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Deliverable D3.6

Manuscript to a peer-reviewed journal on seafood industry dynamics and competitiveness

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Executive Summary

This deliverable consists of a scientific paper "Industry dynamics and the role of aquaculture sustainability certification in pre-competitive sectoral strategic positioning" that has been submitted to the scientific journal, Marine Policy. The intended audience of the journal is researchers, analysts and policy makers. Additionally, in the appendix of this deliverable another manuscript is included, based partly on research within PrimeFish, called "Testing Governance of Value Chains: Weak Exogeneity of Prices in the Pangasius Value Chain from Vietnam to Germany".

Aquaculture sectors can be characterised by their stage of evolution linked to consolidation and concentration trends. This paper assesses the potential role of sustainability certification in pre-competitive strategic positioning of aquaculture businesses within an industry dynamics framework. We draw practical lessons for seafood businesses from two case studies of successful and failed industry-wide commitments to sustainability certification under two Aquaculture Stewardship Council (ASC) species standards: (i) The Global Salmon initiative (GSI) and (ii) a Government driven commitment for the Vietnamese pangasius sector. We show how GSI collective certification and interim transparency commitments (on environmental and social performance indicators) have been fostered as part of a pre-competitive industry strategy to support social licence for global site-expansion objectives. High certification adoption rates attest to the success of this strategy. Applying our industry dynamics framework, we evaluate reasons for this success, contrasting it with the demonstrable failure of the second Vietnamese pangasius case-study. Key reasons for static adoption rates include greater challenges reaching consensus in this more fragmented sector, the "state-capitalism" socio-political framework within which it operates, and associated lack of a pro-active industry driven commitment as witnessed in the GSI case. The truly global nature of the GSI with its many multi-national members was also highly instrumental in framing and achieving its shared pre-competitive objectives.

Thus, success is highly contingent on the initiatives origin (internal or external) and associated level of ownership and commitment of sector members; further enabled in consolidated sectors dominated by a few large international players. Findings are used to highlight opportunities and challenges for pre-competitive sectoral strategic positioning at different stages of 'industry-dynamic' evolution i.e. action aimed at the development of the sector as a whole. One such emergent pre-competitive initiative; the Sustainable Shrimp Partnership (SSP) which aims to emulate the GSI is evaluated in this context.

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1 Introduction

The sustainable development of aquaculture globally depends on effective governance of common pool resources. However, development and enforcement of relevant national laws, particularly in developing countries, where both capture fisheries and farmed production value-chains are highly fragmented, is often perceived as ineffective. Given that the global trade flows of seafood are largely from the developing to developed countries, the requirements by importing markets for the adherence to sustainable practices and the lack of effective provision of such from exporters has driven demand private governance in the form of third party certification over recent decades (Oosterveer, 2015).

A lot of hope has been placed on these market-based mechanisms of governance as a means to the sustainable development of the aquaculture sector. However, a recurrent opinion voiced in interviews with a diverse range of seafood producers concerned what they perceived as the rent-seeking nature of certification schemes; many using emotive terms such as 'parasitic' and 'self-serving' with regard to this emerging sector. At the crux of these sentiments lay the fact that for many, certification has become a necessity for continued access to sizeable market sectors, without affording a commensurate price premium sufficient to cover additional costs of compliance.

Furthermore, such costs are amplified where multiple recurrent compliance audits for different standards are required to meet the divergent or overlapping demands of different market segments. Extending this logic, lead seafood companies (especially retailers and processers) are viewed as accruing direct commercial benefits of certification in terms of brand protection whilst passing a disproportionate share of costs onto producers. This argument also has its corollary in an anti-globalisation critique of international trade, whereby the disproportionate financial burden of certification on smaller producers further accelerates sectoral consolidation resulting in their acquisition or exclusion. Furthermore, re-enforcing this pressure, standards themselves are subject to periodic revision with intent of driving continuous performance improvement by individual farms.

The rising importance of market based governance and the fact that predominantly western economies have imposed such standards on developing nations has been equated by some as a form of neo-imperialism (Vandergeest and Unno, 2012). Others have questioned the effectiveness and extent to which standards can actually improve environmental management (Jacquet and Pauly, 2007) or even how impacts can be reliably measured (Thomson et al 2014) though this debate is largely beyond the scope of this paper.

The above equity critique also creates a paradox for standards targeting more equitable social sustainability outcomes. Response to this problem include a range of strategies designed to reduce audit costs for both single standard and multiple audit situations. A range of 'benchmarking' schemes have emerged designed to calibrate degrees of equivalence between standards. Larger standards bodies are also increasingly collaborating on their own inter-standard harmonisation and equivalence efforts as well as launching multi-site and group certification schemes designed to spread and lower costs of individual site audits. Whilst many standards bodies, particularly those with strong social components (such as the ASC standard), list the ability of producers to secure a price premium to reward their stewardship efforts as a key element of their mission statements.

At the background of this dynamic, the objective of this manuscript is to investigate the factors underlying the success of certification commitments, by examining two case studies of success and failure of such commitments. In particular, we evaluate (1) the role of sustainability certification in company strategic positioning based on a case study of the Global Salmon Initiative, an industry collaboration predicated on a commitment to 100% ASC certification of all member sites by 2020, which appears on track to be met, and (2) the case of the pangasius catfish industry in Vietnam where a to achieve certification rate 30% of production volume by 2012 & 2014 has not been successful.

The paper proceeds with an examination of the rationale behind sustainability certification and advances the hypothesis that industry structure and associated competitive environment are important determinants for the adoption of sustainability certification.

2 Theoretical background and literature review

2.1 Principles of sustainability certification

Certified food sustainability standards are voluntary, usually third party-verified norms relating to environmental, social ethical and food safety aspects of food production. They are developed, to varying degree, in consultation with a range of primary and secondary stakeholders and experts in these fields adopted by companies either as a complement or alternative to their own internal and supply chain quality assurance systems in order to demonstrate acceptable performance of their organizations or products in these areas.

By addressing societally perceived deficits in areas of statutory governance, they offer companies an 'outsourced' means of defending their reputations and brands against civil-society (e.g. NGOs, media, celebrity chefs etc.) campaigns linked to such deficits (Bush et al., 2013). Consistent with this brand management rationale; standards may simply operate at a business to business (B2B) and/ or business to consumer (B2C) levels i.e. with or without a consumer-facing label.

Civil society campaigns of the kind described above are also likely to have greater influence in these rich markets, providing further impetus for seafood companies to engage in 'ethical supply chain management' of commercial entities beyond their own direct ownership and geographical legal jurisdictions (many standards also incorporate a separate chain of custody (CoC) standard to prevent non-certified products being sold as certified/ labelled along the supply chain).

Whereas traditional corporate social responsibility' (CSR; AKA 'corporate philanthropy') and sustainability certification may both contribute to the same over-arching goals of improved business and brand reputation management, CSR implies company-led change, whilst third-party certification responds more directly to wider civil society and (theoretically) consumer concerns.

The credibility, and arguably greatest inherent value of such standards is underpinned by a 'third-party' verification process, whereby in place of self-claims, independent 'certification assessment bodies' (CABs) audit compliance of companies or external suppliers against the standards. Both the eligibility and performance of CABs, along with standards setting procedures are themselves subject to formal accreditation processes and other tiers of normative standards, designed to further enhance credibility of the approach.

From a retailer perspective, certification commitments also serve as (i) a strategy for codification and independent verification of corporate social responsibility (CSR) efforts in line with increased demand for transparency and ease of monitoring by stakeholders (Dawkins and Lewis, 2003), (ii) to transfer costs of auditing to the previous stages of the value chain and (iii) serve as a means to protect retailers' reputation from attacks by civil-society pressure groups. As such the retail sector has had a major role to play in the proliferation of sustainability standards, and creating a market for sustainability (Bush et al., 2013).

The role different interest groups in driving this market are postulated in Figure 1. In this conception lead companies and brands in seafood value chains effectively take on the role of sustainability 'choice-editors' as they are compelled to respond to demands of multiple pressure groups. Of particular note here, is the marginal position of consumers, academics and industry bodies as influencers relative to other 'civil society bodies' and 'opinion leaders'. This also underscores the ascendency of polemic (i.e. often based 'worst-worst case' narratives around environmental, social, food-safety or other ethical transgressions) over more evidence-based debate in driving demand for sustainability certification (certification bodies, in turn, compete for recognition and adoption by retailers in order to utilize their leverage over their suppliers). This assessment can be contrasted with the erstwhile theoretical view of consumer choice as the primary driver of demand for sustainability certification i.e. whereby citizens also make inherent sustainability decisions every time they approach the till!

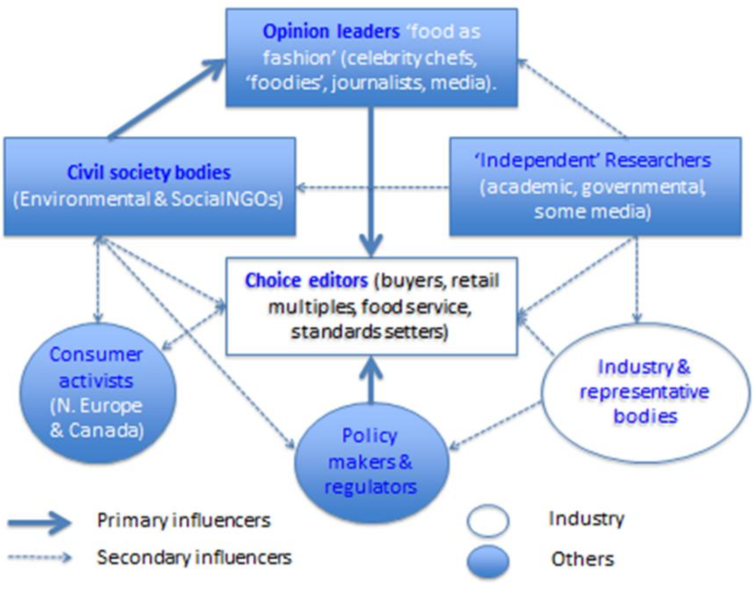

Figure 1. The relative influence of different stakeholder groups in driving demand for third-party certification by leading seafood brands as 'choice-editors' (Murray et al 2014[4]).

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[4] Murray. F., L'Etang. J., Little D., Jahansoozi, J. 2014 Aquaculture's challenging 'communications complex': meanings, discourses and relationships – towards anew research agenda. Unpublished

2.1.1 Certification and premium pricing; the evidence

Certified products may fail to generate adequate premium due to a low level of recognition by consumers and concomitant low willingness to pay; especially true of price sensitive markets such as seafood (see below). Secondly, as we have seen, differentiation-based competition strategy is fundamentally at odds with the aim of standards bodies to ever expand their customer base in order to maximise sustainability benefits. This means first mover (differentiation) advantage is often only temporary. For example, ASC certified salmon is arguably still a niche product preferred by some buyers over non-certified salmon. But as more product becomes certified (>50% of global production is targeted to be certified by 2020) certification would become a normal non-competitive practice e.g. such the ISO industry wide standards, ultimately leading to 'commoditization' of certification.

Divergent pricing strategies of retailers must be considered in any assessment of price transmission and return to 'certification value-added'. For example, differentials between certified and non-certified substitutes may be masked by uniformly higher pricing levels by higher-end retail brands such as Waitrose or Marks & Spencer.

The role of sustainability certification and labelling is to transmit information about an intrinsic quality of a product, e.g. relating to public benefits such as environmental integrity, which is not obvious to consumers when choosing a product. The incentive of producers to augment practices to more sustainable ones must be in the form of a premium received from the final consumer and transmitted up the value chain to the producer, in order to cover for the increased costs of the augmented practices. Therefore, consumer demand is meant to be the driving force resulting in a more sustainable management at the production level.

However, there has been a debate in the literature (e.g. Bush et al., 2013) as to whether sustainability certification schemes reward the producers or only serve as a 'tickets' to enter a market controlled by powerful retailers. The consensus increasingly focuses on the later. The main argument is that the majority of end consumers do not recognise the labels and are not actively looking for them, but it is the retailers who require that their suppliers obtain the certification, as a form of CSR and reputation management. Moreover, given the commitments of certification bodies and retailers to increase the proportion of certified products, any potential price premium based on uniqueness is likely to suffer as the certification becomes 'the norm', as is the case with many ISO certifications nowadays. Nonetheless, as Asche et al. (2015) point out, even if a price premium for certified products is not observed, a continued access to the market can still be seen as a form of price premium because it relates to the supplier's "market of choice". This "preferred market" it is supposedly the most profitable one for the supplier, who if denied access to that market, must sell to a less preferred one at a higher cost or lower price, resulting in an overall lower profitability. With the majority of seafood nowadays being distributed through multiple retailers, it is a matter of discussion how much "choice" the producers actually have.

