs have incentives to process the resource into value-added products. Put differently, if the sales price of unprocessed seaweed does not offset extraction costs, we should expect to see value-adding initiatives. However, processing requires affordable technologies. In 2015, Chen et al. [63] showed that refinery concepts for macroalgal biofuels were commercially promising, but still in their infancy. This assessment was nuanced by [64], who argued that refinery concepts needed a lot of improvements in drying methods and genetic engineering. However, optimism increased already in 2017, where [3] argued that macroalgal bio-refineries would be able to operate at commercial scale very soon. Taking these arguments into perspective, the second likelihood ratio is considered high: it seems probable that Faroese seaweed cultivators are willing and able to process seaweed if sales prices for unprocessed seaweed are too low.

4.1.2. H1: Third likelihood ratio

If the sales price of unprocessed seaweed *does* offset extraction costs, how surprising would it be to observe value-adding initiatives anyway? Put differently, could factors other than cost pressure create incentives for local processing? Staples theory focuses on export and largely ignores domestic demand. However, if local Faroese demand for seaweed-derived products was sufficiently high, there could be incentives for local value-added processing despite low export prices. However, the industries which can currently make use of alginate are not present in the Faroe Islands — there are no large textile, food, pharmaceutical or paper industries. Moreover, with only fifty thousand inhabitants, local demand for other seaweed-derived products such as cosmetics, nutraceuticals, food additives, bio-fuels, chemicals and fertilizers is presumably too small to support a viable business model for seaweed processing. Taking these arguments into consideration, the third likelihood ratio is considered low: it seems unlikely that value-added processing will emerge for reasons other than high export prices for processed seaweed.

4.1.3. Empirical evidence for scope condition 1: is Faroese seaweed cultivation costly?

In Asia, the most common production methods involve near-shore cultivation and manual harvesting, which require little equipment and small initial capital investments [12]. However, it is a very labor intensive approach and hardly feasible in Europe [13]. Instead, off-shore, high-yield cultivation systems are being developed [65], and off-shore cost reduction is a salient topic. [2] assess that 20 per cent of the most cited papers on seaweed aquaculture deal with optimization issues. Optimization is especially pressing for brown macroalgae like *S. latissima* as these go through a reproductive cycle, as opposed to many red and green species, which enable vegetative cultivation. This means that brown algae cultivation often relies heavily on costly, land-based facilities such as hatcheries and nurseries [66]. However, Faroese cultivators have developed a method which enables re-growth for several seasons without needing to re-seed in a hatchery [13]. This innovative method has reduced production costs considerably; it costs between 9.27 and 36.73 to cultivate one kilogram dry weight *S. latissima* (i.e. 9,270 to 36,730 per tonne dw) [13].[2] Compared to other North Atlantic cultivation sites surveyed by [67], Faroese production costs are modest. However, compared to the present value of unprocessed *S. latissima*, production costs remain unfavorably high: In 2018, the value of unprocessed *S. latissima* was 4,482 per tonne dry weight [68].[3] To sum up, empirical evidence suggests that Faroese seaweed cultivation will indeed be costly. Thus, the first necessary scope condition seems fulfilled.

4.1.4. Empirical evidence for scope condition 2: does processed seaweed sell at high enough prices?

Table 1 shows the share and price of components which can be derived from *S. latissima*. For instance, alginate makes up 28 per cent of *S. latissima*,[4] and sells at approximately 6 per kg. When extracting alginate and all other components, one tonne of dry weight *S. latissima* is worth 6,459, or roughly one and a half times more than unprocessed *S. latissima*. Thus, processed seaweed does sell at higher prices than unprocessed seaweed. However, these prices can only compensate production costs to some degree and not completely offset them, as Faroese production costs range between 9,270 to 36,730 per tonne dry weight [13]. In summation, there is strong evidence against the second necessary scope condition.

[2] Bak and Mols-Mortensen [13] use a conversion factor of 1:10 between dry weight and wet weight.

[3] Using a currency exchange rate 1 NOK=0,09 as of September 2019

[4] Measured in dry weight as a percentage of an average June harvest.