Two methods have been used by academics to measure the existence and magnitude of a price premium for a product with specific characteristics. On the one hand, the 'stated preference' studies, aiming to capture the willingness of consumers to pay a premium for a superior product, show evidence for a hypothetical premium for sustainable seafood production methods (e.g.

Johnston et al., 2001; Olesen et al., 2010; Uchida et al., 2014). However, as pointed out by Sedjo and Swallow (2002) willingness to pay does not necessarily translate into a market premium, because the method may not reflect the reality i.e. a consumer may not in reality purchase the labelled product (which has been a long standing critique of the stated preference methodology, and/or the retailer may not be able to capture the premium.

On the other hand, 'revealed preference' methods, using actual market data, to decompose the product to its attributes and estimating the contribution of each attribute to the final price through statistical regression, are not numerous and not always conclusive.

MSC is the most studied scheme in seafood utilising revealed preference methods, and the majority of studies cover the UK retail market for white fish. (Sogn-Grundvåg et al., 2013) discovered a 10% premium for chilled MSC haddock and 13% premium for MSC cod and haddock (Sogn-Grundvåg et al., 2014), respectively, in retail market in the Glasgow, UK. A price premium of 10% was estimated for MSC certified cod in Sweden (Blomquist et al., 2015). The highest premium for MSC white fish found was of 14.2% for frozen Alaska pollock in the London metropolitan area (Roheim et al., 2011).

However, Asche et al. (2015) note that the analysis suffers from treating all retailers as identical adds to the analysis by analysing salmon products in the UK also accounting for retailer heterogeneity accounting for the fact that eco-label pricing may be influenced by retailer profiles and competition across labels. Their results show that MSC label achieves an overall price premium of 13.1% but there was a high variation in premiums across retail chains. MSC salmon had a high premium in low-end retail chains but no statistically significant premium in high-end retail chains, thus reflecting the importance of the overall pricing strategy of the retailer. However, MSC certified salmon is always a product of capture fisheries, therefore there might be a co-founding effect arising also from that fact, in a market dominated by farmed salmon.

Organic labelling is another voluntary certification on which various studies have focused. Using actual market data, Asche et al. (2015) found around 25% price premium for organic salmon in UK retail. Fresh and smoked salmon in Norway have been shown to attract a premium of 24% and 38% respectively (Aarset et al., 2004), while Ankamah-Yeboah et al., (2016) finds a premium of 20% for organic salmon in the Danish market, using panel data. Similarly, EUMOFA (2017) describes significant price premiums for organically certified seafood in the EU, but not always improved profitability.

One of the possible explanation between the substantial difference in premiums for MSC and organic is that the organic label is better known by consumers than the specific sustainability labels such as MSC and ASC (Ankamah-Yeboah et al., 2016).

As a relatively new certification scheme, there are no studies examining the pricing of ASC certified products. However, some evidence suggests that it might be attracting a premium in the UK retail market. Stuart Smith, a technical manager for fish with ASDA says (as reported by Intrafish, November 2010):

"Talking to ASC, their aspiration is to have 10% of farmed seafood certified... which in my opinion is very deliberately driving a product which is seen as premium and delivers a high price... As a budget

retailer, we won't see any of that product because we don't have the ability to pay more for it and charge more for it as you would in a high-end retailer."

Currently (as of Oct 2017) there are no ASC certified products in ASDA shops in the UK. ASC products can be found in the UK retailers Waitrose, TESCO, LIDL, ALDI, Sainsbury's and IKEA.

2.2 Global trends in seafood sustainability standards

The trend for this form of quality assurance steadily gained pace with introduction of consumer-facing eco-labels and organic food standards in the 1980's and 90's. There has since been a proliferation in the development of sustainability standards across the food production systems. According to SustainabilityMap (www.sustainabilitymap.org) there are currently 240 standards relating to agri-food products globally, of which 50 are aquaculture and 46 fisheries related. In 2015 14.2% of the total volume of seafood from capture fisheries and aquaculture was certified sustainable, Figure 2.

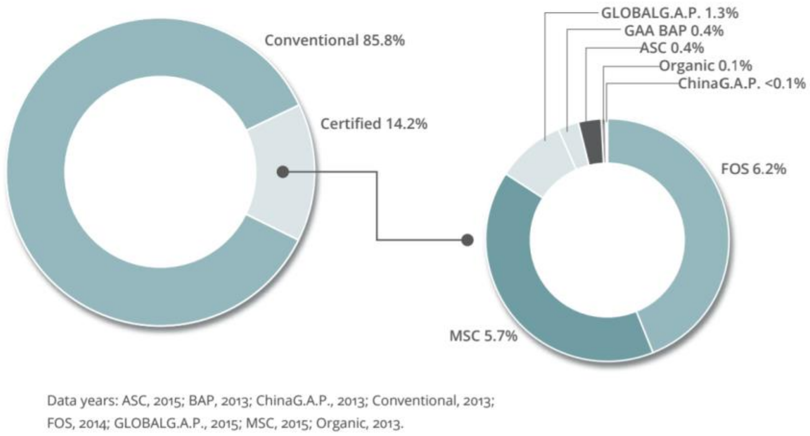


Figure 2. Certified vs certified sustainable seafood production, volume. Source: Potts et al., (2016)

Theoretically the geographic distribution and overlap between alternative certification schemes can be attributed to (i) proximity to and ability to supply demand in certification-centric markets (ii) more local reputational considerations responding to regulatory and advocacy group pressures (iii) location and industry-specific challenges in meeting scheme-specific compliance requirements.

Figure demonstrates the broader market segmentation of different schemes; consistent with their regional genesis and stakeholder involvement in historic standard-setting efforts. Thus, BAP dominates marine salmonid certification in the Americas having become a requisite B2C standard for continued access to large segments of the US market. Conversely it has negligible presence in Northern European market where GlobalGAP dominates with its B2B standard and emerging B2C labels (starting with an option to incorporate an FoS B2C label under defined certification equivalence conditions, prior to developing its own 'GGN' Chain of Custody number as a consumer label). The ASC certified salmonid sites exhibit the broadest distribution, consistent with the WWF (a highly devolved global e-NGO) lead-facilitation role in stakeholder 'dialogues' that were the precursor to the ASC salmon (& other species) standards. Nevertheless, with just 46 sites certified or under-audit in Chile as of October 2017, ASC lags along way behind BAP with 330 certified entities including 245 cage grow-out sites. Although BAP clearly enjoys some first mover advantage[5], the scale of this differential in a context of high GSI member and sector commitment to ASC certification also appears indicative of standard specific-challenges in complying with certain requirements of the ASC standard. A similar differential exists in Canada with 29 ASC and 155 BAP certified sites; though against of a lower sectoral GSI commitment.

Using data in ASC audit reports shows the extent to which sites certified under the ASC Salmon Standard have also achieved multi-certification under GlobalGAP and/ or BAP standards. Results are broadly consistent with the above observations i.e. almost all ASC sites share GlobalGAP certification in Norway whilst BAP overlap is limited to Chile (16% of all ASC sites) and Canada (20% of ASC sites); in both cases all GSI member operated. The surprisingly low overlap level in Chile and Canada given the extensive BAP presence there, may be in part due to selective reporting in ASC audits; there is no stipulation for CABs to report this information. However Figure 3 (inset) indicates a degree of geographic seperation in Chile; BAP achieving almost blanket coverage of sites in the longer established and denser farming concentrations in Regions X and XI; including many smaller sites in smaller sheltered channels. Whilst ASC also has certified sites in the both these regions (mainly in larger channels closer to the mainland) it, exclusively has also certified 13 sites (operated by Cermaq, Nova Austral and Australis Mar) in the pristine and isolated Antartic Magallanes Region XII (BAP and GlobalGAP certification is limited to 3 processors and smolt-producers in the region).

This might be taken as evidence of a social license strategy in support of contested site-licensing requirements for organic growth i.e. with 8 of the 13 Region XII ASC sites being operated by GSI member Cermaq. The most southerly site, the first in the pristine Magellan Strait, operated by Nova Austral and owned by GSI 'cooperation partner' EWOS (a multi-national feed company) has four more sites were under initial ASC audit (the company is also one of only 2 in Chile to achieve Monteray bay yellow-status). In 2015 GSI multi-national, Marine Harvest Chile operated 22 fresh water and 53 sea water sites supplying its 4 processing plants; although 21 of the marine sites had achieved BAP certification, non had achieved ASC certification or were under assessment as of October 2017. Significant losses due to infectious salmon anamia in its core operations-base in region X (Los Lagos) has prompted the company sell some of its sites with a view to relocating further south to Region XI (Aisén)[6] i.e. also consistent with the above hypothesis. Similarly, GSI member NZ King Salmon which has 9 BAP certified marine farm sites has also yet to achieve any ASC certification; likely due to standard-specific compliances challenges discussed below.

[5] The first BAP finfish standards were launched in 2002 prior to a specialised salmon standard being launched in 2011. http://www.worldfishing.net/news101/industry-news/first-salmon-farm-earns-bap-certification
[6] https://en.wikipedia.org/wiki/Marine_Harvest, Annual Results 2015"

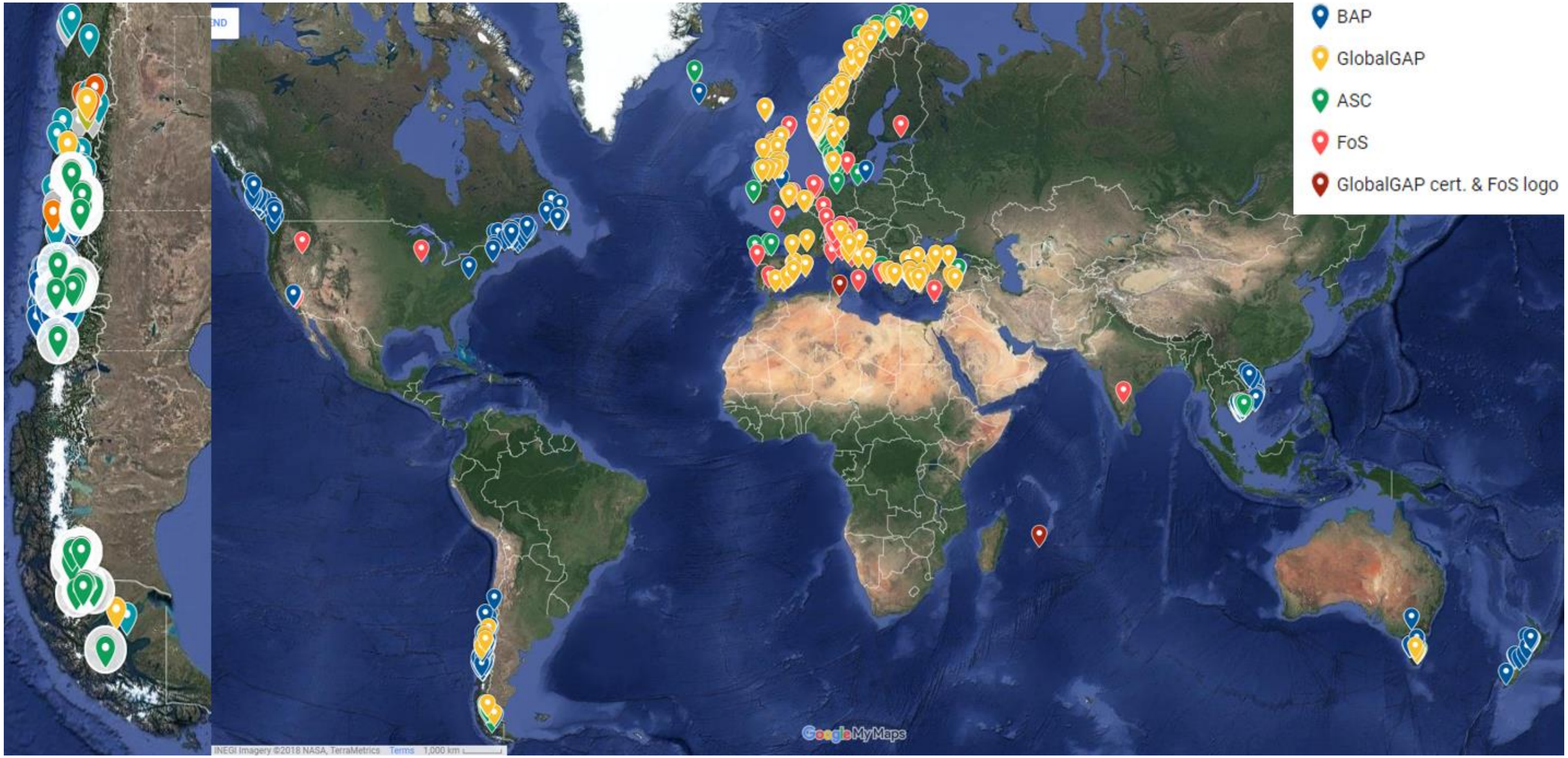


Figure 3. Global distribution of individual certified aquaculture production entities by standard body as of Oct 2017: certified entities include farms, hatcheries/nurseries, feedmills, processing plants and pharma units (n = 1,383; Source: BAP, ASC, GlobalGAP, FoS websites). Inset left; Chile enlarged with ASC farm-sites highlighted in green