Table 1
Extricable value from *S. latissima*.
Source: Adapted from [69]. Estimation by Inga Marie Aasen.

	Extricable components	Content share	Price (€/kg)	Total extricable value of 1 tonne resource (€)
Seaweed	Alginate	28%	6	1680
	Laminarian	2%	5	100
	Mannitol	10%	1	100
	Fucoidan	5%	50	2,500
	Cellulose	5%	–	–
	Protein	13%	1,5	195
	Polyphenols	2,5%	50	1,250
	Fucoxanthin	0,2%	300	600
	Minerals	34%	0,1	34
	Total	99,7%		**6,459**

4.1.5. Posterior confidence in H1

The analysis found empirical evidence indicating the presence of scope condition 1 and the absence of scope condition 2. When applying Bayes' theorem to these findings, posterior confidence in H1 decreases quite dramatically and falls below the 0.5 threshold (see calculations in Appendix). Put differently, we should have little confidence in H1 and not expect forward linkages to develop in the Faroe Islands even though the export price for unprocessed seaweed does not offset extraction costs.

4.2. Fiscal linkages: Initial confidence in H2

Initial confidence in H2 is high due the fact that legal tools for extracting rent from marine resources already exist; seaweed cultivators abide by the rules that govern aquaculture in general [70]. These rules do in fact enable rent extraction under certain circumstances. In 2014, the home rule government imposed a special tax on aquaculture. In 2016, this was replaced by a turnover tax of 4.5 per cent, and from 2019 onward the turnover tax increased to 5 per cent. Companies only pay this turnover tax when the selling price of their products exceeds DKK 36 per kg. In 2018, the aquaculture turnover tax yielded DKK 136 million in total [24]. As seaweed prices that year were approximately DKK 48 per kg[5], a small portion of this rent can be attributed to seaweed. The seaweed harvest accounted for only 0.07 per cent of total aquaculture harvest[6], so rent from seaweed may have contributed around DKK 100,000 (i.e. 0.07 per cent) of the DKK 136 millions. Thus, although fiscal linkages do exist, rent extraction from seaweed cultivation is negligible. Should we expect that stronger tools for rent collection will emerge? According to staples theory, the answer to this question depends on whether seaweed as a resource grows pointier in terms of both spatial distribution and ownership structure.

4.2.1. H2: Second likelihood ratio

The wish for independence is quite strong among several political parties in the Faroe Islands [24]. Thus, Tapping into a new wealth stream could decrease economic reliance on Denmark, and thereby bring the Faroe Islands a step closer towards independence. [71] argues that the value of user-rights to marine resources (both fishery and aquaculture) amounts to DKK 2 billion annually. In comparison, the Danish block grant was DKK 641,8 million in 2019 [24]. Thus, if marine resources, including seaweed, become more appropriable there would be a strong incentive to implement tools for rent extraction, as this would enable economic independence. However, the history of Faroese demersal fisheries[7] suggests that such tools are controversial and not easy to agree upon despite the fact that demersal fish populations such as cod and haddock have become increasingly spatially pointy as stocks have depleted [59,72]. Meanwhile, user-rights to demersal fishery have become pointier too. [59] trace the development and show that still fewer owners control fewer, but larger licensed vessels. In other words, rent from demersal fisheries should have become more appropriable in recent years.

Nonetheless, no rent has ever been extracted from demersal fisheries according to [60]. This is true even though the reforms which followed the economy's collapse in the early 1990s authorized the home rule government to charge fees consistent with the resource rent generated by demersal fishery licenses. [60] argues that this provision was never put to use before it disappeared in the 1996 law amendment. The 2018 fishery reform introduced rent collection tools anew. The reform imposed public auctioning of 15 per cent of licenses [24], and obliged actors operating on non-auctioned licenses to pay a resource fee in accordance to the profit generated in previous years [73]. However, the government, which took office after the September 2019 parliamentary election, revoked the planned auctioning of fishing licenses. This means that there are yet again no legal tools for collecting rent from demersal fisheries.[8] Taking these arguments into consideration, the second likelihood ratio is considered low: it seems unlikely that a pointier resource is enough to make fiscal linkages stronger. The political will to create fiscal linkages in the Faroe Islands is fragmented even though stronger fiscal linkages could long ago have reduced economic reliance on Denmark.