2.2.1 Aquaculture Stewardship Council (ASC)

The ASC was founded in 2010 as an outcome of the Aquaculture Dialogues lead by the WWF and Sustainable Trade Initiative (IDH). The current eight ASC farm-level standards cover 12 species groups: abalone, bivalves (clams, mussels, oyster, scallop), freshwater trout, pangasius, salmon, shrimp, tilapia, seriola and cobia. There is also a joint ASC-MSC standard for seaweed. Since its inception, ASC adoption has been quick, primarily driven by large scale producers targeting the multiple-retail chains in developed countries, particularly Europe, partly due to the robustness of the scheme and the wide scope of issues addressed.

While it is not clear whether a price premium is achieved, the volumes certified are expected to grow quickly in the near future, due to increasing retailers' demand of the certification as a part of their CSR strategies, on the one hand, and producer initiatives such as the Global Salmon Initiative (GSI) make commitments for full certification of its members, on the other. The majority of the ASC certified production comes from developing countries in Asia and South America. However, the producers are mostly large-scale enterprises, sometimes foreign owned (e.g. Marine Harvest Chile) targeting the export sector to developed countries, which arises questions of inclusion of more vulnerable actors (Bush et al., 2013). Europe is the largest market for ASC certified products.

Of the four major Aquaculture standards ASC and BAP can be considered 'metrics based' i.e. where possible setting indicators that can audited against quantitative performance thresholds. The ASC standard has arguably gone furthest down this route, seeking to differentiate itself from other standards on this and its ISEAL compliant stakeholder engagement approach. Furthermore the ASC Salmon standard has highest number of such metrics of all it's species standards consistent with highly consolidated nature of the sector & a continuous improvement ethos. The underlying approach of GlobalGAP and friends of the sea is to base compliance on conformity against other normative or third-party standards and local regulations.

For example all the schemes make reference to sourcing of marine feed ingredients from fisheries certified under MSC or IFFO (Marine Ingredients Organisation) Responsible Sourcing (RS) standards or, given supply limitations, interim fisheries sustainable management assessment schemes, notably the Sustainable Fisheries Partnership's (SFP) 'Fish Source' scoring system. However only ASC and BAP go on to incorporate thresholds within their farm standards requiring to reduce overall dependency on marine ingredients linked to sourcing decisions and improved husbandry/ feed management efficiency (

Table 1). This 'addititivity' clearly creates greater compliance challenges for farmers in these performance areas, differentials which in turn point to strategic differentiation opportunities in company choice of standards schemes, discussed in the concluding section.

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 635761

Table 1. Selected Environmental GSI indicators & corresponding ASC & BAP compliance thresholds (Source: ASC and BAP aquaculture standards 2017)

GSI Indicator	ASC	BAP
1.1 Fish Escapes	≤300 over the most recent production cycle	≤3 escapes of >500 fish from individual cages or cumulatively >5,000 fish over 2 consecutive production cycles, or any single escape >5,000 fish
2 Antibiotic Use	≤3 over the most recent production cycle	
5.1 Sea lice treatments – in bath	NS: addresses ASC 'therapeutic treatments' criterion	
5.2 Sea lice treatments – in feed		
4 Sea lice counts	< 0.1 mature ♀ lice/ farmed fish, during sensitive periods for wild salmonids	Evidence of procedures in place to address criterion
7.1 Wildlife interactions: birds	< 9 lethal incidents over the prior 2 years Inc. ≤ 2 marine mammal deaths	
7.2 Wildlife interactions: mammals		
8.1 Use of Marine Ingredients in Feed – Fish Meal	Fish Meal Forage Fish Dependency Ratio (FFDRm) <1.2	The facility shall calculate and achieve a final fish in: fish out ratio of 1.5 or less for each year class harvested
8.2 Use of Marine Ingredients in Feed – Fish Oil	Fish Oil Forage Fish Dependency Ratio (FFDRo) <2.52	

To better understand the genesis of the GSI one must also examine the concurrent emergence of the ASC Salmon Standard; two 'USPs' underpinning the development of which would be instrumental in shaping the GSI. First was the 'multi-stakeholder' nature of the Salmon Aquaculture Dialogue (SAD) initiated by the WWF in 2004 to engage industry, social and environmental NGO consensus in drafting the standards. Uniquely amongst aquaculture sustainability standards, the WWF adopted the ISEAL Alliance code of good practice. Second was the WWF focus on 'metrics-based' standards, whereby as far as possible indicators are audited against quantitative performance thresholds, themselves subject to periodic revision in order to 'drive continuous-improvement'.

The ASC adoption rate by different species is presented in Figure 4, where it can be seen that the largest proportion of certified farms are producing Atlantic salmon, and this is also the section most of the growth in the number of farms has occurred. For comparison, the number of pangasius farms has stagnated over the years.

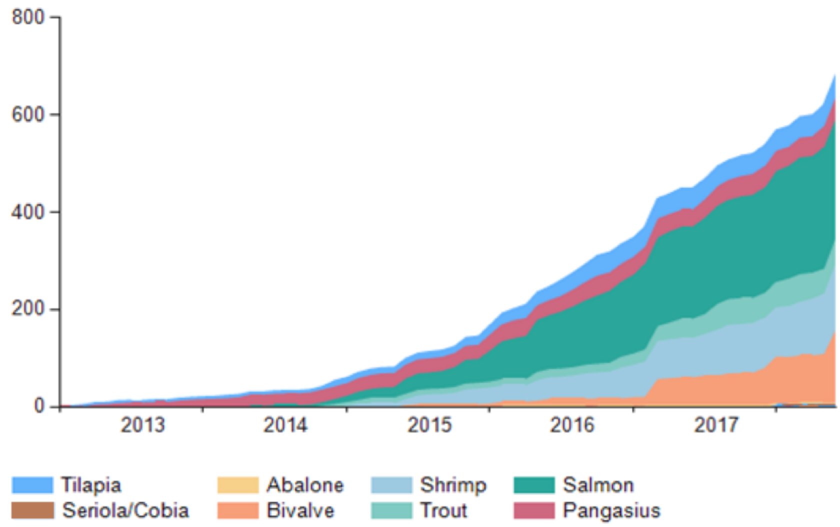


Figure 4. ASC Certified Farms by number of annual audits - May 2017 (& farm capacity MT)

2.3 Analytical framework

The working hypothesis of this paper is that the strategic options including certification are correlated with sectoral concentration trends. Thus, the evidence has been analysed through an 'industry dynamics' lens, in order to uncover the sectoral (external), while not undermining the importance of firm-level (internal) variables, such as size, ownership structure etc, as determinants in the adoption of a sustainability certification.

Industrial dynamics is the study of the means and processes through which industries change over time, through their own processes of evolution – as first analysed by Joseph Schumpeter. It is the complementary study to that of an industry's comparative statistics, which still dominates economic analysis. Several stages in the evolution of an industry can be distinguished in which key variables such as level of output, number of companies, concentration, and profitability change significantly, Figure 5.

In the early stages of a new industry/product, competition is typically low and often depends on technological advantage. As technology becomes standardised and more widely available, the number of competitors increases and competition on price becomes more important. As the industry matures, scale economies can place very high barriers to entry for new entrants and force smaller producers to seek new or niche markets.

The two case studies, of Atlantic salmon across main producing countries and Vietnamese pangasius, examined below, are arguably in different stages of industry evolution which creates different conditions for sustainability certification.

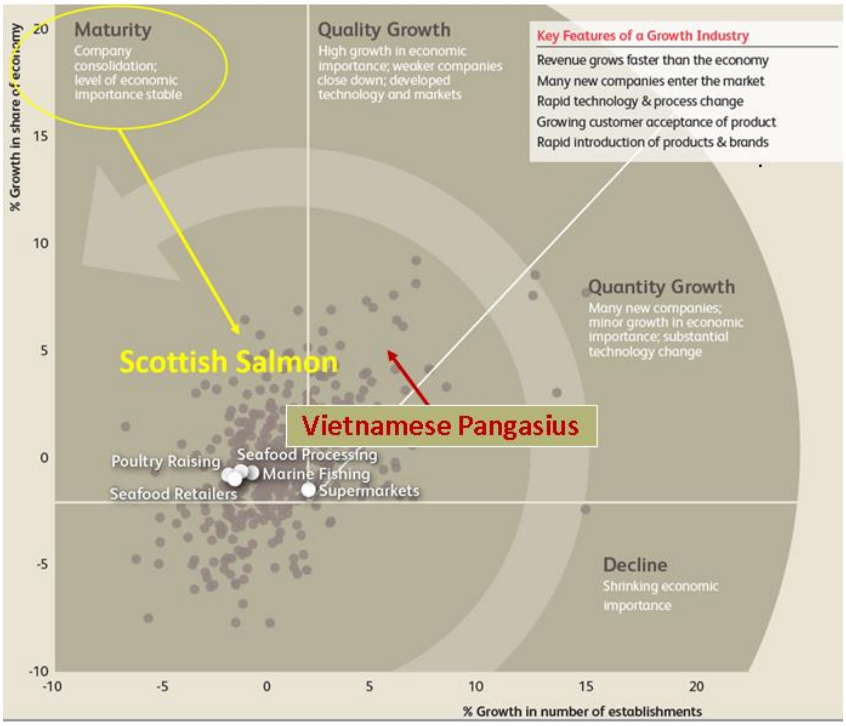


Figure 5. Industry dynamics. Source: IBISWorld

3 Methods

The study followed a mixed-method explanatory sequential design (Creswell and Clark, 2011). A descriptive analysis of quantitative data on third party certification in aquaculture collected from publicly available sources, as well as a review of relevant literature, formed the first (exploratory) phase of this study which served as the basis for the identification and of in-depth case studies. Data on third party certification in aquaculture were extracted from the websites of the following certification bodies: ASC, FoS, GlobalGAP, GAA-BAP. The data was compiled into and integrated relational database management system using MS Access and analysed using the embedded pivot-chart/ table functionality. The same approach was replicated for analysis of GSI sustainability indicator data. GPS coordinates of certified seafood companies (GlobalGAP, FoS) or individual sites where available (ASC and GAA-BAP) was extracted and or interpolated from the same sources and visualised using Google MyMaps and Excel Powerview.

The results from this first level prompted narrowing down the analysis to a single certification scheme (ASC) and pointed to the identification of case studies of different success in adoption of this certification scheme. The cases have been constructed using a range publicly available data. In the case of Atlantic salmon, Global Salmon Initiative (GSI), consistent with the GSI strategic social licence objective, we limit our in-depth focus to indicators dealing with arguably the most contentious environmental impact areas challenging the global marine salmonid industry. For example Monteray Bay Aquarium's influential consumer guide 'Seafood Watch' on its webite, advises avoidance (i.e. 'red-lists') most net-cage farmed Atlantic salmon from Chile, Norway, Scotland and Canada (with exception of a limited number of brands and regions). Indicators with recurrent 'red' scoring include the inter-linked issues of 'disease' and 'chemical use'. These criteria correspond directly with GSI indicators on sea-lice counts (disease) and antibiotic-use and sea lice treatments (chemicals). Data covering four sustainability report years, from 2013-2016 was extracted from the GSI website 'dashboard' and compiled in a relational database for analysis using embedded query, pivot-chart and pivot-table functionalities.