4.2.2. H2: Third likelihood ratio

If pointiness is not enough to spark stronger fiscal linkages, could other factors then affect the development? Attitudes towards Faroese aquaculture might enlighten this issue. A study combining narrative analysis, participatory GIS-mapping and a survey of land- and seascape values conducted by Plieninger et al. [74] shows that negative attitudes towards aquaculture are common in the Faroe Islands. Aquaculture is very big business; in 2017 it comprised 47 per cent of export earnings, employed 4.3 per cent of the workforce and was geographically dispersed all over the country (see Fig. 1. Aquaculture output has more than tripled from 1998 to 2018 [75]). Consequently, Plieninger et al.'s respondents express concerns over aquaculture's growing environmental impacts (e.g. chemical pollution, disease, habitat destruction) and

[5] The price for seaweed in Table 1 are stated in Euros. Using a currency exchange rate of 1=DKK7.5, sales price per kg amounts to approximately DKK 48.

[6] Seaweed harvest 2018: 45 tonnes; Salmon harvest 2018: 64,732 tonnes [24]

[7] The demersal fleet catches bottom feeders within the exclusive economic zone along the continental shelf, often using nets or trawlers. Demersal species include cod, saithe, haddock and redfish. The pelagic and far-fishing fleets catch fish beyond the exclusive economic zone, and are not regulated through Faroese law but through international agreements [59,60].

[8] There are tools for rent collection in non-demersal fisheries, for instance a tax per kilogram catch and a tax per kilogram landing processed by non-Faroese businesses or vessels. These taxes apply to mackerel, atlanto-scandic herring and blue withing [60]

community impacts (e.g. noise, smells, rubbish). Plieninger et al. [74] identify two dominant aquaculture narratives. In the first narrative, it is a firm public conviction that aquaculture companies do not invest any of their profits into mitigating negative environmental impacts of fish farming. However, this conviction has not translated into sufficient political pressure for creating stronger fiscal linkages to extract rent from aquaculture operations in order to finance environmental protection. The second narrative blames the home rule government of lacking both power and will to regulate the few large, foreign aquaculture companies because they want to maintain a good relationship with big employers. Taking these arguments into consideration, the third likelihood ratio is considered low: it seems unlikely that alternative factors can spark the development of stronger fiscal linkages. Even strong environmental concerns have proven insufficient.

4.2.3. Empirical evidence for scope condition 3: is seaweed becoming a pointier resource?

[48] argues that rent becomes more appropriable when resources grow pointier in terms of both ownership structure and spatial distribution. Looking at the aquaculture industry in general, license ownership has since the 2009 liberalization consolidated to quite an extreme extent; only three major companies hold aquaculture licenses in the Faroe Islands: *Bakkafrost*, *HiddenFjord* and *MarineHarvest*. This is a much more pointy ownership structure than in demersal fisheries, where maximum license share is between 20 and 35 per cent, depending on the vessel group [59]. This kind of concentration is not a unique Faroese phenomenon. [23] observe a global trend towards fewer but larger firms, because aquaculture is a knowledge-intensive, vertically-integrated and global-scale business. Vertical integration is necessary because salmon has a long lead time; it takes two years from a smolt hatches to the grown salmon is butchered. Companies need a lot of liquidity to pay for feed and salaries in the meantime [24]. Large corporations therefore dominate the market.

Seaweed cultivation is innovation and knowledge-intensive too, and relies on costly land-based facilities, just like salmon farming [35,76]. However, Faroese seaweed farmers have partly circumvented the need for knowledge-intensive investments by importing seeding material rather than developing technologies on their own. Ocean Rainforest, for instance, imports seeding material from the company *Hortimare BV*, which is located in Norway and the Netherlands. Doing this, cultivation does not require high initial capital investment. Neither does it require huge operational costs. [13] estimate that operational cost and capital expenditures for Ocean Rainforest's macroalgae cultivation rigs and growth lines accumulated to 63,500 in the rigs' five-year life-span. In other words, seaweed cultivation seems a lot less capital intensive than fish farming, and seaweed has short lead times too, as it takes approximately seven months from deployment of seed lines to the first harvest (ibid). Thus, there are no strong economic indications that ownership structure will necessarily grow more pointy as has been the case with fish farming. How about spatial distribution?

Section 1.1 highlighted that lack of available space constitutes a major challenge for expansion of seaweed cultivation. Another challenge is that ecosystems and fragile coastal environments might be disrupted by aquaculture expansion [15,77]. Integrated multi-trophic aquaculture (IMTA) systems may prove a solution to these challenges. By integrating fish farming and seaweed cultivation, higher biomass yield can be harvested without using more space. [37] show for instance that IMTA farms have 60 per cent higher yield than non-IMTA kelp farms, and [35] argues that IMTA can reduce the amount of waste emitted from fin-fish farming. If fish farmers include seaweed cultivation into their business model, seaweed could spread to many fjord locations and become a much more diffuse resource than is the case today.

In their review of the state of the art of IMTA, [78] argue that there are no commercial scale, offshore IMTA systems anywhere outside Asia. However, IMTA is implemented at a non-commercial and experimental scale in many countries. In the Faroe Islands, two factors challenge commercial-scale implementation of IMTA. First, a seasonal mismatch between the maximum effluents from fish farms and peak nutrient uptake in *S. latissima* [62] might discourage co-production. Second, very large areas of seaweed cultivation are required in order to uptake nutrients from fin-fish farms. [35] argues for instance that removing just 10 per cent of the nitrogen from a 1,000 tonne salmon farm requires approximately 10 hectares of seaweed cultivation. The Faroe salmon harvest of almost 65,000 tonnes in 2018 would therefore require an extra 650 hectares of seaweed. All fjords and sounds suitable for aquaculture are already occupied [23], and [74] identify widespread and conflicting landscape values in relation to increased aquaculture in coastal areas. It therefore seems difficult to expand aquaculture areas in the Faroe Islands to the size needed for IMTA to make a significant environmental impact. Summing up, there are no strong indications that seaweed will necessarily become a pointier resource. Empirical evidence for scope condition 3 is therefore weak.

4.2.4. Posterior confidence in H2

The analysis found no strong evidence supporting the claim that seaweed will become pointier in terms of ownership structure and spatial distribution. Applying these findings to Bayes' theorem, the posterior confidence in H2 becomes smaller than the prior and falls below the 0.5 threshold (see calculations in Appendix). Put differently, we should have little confidence in the claim that current fiscal linkages will grow stronger.

5. Discussion and policy implications

Even though seaweed cultivation is not yet economically sustainable, the green transition is a very compelling reason to cultivate macroalgae anyway. However, the empirical analysis indicates that the Faroe Islands will not benefit much from seaweed cultivation as linkage potential is very restricted. Even though the export price for unprocessed seaweed does not offset extraction costs, forward linkages seem unlikely to develop because the export price for processed seaweed does not offset extraction costs. Put differently, necessary scope conditions for developing forward linkages are not fully present. Appendix shows that these conclusions are rather robust. A core assumption in [17]'s staples approach is that forward linkages make resource dependent regions less vulnerable to trap dynamics caused by volatile markets [47]. Fig. 2 shows that seaweed prices are indeed quite volatile. On one hand, the limited potential for forward linkages is therefore reason for concern; the Faroe Islands have no protection against trap dynamics. On the other hand, seaweed cultivation is still a small-scale business, and as long as high extraction costs and limited fjord space make expansion difficult, price fluctuations will not affect the Faroese economy at large. However, if cultivation techniques and bio-refinery concepts were to improve, as indicated in Section 4.1.1, the findings in this analysis may serve as an early warning that the development of forward linkages need to be a political priority if seaweed cultivation is to be economically sustainable.