GSI metrics are presented as annualised means, (net) totals, or treatment-frequencies; with varying degrees of data-normalisation i.e. with respect to site biomass, stock number, number of cages/ sites etc. Data on escapes and antibiotic-use are particularly deficient in this respect. We infer that sustainability indicators summarise performance across entire company-country sectors i.e. including ASC certified and non-certified sites, although this not-explicit and the GSI site provides no relevant information e.g. on member site numbers or their production capacity.

Data is compiled as monthly means for the only metric with any graphical interface; sea-lice counts consistent with the ASC load thresholds on farmed animals during sensitive periods for wild-salmonid migration. Data is presented on a case-by-case basis for indicators associated with irregular events e.g. fish escapes, fines for environmental/ labour standards infringements.

Based on this context the aims of the study were to assess country-company specific progress toward the 2020 GSI ASC certification commitment, where possible assessing GSI member performance against ASC standards compliance thresholds; to gain further insights into strategic decision-making based on the overlap of GSI - ASC site certification with other major standards.

Additional data was extracted from an online ASC audit registry[7] for all companies with sites certified under the ASC marine salmonid ('Salmon') standard and compiled in a linked ACCESS database. Audit data included; certification status (initial/ current/ expired/ withdrawn & associated dates), site location (country & GPS coordinates), production data (species cultured, system type – and where available site production capacity). Site-level audit data was also used to estimate total farmed output corresponding with different certification categories for GSI and 'non-GSI' member companies. Output was calculated as (i) the maximum annual output recorded across individual audits (available for 157 of 268 sites) and, in absence of this data as (ii) as 77% of maximum site biomass capacity with the correction factor estimated from output data of the previously mentioned 157 sites (23 sites). For the remaining sites output was imputed from (iii) company-country (25 sites) or (iv) country maximum-output averages (28 sites). Finally, company level annual production data from 2013 to 2016 (Kontali) was also compiled in order estimate national sectoral outputs in order to compare and profile certification trends against global production.

4 Results

4.1 Case study 1: The Global Salmon Initiative (GSI)

This case-study examines the strategic co-evolution of the Global Salmon Initiative (GSI), a collective CSR initiative and the Aquaculture Stewardship Council's (ASC) Salmon Standard, a third-party audited ecolabel initiated by the World Wildlife fund (WWF).

[7] https://www.asc-aqua.org/what-you-can-do/take-action/find-a-supplier/

Launched in August 2013, the GSI is a pre-competitive industry commitment toward greater transparency and cooperation for continuous improvement in the environmental and social performance of salmonid aquaculture around the world. Following a meeting of 6 Norwegian, Scottish and Chilean farmed salmon CEOs in 2012 the GSI was framed around a perceived need, and opportunity for greater dialogue, cooperation in an increasingly consolidated sector; 'to 'reach the global potential of the salmon [farming] industry'. More specifically, the GSI aims to secure greater social license and market acceptability by demonstrating industry sustainability leadership. This is achieved through regular disclosure of performance metrics against a suite of environmental and social indicators ('increased transparency'), along with positive messaging around the health-benefits of eating salmon and the [superior] performance of salmon farming on a range selected indicator (e.g. yield, feed, protein and energy conversion ratios) compared to animal protein substitutes.

Strategically, the framing of the GSI mission around improved transparency and progressive improvement' provided a means for industry stakeholders to reassert themselves as sustainability leaders whilst accommodating objectives of the WWF. This includes a commitment of the membership to achieve ASC certification of all their farming operations by 2020 and the interim publication of annual 'Sustainability Reports' documenting performance against 14 groups of environmental and social indicators.

As of February 2017, the GSI had 17 members with farming operations in eight countries in both northern and southern hemispheres. Chile with 9 had most members, followed by Norway with 6. Three of these members are multi-nationals farming in from 3 to 6 different countries (Table 2). The GSI also has 10 affiliate 'cooperation partners' including the WWF, FAO and major 8 feed and service-provision value-chain intermediaries.

Since 2013 membership has fluctuated from 12-18 companies, 7 companies joining and leaving between 2013[8] and 2015, 4 medium-sized companies joined in July 2017 whilst Tassal, Australia's largest salmon producer (with 10 sites ASC certified or under-assessment) joined in February 2018[9] (Table 2). Norwegian departees included two large multi-nationals; Leroy and SalMar in 2013 followed by Norway Royal Salmon, all of which remained commited to ASC certification with 20, 14, 11 sites certified or under assment as of October 2017.

Atlantic Salmon is farmed by the 17 current GSI members in all listed countries except New Zealand, who's single member uniquely specialises in Chinook salmon (listed under its premium brand name 'King Salmon' on the GSI website).

[8] https://www.undercurrentnews.com/2015/06/05/large-norway-scotland-farmers-quietly-exit-sustainable-salmon-group/
[9] https://globalsalmoninitiative.org/en/news/

Table 2. GSI member companies by countries of operation and species-farmed (Source: GSI sustainability reports 2013-2016).

SN	Company	Operational Countries					
		Chile	Norway	Canada	Scotland	Faeroes(DK)	Other
1	Marine Harvest	A	A	A	A	A	Ireland (A)
2	Cermaq	A,Co,R	A	A			
3	Grieg Seafood		A	A (Ch)[1]	A		
4	Empresas Aquachile SA[3]	A,Co,R					
5	Salmones Blumar SA	A					
6	Camanchacha	A					
7	Los Fiordos SA	A,Co[2],R					
8	Multiexport Foods SA	A,R[2]					
9	Ventisqueros SA	A,Co,R					
10	Bakkafrost					A	
11	Huon Aquaculture[10]						Australia (A,R)
12	New Zealand King Salmon						NewZealand (Ch)
13	Australis Seafoods	A,Co,R					
14	Bjørøya Fiskeoppdrett AS		A				
15	Midt-Norsk Havbruk AS		A				
16	Nova Sea AS		A				
17	Tassal[311]						Australia (A)
18	Pacific Star Salmon SA[12]	A, Co					
19	SalMar AS		A				
20	Norway Royal Salmon AS		A				
21	Leroy Seafood Group		A				
22	Fjarolax ehf[13]						Iceland (A)
23	Scottish Sea Farms				A		
24	The Scottish Salmon Company				A		

Key: A = Atlantic salmon, Co = Coho Salmon, Ch = Chinook salmon, R = rainbow trout)

Notes: Companies 1-13 (white) are longstanding GSI members submitting sustainability reports from 2013-2016

Companies 13-14 (green) became members since the last (2016) annual GSI sustainability reports were submitted.

Companies 17-23 (orange) are former members for which no sustainability data is collated on the GSI website

[1] Last Chinook farming harvested by Grieg Canada in 2015 & not included in sustainability indicators

[2] Species reported as farmed on company websites with no corresponding data on GSI indicators

[3] Includes Invermar SA sites acquired by Aquachile in 2014.

[10] https://globalsalmoninitiative.org/en/news/global-salmon-initiative-gsi-announces-three-new-members-from-new-zealand-tasmania-and-chile/

[11] **3** Tassal was the most recent member to join the GSI in Feb 2018 https://thefishsite.com/articles/tassal-joins-sustainable-farmed-salmon-initiative

[12] Merged with Trussal to become Salmonis Austral in 2013; annual production capacity = 58,000 T WFE. http://www.assetchile.com/case-studies-natural-resources-others/merger-of-trusal-and-pacific-star/ https://www.undercurrentnews.com/2013/11/15/pacific-star-invests-4-4m-in-two-new-salmon-farms/

[13] https://globalsalmoninitiative.org/en/news/global-salmon-initiative-gsi-further-expands-its-global-membership-base-with-the-addition-of-fjardalax-ehf/

4.1.1 GSI member and non-member progress toward ASC certification

As of Oct 2017, 134 marine net-cage salmonid farms operated by GSI members had achieved on-going ASC certification, with 38 more still under assessment (ASC 2017: Figure 6 and Figure 7), whilst 67% of a total of 201 sites certified under the ASC salmon standard in October 2018, were operated by GSI members. This total excludes 16 sites with expired or withdrawn certification, only 4 of which are operated by current GSI members (2 by Chilean companies; Camanchacha and Multiexport Foods and 2 by Australia's Tassal).

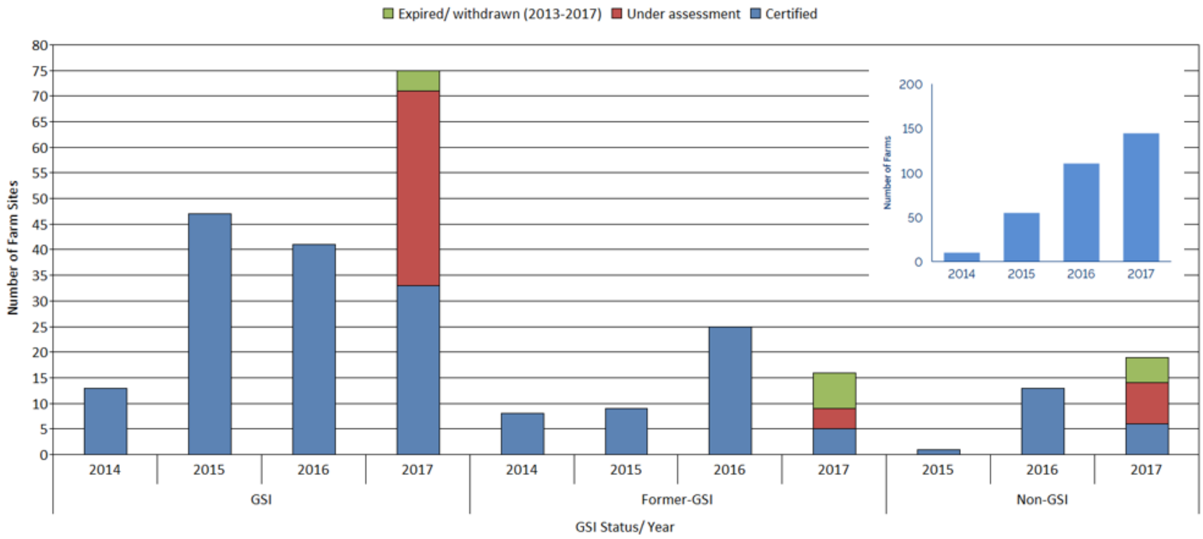


Figure 6. Number of farms audited against the ASC 'Salmon' standard by GSI membership, certification status and year (Source: ASC 2017). Inset: cumulative number of GSI member sites with ASC certification 2014-2017 (Source: GSI 2017)

Figure 7 and Figure 8 show the geographic distribution of GSI member certified sites to be broadly consistent with global production trends; Norway leading with 60 sites, followed by Chile with 34 and Canada with 22. The UK trails with only 2 certified sites (with four more under assessment). Norway also has the lowest proportion of its ASC certified sites operated by GSI members (55%), largely due to the withdrawal of SalMar and Leroy, its 3rd and 4th ranked producers by output in 2016.

Chile has the highest share of ASC certified production output farmed by GSI members; 81% of 147,339T whilst in Norway the corresponding figures were 58% and 444,863T. Based on our output estimates , 6 GSI companies; Marine Harvest, Cermaq, Bakkafrost, Los Fiordos and MultiExport Foods and Tassal are close to achieving the 2020 commitment i.e. excluding any future growth.

By October 2017, we estimate that 'GSI-sites' accounted for 68% (523,695t WFE) of a total of 772,379T of ASC certified marine salmonid output globally. These figures respectively correspond to 20% and 30% of global production in 2016 (2,596,700T). In turn the total GSI certified output corresponds to 48% of the total 1,091,824T harvested by the 17 current members in 2016 (Table 3).

The sustained growth in GSI site certification over its first 5 years (Figure 6) demonstrates good progress toward the 2020 GSI commitment of 100% site certification. However, our estimates also indicate that approximately 568,129T of GSI member production capacity remains to be certified over the next 3 years, at the same time global production continues to expand. Furthermore, it seems reasonable to assume that sites with the least intractable compliance issues will have been the first to be certified.