The same is true for fiscal linkages. According to staples theory, pointiness is a necessary scope condition for improved rent appropriability [48]. However, the analysis found no strong indications that seaweed will inevitably become a pointier resource. Thus, we should not expect fiscal linkages to grow stronger. The sensitivity tests in Appendix show that this conclusion is sensitive the numerical value of the second likelihood ratio ($p(e|H2)$), i.e. *the likelihood of observing stronger fiscal linkages given that H2 is true*. This statement was deemed improbable and thus received a score of 0.33 because Faroese decision makers have previously failed to develop fiscal linkages around demersal fisheries, even though rent from fisheries could greatly decrease economic dependence on Denmark. If ($p(e|H2)$) had been given a score below 0.16 instead of 0.33, Bayesian updating would have resulted in a higher posterior confidence in H2 (see Table 4 in the Appendix). Thus, if readers believe that a Faroese wish for independence does not create sufficient incentives for rent collection, appropriability is the *only* mechanism through which fiscal linkages are likely to grow stronger. Cultivated seaweed is presumably pointier than wild fish stocks, so confidence in H2 could reasonably be higher than calculated in Section 4.2.4. However, presence of stronger fiscal linkages does not improve economic sustainability the same way that forward linkages do. Instead, they ensure that higher amounts of resource rents accrue to the Faroese people. Perhaps this could abate the widespread opposition against large-scale and foreign-owned aquaculture, which [74] identify among respondents in their survey. Less opposition might make expansion through IMTA a more plausible scenario, which takes us back to the importance of considering forward linkages before expanding production.

As linkage potential is negligible, decision makers may need to consider alternative ways to improve economic sustainability. An important tool could be valuation of and payment for ecosystem services. This requires internalization of positive and negative externalities associated with natural resources and their exploitation[9] [79]. [3] argue that seaweed cultivation could be profitable and expand more easily if decision makers adopt payment for seaweed's ecosystem services. There is currently a very fragmented stance towards integrating valuation of ecosystem services into legislation in the European Union [80]. However, as a non-member of EU, the Faroe Islands are not restricted by the conditions, which make payment for ecosystem services controversial in the European context. Consequently, the Faroe Islands could become first-movers.

6. Conclusions

This analysis applied staples theory to an emerging staple in the green transition. The search for renewable and environmentally sustainable resources intensifies as the green transition becomes more urgent, and seaweed is a very promising resource in this perspective. The research design allowed inference on the likely development of linkages surrounding the nascent seaweed cultivation business in the Faroe Islands. The paper hereby showed that staples theory is not only a tool of historical research, but also useful in foresight analysis. A conservative conclusion is that both forward and fiscal linkages are unlikely to emerge, while a more permissible interpretation leaves open the possibility of stronger fiscal linkages. Either way, the findings suggest that seaweed in the Faroese context is not the ultimately sustainable crop as otherwise argued by [2]. Economic sustainability is still an issue, but the findings do not rule out stronger linkages entirely. However, if they develop, they will do so for reasons beyond the scope of Watkins' staples approach. The discussion suggested that lack of linkage potential is not necessarily an issue, at least not yet. Seaweed cultivation is only nascent, and several factors challenge expansion: lack of economic sustainability, limited fjord space and negative public sentiments towards aquaculture expansion. The findings of this analysis may nonetheless serve as an early warning that expansion without linkages will make the Faroese economy sensitive to the volatile seaweed market. Decision makers and private investors might therefore consider ways in which to improve linkage development. Alternatively, they might circumvent the challenge of volatile prices – thereby also circumventing the need for linkages – by implementing payment for seaweed cultivation's ecosystem services.

Declaration of competing interest

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

[9] Examples of ecosystem services performed by natural resources are provision of food, fiber and fuel, purification and protection of soil, water and air, nutrient recycling, CO2 uptake, recreation and protection of traditional lifestyles.

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Appendix. Sensitivity of findings

A.1. Updating confidence in H1

Likelihood ratios:

1. $p(H1) = 0.67$
2. $p(e|H1) = 0.67$
3. $p(e| \sim H1) = 0.33.$
4. Scope condition 1 identified empirically
5. Scope condition 2 not identified empirically

$$P(H1|\, e_{scope\ condition\ 1}) = \frac{0.67 * 0.67}{(0.67 * 0.67) + (0.33 * 0.33)} = 0.80 \quad (2)$$

Eq. (2) shows that confidence in H1 increases given that Faroese seaweed cultivation is quite costly. This updated confidence is then used as a new prior confidence (p(H)) in Eq. (3) below. Given that the analysis found no strong empirical evidence to support the claim that scope condition 2 is present, the updated confidence in H1 is the following:

$$P(H1 \mid \sim e_{scope\ condition\ 2}) = 1 - \frac{0.80 * 0.67}{(0.80 * 0.67) + (0.67 * 0.33)} = 0.11 \quad (3)$$

Eq. (3) shows that the posterior confidence in H1 is very low.

A.2. Updating confidence in H2

Likelihood ratios:

1. $p(H2) = 0.67$
2. $p(e|H2) = 0.33$
3. $p(e| \sim H2) = 0.33$
4. Scope condition 3 not identified empirically

$$p(H2 \mid \sim e_{scope\ condition\ 3}) = 1 - \frac{0.67 * 0.33}{(0.67 * 0.33) + (0.33 * 0.33)} = 0.33 \quad (4)$$

Eq. (4) shows that the posterior confidence in H2 is quite low.

A.3. Sensitivity tests

Scholars may reasonably disagree on likelihood ratios used in this analysis and the conclusiveness of the evidence. The question is, *how much* and upon *which elements* would they need to disagree in order to question the validity of the findings? The sensitivity analysis addresses this question by performing three tests. The first test assesses whether the sequence in which evidence is presented matters. This test is only relevant for H1, which relies on two types of evidence, i.e. scope condition 1 and 2. The second and third tests are relevant for both hypotheses. Recall that prior probability in both hypothesis was high and that posterior confidence in both hypotheses was qualitatively different, i.e. smaller than 0.5. The second test identifies the ranges within which likelihood ratios can vary without making the posterior probability qualitatively different from the prior. The third test goes one step further and assesses the range within which likelihood ratios must vary in order for the posterior probability to change in the opposite direction than the one identified in the empirical analysis. Put differently, the second test identifies likelihood ratios for scholars who slightly disagree, while the third test identifies likelihood ratios for scholars who strongly disagree with the findings in this study.

Table 2
Sensitivity test for the analysis of forward linkages, scope condition 1.

	Initial likelihood ratios P(H1|e1)=0.8	Sensitivity test 2: 0.5 < P(H1|e1) < 0.67	Sensitivity test 3: < P(H1|e1) <
p(H1)	0.67	0.33 < p(H1) < 0.50	0.50 < p(H1) < 1
p(e1|H1)	0.67	0.33 < p(e|H1) < 0.50	0.50 < p(e1|H1) < 1
p(e1|~H1)	0.33	0.67 < p(e1|~H1) < 1	0 < p(e1|~H1) < 0,67

Table 3
Sensitivity test for the analysis of forward linkages, scope condition 2.

	Initial likelihood ratios P(H1|~e2)=0.11	Sensitivity test 2: 0.11 < P(H1|~e2) < 0.50	Sensitivity test 3: 0.50 < P(H1|~e2) < 1
p(H1)	0.80	0.33 < p(H1) < 0.80	0 < p(H1) < 0.33
p(e2|H1)	0.67	0 < p(e2|H1) < 0.16	0 < p(e2|H1) < 0.16
p(e2|~H1)	0.33	0.16 < p(e2|~H1) < 1	*no values*

Table 4
Sensitivity test for the analysis of fiscal linkages, scope condition 3.