Perhaps, most challenging in terms of wider collective reputational benefit may be (i) the slower growth in non-GSI site certification and their greater propensity for de-certification. This amounted to 18% of non-GSI certified sites up to Oct 2017, compared to 3% of GSI sites – and (ii) free-riding effects of companies with no capacity and/ or intent to become certified. Conversely, arguably greatest scope for growth exists amongst the GSI membership as a consequence of its mix of (i) larger nationals and multinationals with capacity to acquire smaller operators as the industry continues to consolidate (ii) success in enlisting membership in jurisdictions with greatest potential for short term organic growth, most notably southern Chile.

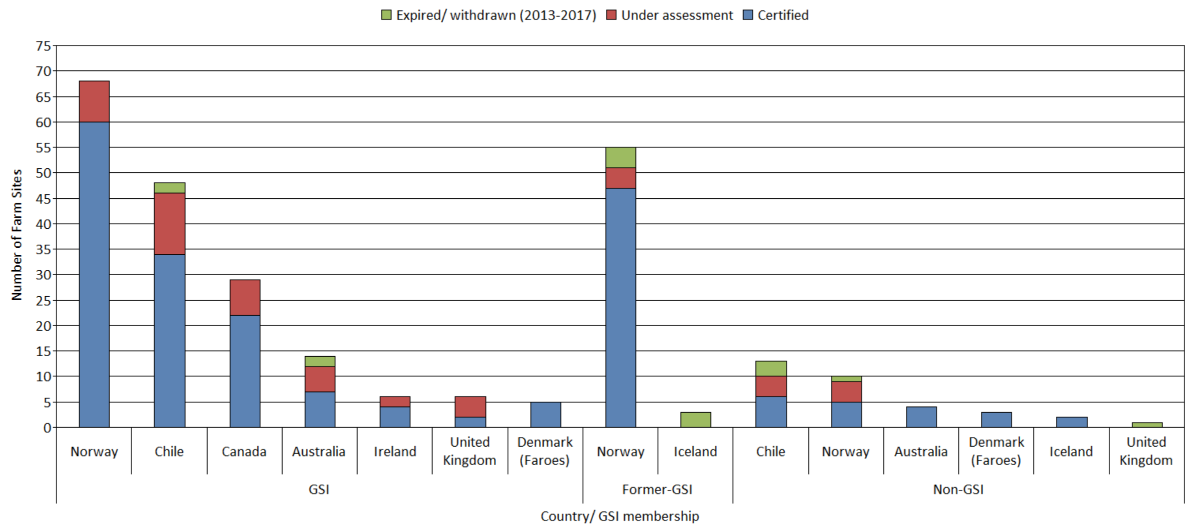


Figure 7. Country-wise distribution of ASC certified marine salmonid cage sites by GSI membership and certification status as of Oct 2017 (Source: ASC 2017, GSI 2017)

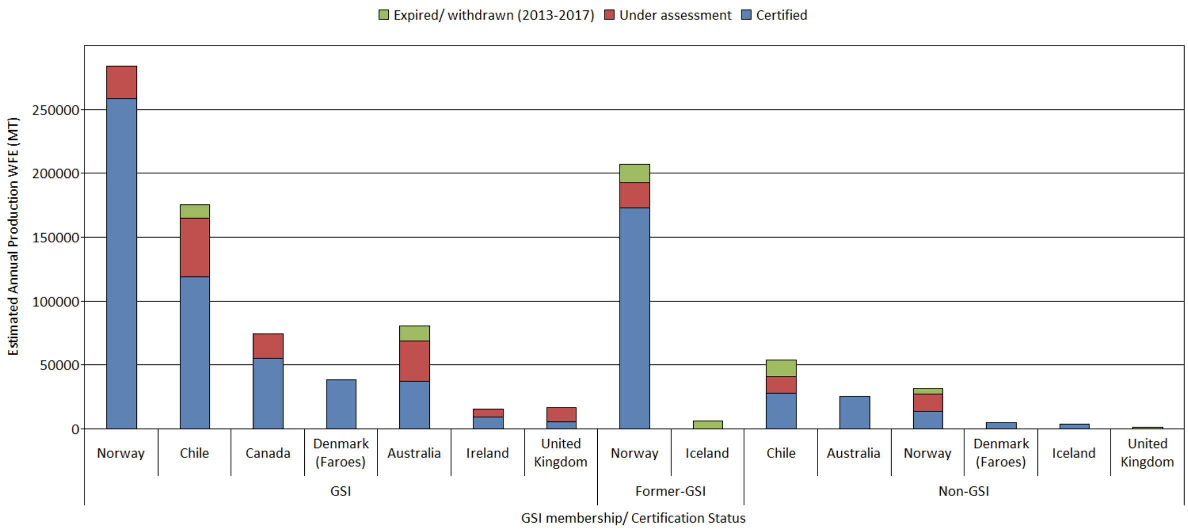


Figure 8. Estimated total annual output (WFE) of ASC certified marine salmonid cage sites by GSI membership, country and certification status as of Oct 2017 (Source: ASC 2017, GSI 2017)

Table 3. Global marine salmonid output by country and 11 GSI companies in 2016 T WFE (Source: Kontali 2017 & indicated company websites)

Farmed	Total	Norway	Chile	North America	UK	Faeroe Islands	Australia & N Zealand	Others
By Species								
Atlantic Salmon	2,166,100	1,171,200	504,500	168,500	157,400	77,300	50,900	36,300
Large Trout	280,800	84,500	74,200	2,500	4,700	0	4,000	110,900
Coho	130,800	0	119,800	1,000	0	0	0	10,000
Chinook	19,000	0	300	2,500	0	0	6,300	16,200
Total	**2,596,700**	**1,255,700**	**698,800**	**174,500**	**162,100**	**77,300**	**61,200**	**173,400**
By GSI Company								**Ireland**
Marine Harvest	423,000	262,200	41,000	48,200	50,100	12,100	0	9,400
Cermaq	135,500	64,500	0	48,000	23,000	0	0	0
Grieg Seafood	71,900	45,000	0	11,900	15,000	0	0	0
AquaChile	81,616	0	81,616	0	0	0	0	0
Multiexport Foods	60,900	0	60,900	0	0	0	0	0
Los Fiordos	60,708	0	60,708	0	0	0	0	0
Australis Seafoods	53,700	0	53,700	0	0	0	0	0
Bakkafrost	52,800	0	0	0	0	52,800	0	0
Camanchacha	32,600	0	32,600	0	0	0	0	0
Nova Sea	41,200	41,200	0	0	0	0	0	0
Tassal	25,000	0	0	0	0	0	25,000	0
Ventisqueros	21,000	0	21,000	0	0	0	0	0
Huon	17,552	0	0	0	0	0	17,552[14]	0
Invermar	15,000	0	15,000	0	0	0	0	0
Midt-Norsk Havbruk	9,900	9,900	0	0	0	0	0	0
Bjoroya	9,300	9,300	0	0	0	0	0	0
NZ King Salmon	6,300	0	0	0	0	0	6,300[15]	0
GSI Total	**1,117,976**	**432,100**	**366,524**	**108,100**	**88,100**	**64,900**	**48,852**	**9,400**
GSI % Global Output	**43%**	**34%**	**52%**	**62%**	**54%**	**84%**	**80%**	**(5%)**
GSI-ASC avg site T[1]	**3,908**	**4,311**	**3,505**	**2,517**	**2,825**	**7,632**	**5,304**	**2,394**
Max Site T	11,882	8,108	6,000	5,373	4,200	11,882	5,980	3,127
Min Site T	385	979	847	498	1,450	4,350	1,245	385
Site Std Deviation	1,983	1,998	1,036	1,178	1,945	3,246	1,790	1,340

[1] **Mean Max site output of sites 2013-2016 of ASC certified to Oct 2017; est. from farm audit data (ASC 2017)**

[14] http://investors.huonaqua.com.au/FormBuilder/_Resource/_module/y8hXOlgfx0a4WjSUgjZk7A/docs/Reports/Annual/2017/HTML1/key_financials.htm

[15] https://www.kingsalmon.co.nz/kingsalmon/wp-content/uploads/2016/10/3309_NZKS_PDS_v26-no-forms.pdf

4.1.2 Performance on GSI Indicators

In this section we evaluate the performance of 12 GSI founder members on two selected environmental indicators over four years of sustainability reporting, 2013-2016. Results are compared against ASC compliance thresholds on these indicators and where feasible those of alternative aquaculture standards schemes. Complementarities and inconsistencies between the different schemes are highlighted and inferences drawn for company strategic-decision making around certification choices.

4.1.2.1 Antibiotics Use Index (AUI)

GSI Indicator 2: The AUI is calculated as: *'the number of treatments over the entire production cycle (under veterinary prescription and supervision by certified fish health professionals)'*. A single treatment is defined as '*an application of a specific medication or multiple, consecutive applications with no more than a 7–15 day gap between applications of the same medication for the same diagnosis'.* A production cycle is defined as *'the total number of fish stocked at a farm site from smolt to harvest'.* Using these definitions the total number of fish per treatment is divided by the total of smolts stocked in the same site over a production cycle and calculations repeated for all treatments and sites per company region to derive a weighted average index. The GSI also cautions that inter-company comparisons 'should be avoided' due to 'differences in regional treatment regulations and practices'. Furthermore, GSI data is not systematically differentiated between farmed species or, more critically between sea and freshwater culture phases. Active ingredient concentration is also not incoporated in the metric. Qualitative stipulations e.g. a prohibitions on prophylactic treatments or use of antibiotics designated by the WHO as critical for human health fall under the scope of separate indicators. Antibiotic treated fish can not be marketed with the ASC label, though non-treated fish on the same site retain eligibility.

The primary intent of these ASC indicators, and by inference the GSI AUI is to mitigate development of anti-microbial resistance (AMR) to antibiotics (food-safety being a secondary outcome). This is an extremely complex issue and interpretation of additional active ingredient, dose and treatment duration data linked to sub-therapeutic dosing would be challenging.

The ASC salmon standard imposes an absoloute limit of upto 3 such treatments in the most recent production cycle i.e. not subject to the above weigthing approach, whilst there is no directly comparable compliance threshold in the BAP standard. Thus the GSI data as presented can only provides an indicative assessment of company ASC compliance performance.

Results show 18 country/ company combinations with positive AUIs in one or all four reporting years (Figure 9). Geographical trends are broadly consistent with recognised health status and challenges across GSI countries i.e. the highest recorded AUI were recorded in Chile and the lowest in the Faeroes benefiting from its oceanic off-shore' location whilst NZ King Salmon's zero-use status is consistent with the premium market positioning of its exotic Chinook Salmon (*Oncorhynchus tshawytscha*).

Eleven companies operating in Chile and Canada recorded AUI from 1.9 to 4.2 to in 2016, significantly higher AUI than recorded in any other country (Figure 9). Eight of these companies recorded small rises in AUI over 2013 to 2016 whilst 3 reduced or stabilised AUI in 2016. Separately, the Canadian industry reported declining antibiotic use from a peak mean of 350 grams/tonne in 2002 to less than 50 grams in 2014, much of the drop accounted for by 'a shift from Pacific to more pathogen resistant Atlantic salmon' (in British Columbia) and on-going vaccine development[16]). However, this trend is not apparent for the 2 GSI member Atlantic Salmon operations on the Atlantic Seaboard. The intermediate AUI reported by Marine Harvest Scotland are more likely to be associated with FW rather than marine treatments.

Over 2015 to 2016, 3 companies, both operating in Chile, Multiexport Ventisqueros and AquaChile (2015 only) recorded mean AUI across all their operations (i.e. certified and uncertified) exceeding the ASC compliance threshold of ≤3 treatments. Only Multiexport has reported values above this threshold in all four years, whilst the 2016 result represented a single year reversal for Ventisqueros.