	Initial likelihood ratios P(H2|~e)=0.33	Sensitivity test 2: 0.5 < P(H2|~e) < 0.67	Sensitivity test 3: 0.67 <P(H2|~e) < 1
p(H2)	0.67	0.16 < p(H2) < 0.35	0 < p(H2) < 0.16
p(e|H2)	0.33	0.08 < p(e|H2) < 0.16	0 < p(e|H2) < 0.08
p(e|~H2)	0.33	0.67 < p(e|~H2) < 1	*no values*

A.4. Test 1

Does sequence matter when updating confidence in H1? If updating posterior belief in the opposite sequence, i.e. first scope condition 2 and then scope condition 1, the posterior confidence still declines. However, it declines to 0.11 when using the first sequence, and to 0.33 when using the reverse sequence. The main takeaway is that the posterior probability declines in the same direction, and that the posterior in both cases falls below 0.5. The updated confidence in H1 is therefore robust to the sequence in which evidence is assessed.

A.5. Tests 2 and 3

When calculating alternative likelihood ratios, two ratios are held constant at their initial level, while one ratio is left to vary. Tables 2–4 show how much scholars would need to disagree in order to question the findings.

Table 2 shows that $p(H1)$ and $p(e1|H1)$ are positively correlated with posterior confidence. These likelihood ratios would need to be between 0.33 and 0.50 in order for posterior confidence in H1 to be in the same range as the prior confidence. Assessment of $p(e1| \sim H1)$ would need to be dramatically different from the initial value, i.e above 0.67 instead of 0.33, in order for the evidence to lead to a posterior probability higher than the prior. In other words, the analytical results are not very sensitive to numerical changes in likelihood ratios. Scholars would need to strongly disagree about initial assessments before posterior probabilities could be reasonably altered.

Table 3 shows the robustness of the second round of Bayesian updating for H1. Confidence in H1 was quite high after considering the evidence for scope condition 1. Given this high confidence and the fact that there was strong evidence *against* scope condition 2, likelihood ratios become highly robust to numerical changes. One would need to disregard the first round of updating and set $p(H1)$ at values below 0.33 in order for the posterior confidence to increase rather than decrease. The second likelihood ratio, $p(e2|H1)$, would need to take on values below 0.16 for that to happen. There are no $p(e2| \sim H1)$ values which would lead to increased posterior confidence in H2 given the strong evidence against scope condition 2. In sum, the analysis of forward linkages is highly robust.

Table 4 shows that initial confidence in H2 – $p(H2)$ – is negatively correlated with posterior confidence. In order to claim that the potential for developing stronger fiscal linkages around Faroese seaweed cultivation is fairly credible, i.e. above 0.5 and below 0.67, initial confidence in H2 must be between 0.16 and 0.35 (*test 2*). In other words, scholars must strongly disagree with the initial assessment of the credibility of H2 in order to challenge the finding that the potential for fiscal linkages is small. Claiming that the evidence provided actually *increases* confidence in H2 would require the initial confidence to be very small, i.e. below 0.16 (*test 3*). In sum, the posterior confidence is not very sensitive to changes in the first likelihood ratio.

The second likelihood ratio – $p(e|H2)$ – is also negatively correlated with posterior confidence. Test 2 suggests that posterior confidence is somewhat sensitive to changes in $p(e|H2)$ as values between 0.08 and 0.16 make the posterior confidence qualitatively different than the initial likelihood ratio of 0.33. $p(e|H2)$ values below 0.08 makes the posterior confidence increase rather than decrease. An improbable statement can be expressed by all numerical values between 0 and 0.5, so defining $p(e|H2)$ as 0.08 or 0.16 is just as reasonable as 0.33. The updated confidence in H2 therefore runs the risk of being arbitrary.

The third likelihood ratio – $p(e| \sim H2)$ – is positively correlated with posterior confidence. Test 3 suggests that posterior confidence is very insensitive to changes in $p(e| \sim H2)$. $p(e| \sim H2)$ must take on values above 0.67 in order to claim that the empirical evidence shows potential for developing stronger fiscal linkages. $p(e| \sim H2)$ can take on no value that would actually make posterior confidence increase.

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