16 http://www.vancouversun.com/salmon+farmers+publish+monthly+lice+numbers/11469675/story.html

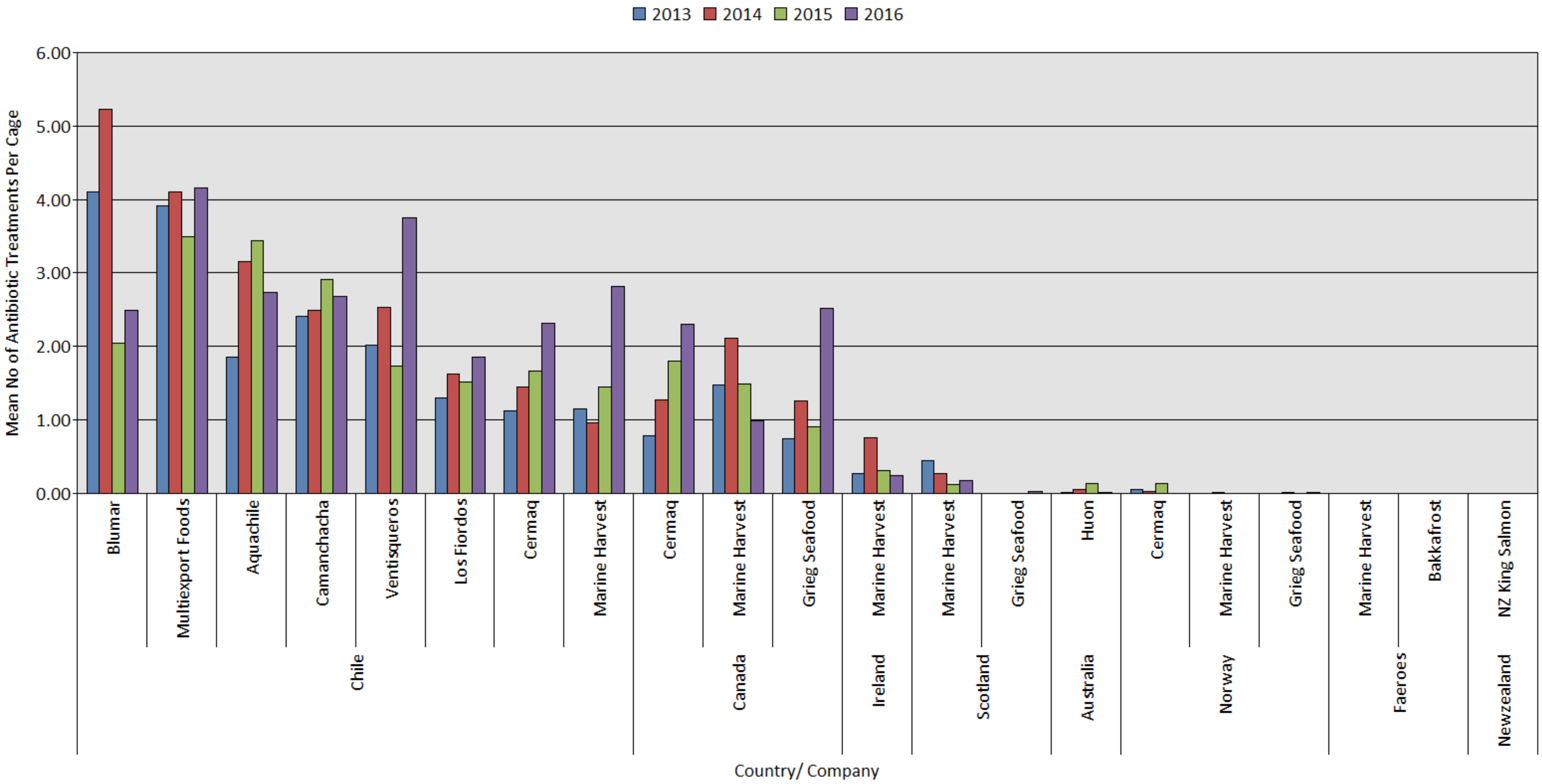


Figure 9. Antibiotic Use Index (AUI) scores for 12 GSI companies operating in 8 countries 2013-2016 (Source GSI 2017)

4.1.2.2 Sea lice treatments

GSI Indicators 5.1 and 5.2: The amount of treatment used is calculated as the amount of active pharmaceutical ingredients (API) used (in grams) per tonne of fish produced (LWE) - as monthly averages. Medicinal treatments defined as those using a pharmaceutical and/or other treatment requiring a prescription. This excludes H_20_2[17] which breaks down rapidly and harmlessly[18]. For bath treatments production is estimated as: closing biomass (T) + biomass of harvested fish (T) – opening biomass of fish (T) in the reporting period. For in feed treatments using anti Sea Lice products production is estimated as: closing stock + harvested fish – opening Stock i.e. being calculated on a population rather than biomass basis. The metric is calculated separately for-bath and in-feed treatments, and in some instances differentiating between production species and production phase (grow-out or broodstock).

In their 2016 sustainability report, GSI members with Chilean operations add a second calculation approaches the second adjusted to account for high mortalities associated with a harmful algal bloom (HAB) as follows: (i) for the population '*surviving*' & finally harvested following HAB related mortalities: Production = (closing biomass + harvest biomass) - opening biomass and (ii) for the '*original*', pre-mortality population. Production = closing biomass + harvest biomass + mortalities biomass + biomass of culled fish) - (Opening biomass - stocking biomass).This adjustment means 'surviving' API values are substantially lower (and only in one case equal) to 'original' API values. For comparative purposes, only data based on the 'original' g API calculation in the following analysis (noting cases of high mortality levels (e.g. the 2013 - 37% loss in Ireland) results could still be significantly biased by timing of the loss).

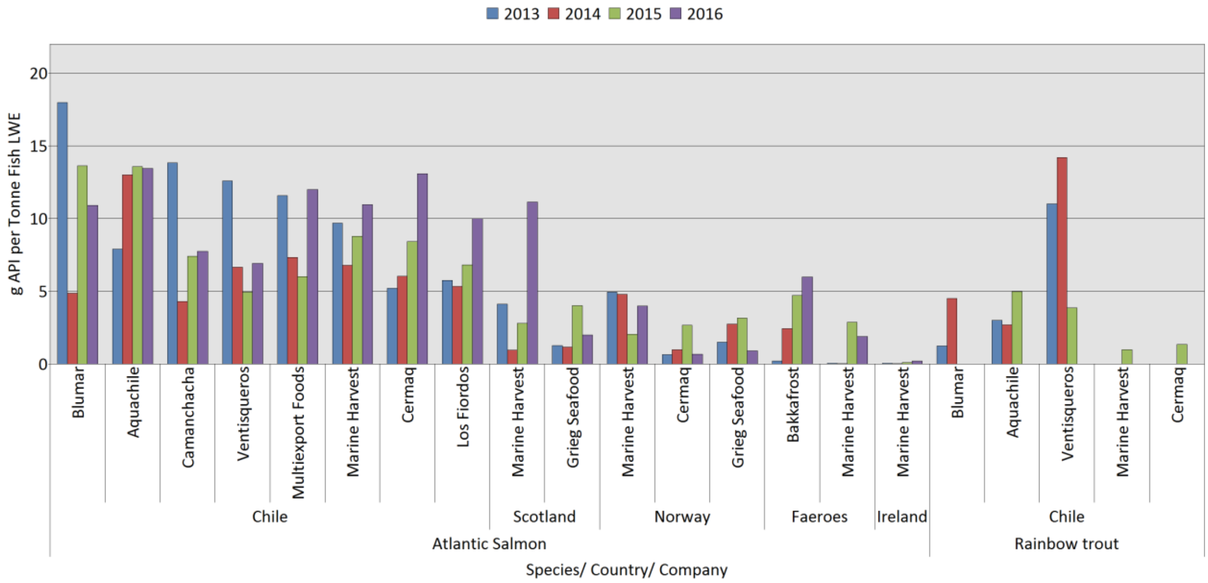
Most Chilean operations appear increasingly reliant on bath treatments for Atlantic Salmon (especially) and rainbow trout (Figure 10 A&B). Only Blumar significantly increased in-feed delivery whilst most other Chilean operations recorded dramatic drops from 2013 peaks; many almost terminating this form delivery by 2015. Only Los Fiordos (6) and Blumar (10) reported significant in-feed rises in 2016 compared to previous years. Atlantic salmon farms in Scotland, the Faroes and Norway show a more mixed pattern. In-bath delivery is generally increasing, though 2015-16 levels of 2-5g API remain much lower than the 5-14g range in Chile in the same years. Six of 8 companies in Chile, MH Scotland and Norway and Faroes' Bakkafrost recorded a year on year increase in in-bath API in 2016, with substantial rises in 5 of 9 of these cases in Chile & Scotland.

Some companies in Scotland, the Faroes and Norway also recorded large increases in in-feed delivery, notably Grieg in Scotland (18g) and Marine Harvest in Norway (8g). Operations in Canada and Ireland report very low reliance on either bath or in-feed treatments. Only Marine Harvest Norway recorded broodstock as well as production/ grow-out scores. Broodstock in-bath and in-feed API scores respectively ranged from 8.2 – 2.5g and 0.1-3.3g from 2013-2015. Cermaq & Los Fiordos recorded zero scores against broodstock treatment, possibly due to data omission. Similarly, no in-bath or in-feed treatments were recorded for Coho or Chinook salmon.

[17] H202 also controls AGD (subject 15oC upper threshold or shorter bath time).

[18] Though MultiExport Foods in Chile still reported this as non-medicinal method in 2015 (Indicator 6)

Interpretation of potential environmental impacts would also be enhanced if APIs were presented together with treatment frequency data[19] e.g. potentially giving some idea of the risk of sub-therapeutic dosing. ASC (or BAP) has no directly equivalent indicator; ASC instead relies on a contested Parasiticide Treatment Index (PTI) based on an aggregate (ordinal) scoring of therapeutants on toxicity, persistence, resistance, 'sensitive timing' and treatment-mode factors.



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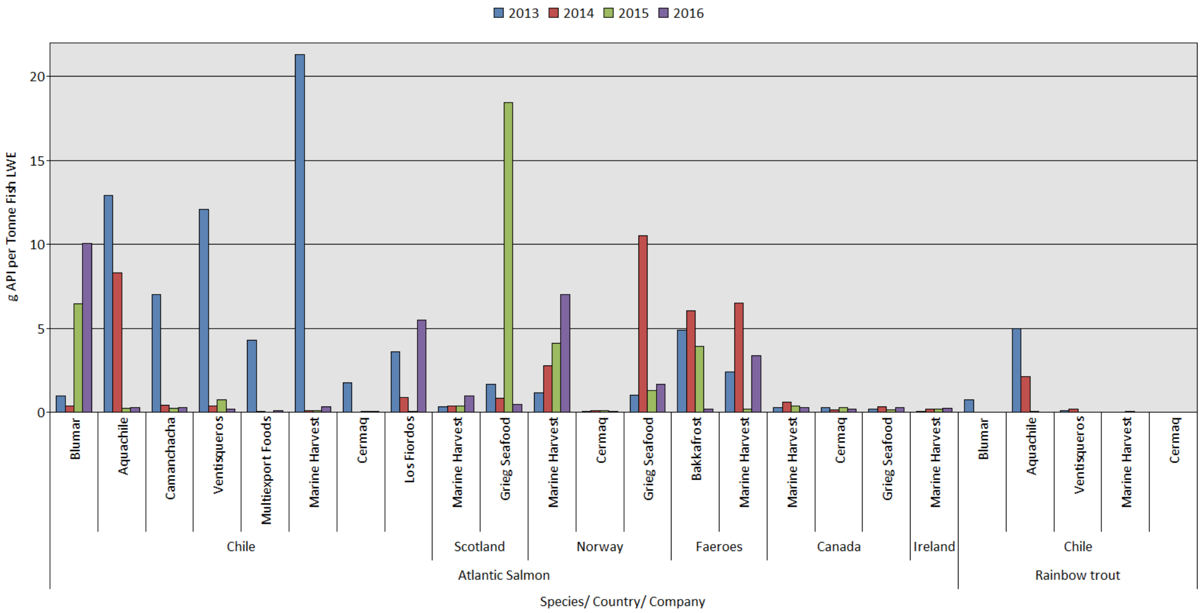

B

Figure 10 A&B. Grow-out bath (A) and in-feed (B) sea lice treatments by species (Atlantic salmon & rainbow trout), country & company 2013-2016 as g active pharmaceutical ingredient per tonne fish, WFE. Note: only Atlantic salmon data presented for 2016 (Source: GSI 2018)

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[19] Chile currently depends heavily of Azomethiphos (an organophosphate) bath-treatments. Emamectin Benzoate ('SLICE', an avermectin) was the (in-feed) treatment of choice in the N. Hemisphere since 1999. Treatments were effective for 7-9weeks prior to build up of drug-resistance.

4.1.2.3 Sea lice counts

GSI Indicators 8.1 and 8.2: Are calculated as the average no. of total adult lice per month (mobiles and gravid females). This is the only GSI metric compiled on a monthly basis.

Before reviewing findings, the following factors complicating ability to compare results should be noted. Although lice sampling-designs may be specified as components of 'local action limits' for treatments (LALs: Table 4), there is no standardisation of approach across countries (i.e. number of fish or cages sampled, randomisation v risk-based approaches etc.). Consistent with lack of standardisation, results are variously reported as counts of four increasingly inclusive life-stage classifications: (i) gravid females (ii) adult females (iii) mobile adults inc. gravid females and (iv) mobile pre-adults and adults[20]. Seven of 8 companies operating in Chile use Class iii, whilst all other companies use Class ii (only Cermaq reports using class i in Chile, but uses Class iv. in Canada). Since 2016 all counts as reported 'average number of gravid females' i.e. class i. though retrospective adjustments are not feasible.

Table 4. National (local) sea lice action-level (LAL) limits ranked in order of stringency.

Rank	Country	National action-levels (mean lice/ fish)	Seasonal operation	Voluntary or Mandatory
1	Norway	0.5 adult females	All year	M
2	Scotland*	3 gravid females	All year	M[2]
3	Ireland	2 adult females	Jun to Feb	M
		0.3-0.5 adult females	Mar to May	
4	Faroes	2 adult females	All year	?
		10 mobiles		
5	Chile	3 adults (mobiles and gravid females)	All year	V
6	Canada	3 mobiles (all pre-adults and adults)	1 Mar to 3 Jun	?

No lice problems reported in Australia or New Zealand

Notes: *'Recommended as good practice' [2] Pending statutory revision to a mandatory year-round requirement to submit a treatment plan to the regulator (Marine Scotland) at counts reaching a avaeragel of 3 gravid females/ fish. The current Scottish LAL based on the SSPO Code of Good Practice is as follows: (i) 01 Feb – 30 Jun: 0.5 gravid females/ fish (ii) 01 Jul – 31 Jan: 1.0 gravid females/ fish.

[20] Classes i and ii have the most direct environmental impact relevance in-terms of transmission risk and are diagnostically also more robust i.e. for *L. salmonis*; it is much more difficult to differentiate early adults and pre-adult chalimus stages morphologically (size being the most obvious factor) compared to male and female adults

Finally, it must be noted that Chile suffers from *Caligus rogercressyi* parasitism whilst *Lepeophtheirus salmonis* is present in all the other lice affected countries in the northern hemisphere (though there are epidemiological/ pathology differences exist between Pacific and Atlantic infections). *C. elongatus* also presents a lesser threat to salmonids and other fish species in Europe[21].

Most companies farming multiple species (i.e. predominantly in Chile) differentiate lice counts by production species. Blumar (farming Atlantic salmon and susceptible Rainbow trout), Los Fiordos and Multiexport Foods (both farming Atlantic and Coho salmon) yet their sea-lice counts are reported exclusively for Atlantic salmon.

Table 4 also clearly highlights a wide divergence in the stringency of LALs underscoring the regulatory influence on performance outcomes. This may be a significant factor contributing to marked performance differences (on this and other indicators) between the countries for the 3 multi-national GSI members.

Figure 11 and Figure 12 show annual and monthly mean counts to persistently higher in Chile than other countries though overall levels show some decline. Counts appear to be rising in Ireland, Scotland (especially) and Canada – perhaps reflecting the Pacific –Coho to Atlantic species shift described above in the case of Canada. Norway with the most strict national treatment action-levels records by far the best count performance with most monthly means <0.2 lice/ fish (Class ii – adult females) and a maximum of 0.41 lice per fish over the 4 year period.

Figure 12 also shows how maximum count levels remain elevated through the year in Chile (with monthly maxima of 4-5 lice per fish, data not shown), whilst Ireland Scotland and Faroes variously have more marked seasonal peaks between August and December (i.e. out-with the main wild juvenile salmonid spring out-migration in vulnerable areas).

Rainbow trout appear as susceptible as Atlantic salmon to *C. rogercressyi* parasitism in Chile, though infection levels also appear to have declined since 2013. Coho Salmon (in Chile) appear much more resistant to *C. rogercressyi* parasitism in Atlantic salmon or Rainbow trout, with mean parasite loads never exceeding a mean of 0.2 lice/ per fish between 2013 and 2015 (class i and iii definitions; data not shown). Pacific salmon (i.e. inc. Coho and Chinook) mount strong tissue responses to attaching lice increasing likelihood of rejection during early infection. However, *Caligus* spp. do transfer readily between different fish species making cross-infection between co-located salmon and sea trout farms in Chile a far greater risk than in regions of *L. salmonis* infestation.

The intent of the aligned ASC indicator to mitigate negative impacts on wild salmonid populations means this and associated lice indicators including a requirement to participate in area-based management schemes, do not apply to Chile, Australia or New Zealand where there are no wild local salmonid populations. In other jurisdictions however the ASC indicator threshold of '*< 0.1 mature ♀ lice/ farmed fish, during sensitive periods for wild salmonids*, combined with growing resistance to

[21] http://www.sciencedirect.com/science/article/pii/S004484861100250X: Caligus elongatus can be the cause of summer/ autumn count spikes in N. Europe (Faeroes an exception. Is transmitted by >100 host wild fish spp. and although easy to treat, this more 'catholic' adult mobile transmission and associated planktonic presence constitutes a large infection reservoir. However, the migratory non-specificity of such populations compared to salmonids, also reduces drug- resistance selection pressure.

available therapeutants, clearly poses a major on-going challenge for certification of inshore (i.e. with lower flushing rates and higher lice transmission risk) producers of salmon in European and N. American countries.

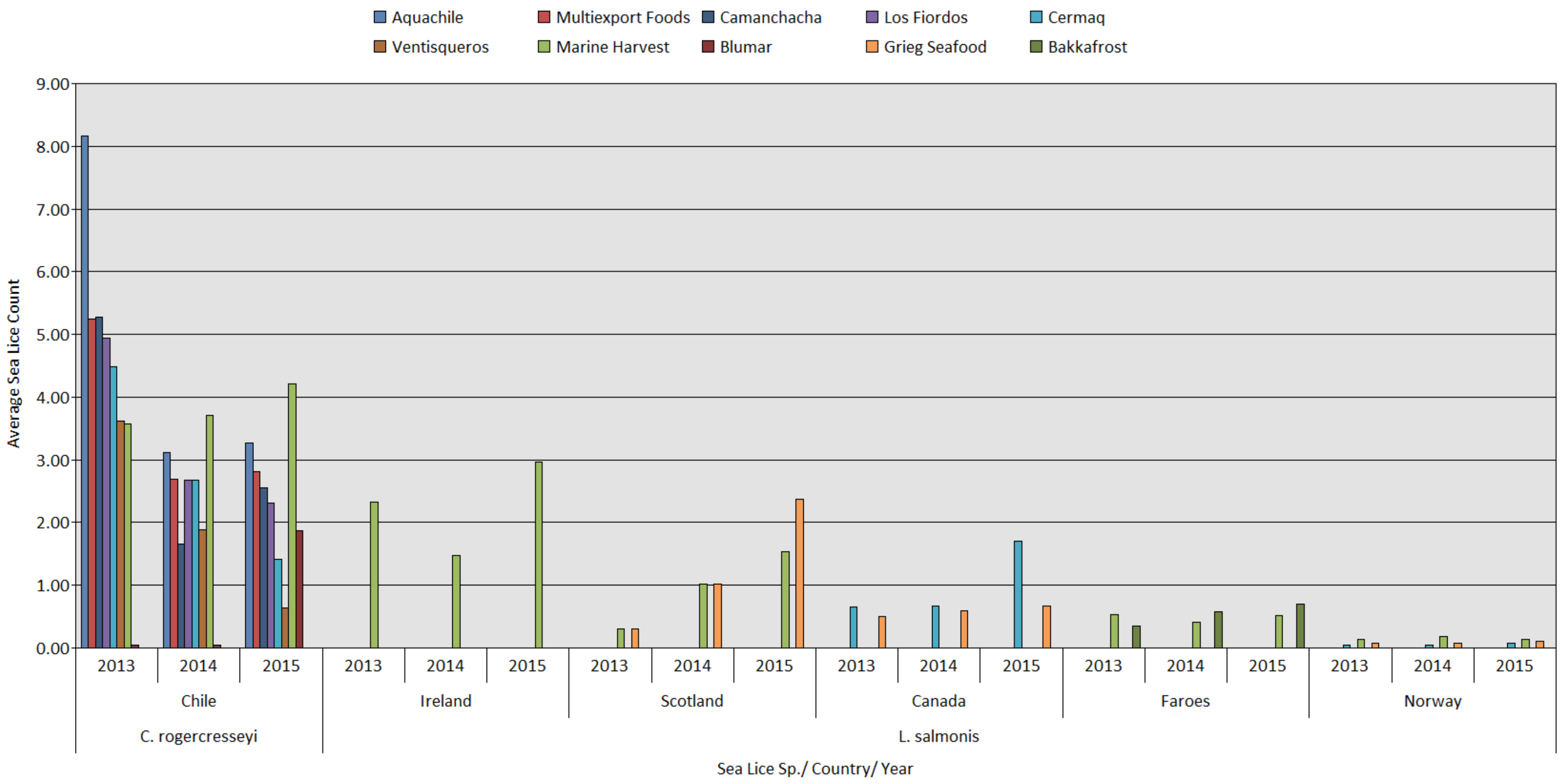

Figure 11. Atlantic Salmon mean sea lice count by company and country 2013-2015 (Source: GSI 2018)

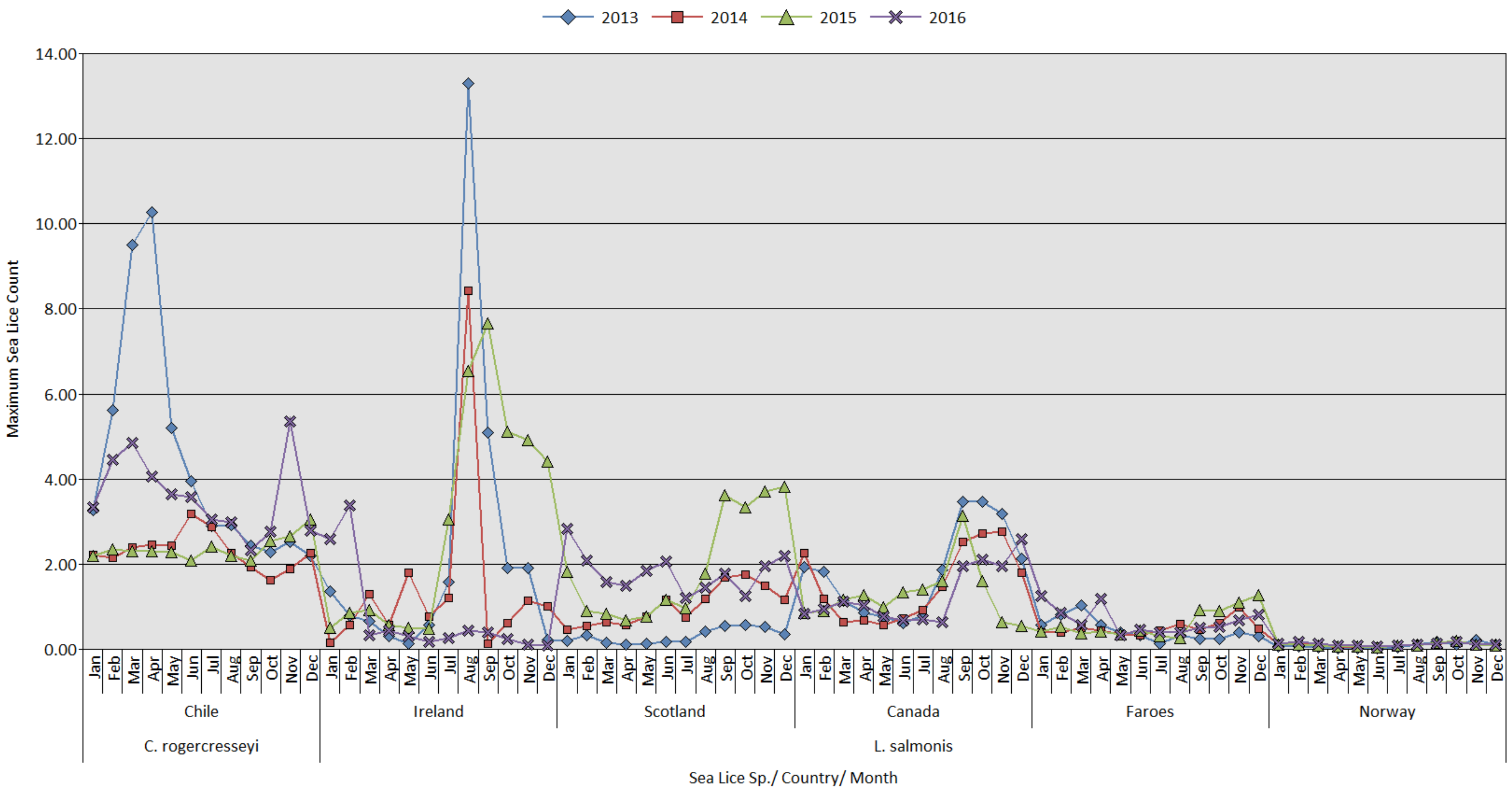

Figure 12. Atlantic salmon maximum mean sea lice count, all companies by country and month 2013-2016 (Source: GSI 2018)

4.2 Case study 2: Pangasius aquaculture industry, Vietnam

Pangasius catfish (*Pangasiusianodon hypopthalmus*) is one of the most important species in aquaculture sector of Vietnam. The country produced about 1.33 million MT in 2018 (VASEP 2018), Figure 13. Vietnam dominates in farming pangasius, its production and export representing over 75% of the global volume (FAO 2010; Globefish 2015; Seafish, 2011).

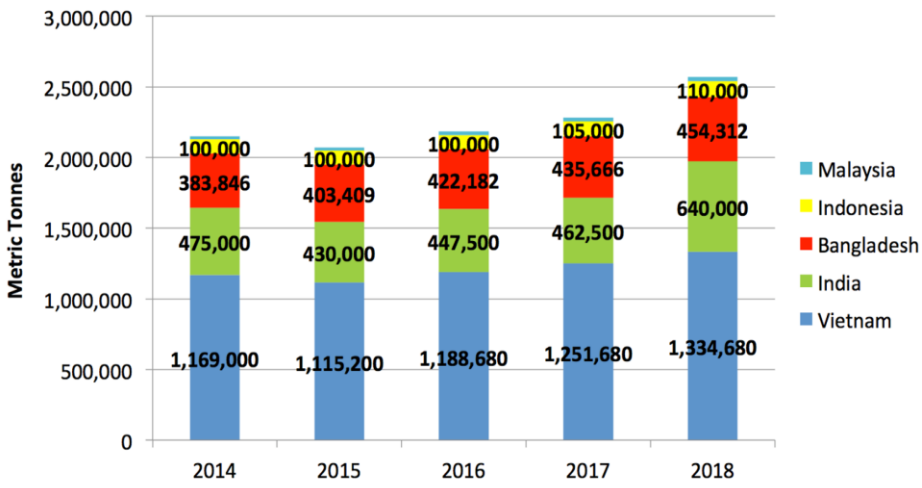

Figure 13. Production of farmed pangasius by Asian countries . Source: VASEP 2018

The species is cultured at the considerably most intensity on a farming area of about 6,000 hectares in Mekong River Delta. Although approximately 300 MT per hectare is more typical, very high yield figures of up to 600 MT per hectare with extremely high stocking densities possible with this species (Seafood Watch, 2014). As a result, Vietnam is well known as the biggest pangasius supplier with a contribution to 80% of the total world production (FAO, 2012).

Starting in the late 1980s Viet Nam's economy has grown at a very rapid pace to transform the country into the middle-income state that it is today. One of the main reasons for the phenomenal growth has been its success in foreign trade where the high competitiveness of Vietnamese products on the export market, including pangasius, has been driven by competitive price. Cost-leadership has been possible due to the abundance of resources and low input costs in Vietnam. High year-round temperatures allow fast growth and thus a short production cycle of this native fish species. In addition, the FAO describes pangasius as a nutritionally low input species, meaning it can be produced efficiently with little animal protein, fishmeal and fish oil, which account for a large proportion of feed costs and which are becoming increasingly expensive. Thus, the low input diet of Pangasius is an advantage in terms of both reduced feed costs and environmental impact. The abundance of freshwater resources in the Mekong Delta, make production of a big scale using traditional earthen pond systems, possible. The low regulatory barriers have allowed the industry to grow very quickly. Importantly, the domestic value chain has been reliant on abundant cheap labour, characterised however, by low labour productivity (output per worker).

However, as the country's average wage rate continues to grow, while labour productivity remains the same, the competitive advantage based on price becomes increasingly eroded, resulting in a slower economic growth. This phenomenon has been termed the middle-income trap (Kharas and

Gill). A country in the middle-income trap will have lost their competitive edge in the exportation of manufactured goods but are unable to keep up with economically more developed economies in the high-value-added market. Future economic growth can thus be achieved only through productivity growth such as resulting from consolidating agricultural landholdings (which are still too fragmented and small in Viet Nam) and introduction of mechanisation and innovation. Another issue is the diversifying product category, focusing on high-value added and ready-to eat product, and branding the aquaculture to overcome the market barriers.

Over 90% of fish is oriented for exports. Since 1995, successful artificial propagation together with expansion and improvement of the marketing of Pangasius products has led to a rapid development of farming activities. As a result, Pangasius products emerged as a leading source of export revenue for the nation. Pangasius is now one of Vietnam's most important export crops by volume and value; the US and Europe are both important market (Loc et al., 2010). However, many problems have been brought about by a rapid and inappropriate planned development as well as sustainable concerns in the Pangasius aquaculture sector.

Pangasius in the European retail market (mainly in the form of frozen fillets) is part of the market of frozen whitefish and thus competes with other, more traditional for that market, frozen whitefish products, such as those based on cod, Alaska pollock, saithe, haddock (Bronnmann et al., 2016) various flatfishes and hake and tilapia in Southern Europe. It is valued as a generic white fish fillet which can be cooked in a number of ways, for the lack of bones, its mild flavour and primarily for its competitive price (Carson, 2013). The lack of sufficient differentiation from other whitefish commodities (being closely integrated into the whitefish market) means however, that producers in Vietnam are exposed to and influenced by external factors such as fisheries quotas and the supply of wild-fish products (Bronnmann et al., 2016).

The EU and US are considered the most important market destinations for pangasius. In 2012, 24.4% of Vietnamese pangasius volume was exported to the EU, while 20.8 % was exported to the US. The figure indicates that almost 50% of exported pangasius goes to several other countries in Asia, Mexico, Brazil, China and other countries (SFP, 2015).

Nearly all pangasius is exported as frozen fillets; less than 1% of the export volume consists of other product types of pangasius (added value pangasius products). Other pangasius products are also imported such as fresh fillets, whole frozen fish and whole fresh products (23, 9 and 7 million euro respectively in 2014 (CBI, 2015), Figure 14.

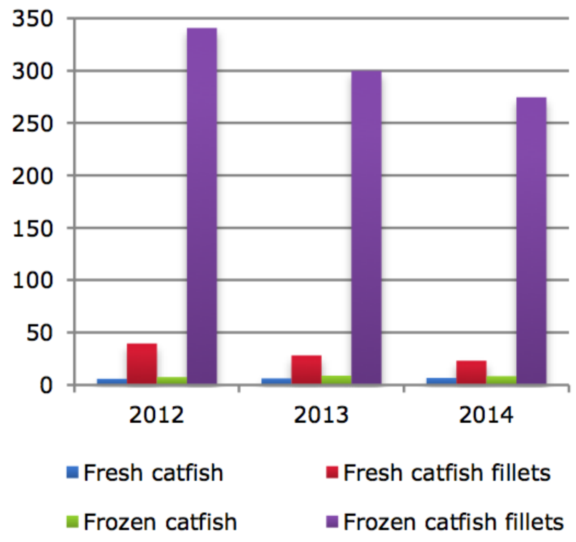

Figure 14. EU imports of pangasius in 2012 – 2014 (million euro). Source: CBI, 2015

In Vietnam many companies are traditionally owned by the state or joint-stock companies. Only recently has the number of private companies risen. Table 5 provides an overview of the types of companies that were licensed for seafood exports in 2009.

Table 5. Type of seafood processing company and geographical distribution in VN in 2009. Source: Duijn et al. (2012)

Type of company	Red River Delta	North Central and Central Coastal	Southern Delta	Mekong River Delta	Total
State-owned	6	33	30	22	91
Joint stock	9	30	47	73	159
Private	3	71	114	104	292
Joint venture	4	0	4	1	9
100% foreign capital	4	0	4	1	9
Total	26	134	199	201	560

4.2.1 Sector trends

The pangasius farming stage of the value chain is fragmented, composed of a large number of small-scale enterprises, due to low barriers to entry. According to MARD in 2004, there are more than 15,000 households who raise pangasius (Khoi, 2010). During the last several years however, the development in the pangasius sector has resulted in more large-scale producers and the disappearance of many small-scale producers. The analysis of the structure of the pangasius industry revealed strong consolidation and concentration trends at the processing stage of the value chain, driven by highly marginal nature of the business model and significant scope for scale-economies. Top 4 exporters are all vertically integrated companies with combined market share of pangasius export value gone up from 25% to 36% for the period 2010-2016, Figure 15.

Although the number of commercial large-scale pangasius farms is increasing the vast majority of pangasius farms are still smaller than one hectare. This especially is the case in provinces that have a long-standing fish farming tradition such as An Giang where more than 70% of pangasius production originates from small-scale producers (CBI, 2012). Provinces located more downstream in the Mekong River Delta, where pangasius farming only arose when it became clear that it had a great export potential, have more large-scale commercial farms. These are often directly owned and managed by export companies.

However, there remains a long residual 'tail' of intermediate size producers – many loosely contracted to supply larger vertically integrated companies i.e. indicative of moderate sector consolidation.

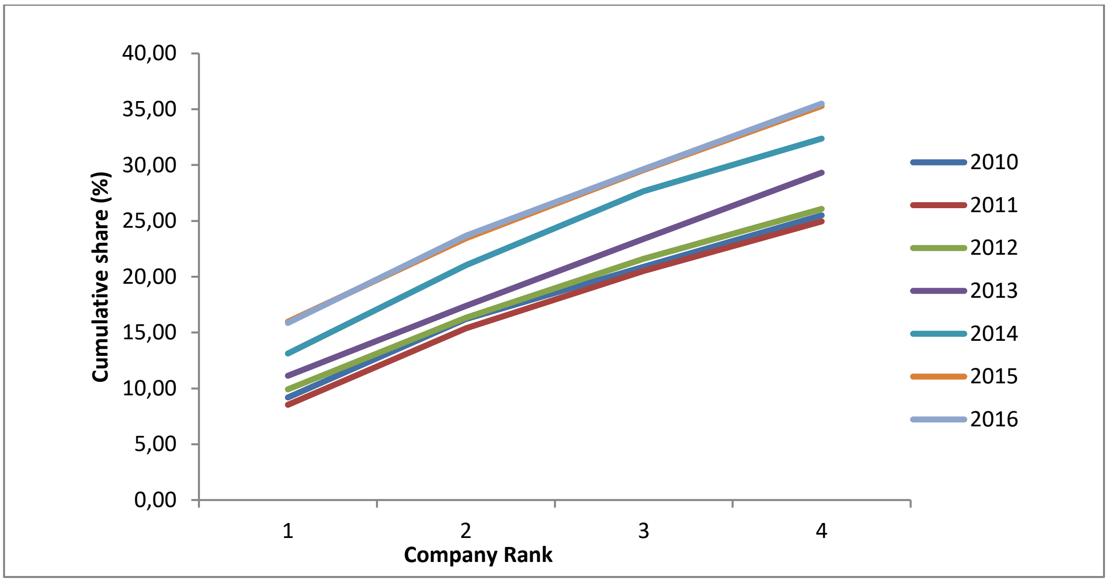

Figure 15. Concentration curves – export value cumulative share top 4 companies 2010-16. Data sources: VASEP, Company Annual Reports

Previous research has shown that sectoral consolidation is also driving concentration of water-intensive pangasius farming along major Mekong & Bassac rivers and primary canals. This trend is apparent in An-Giang where rapid ongoing consolidation over 6 years has resulted in rapid decline in smallest family farms (<500m^2-2000m^2) & growth of larger units from 1-25ha, Figure 16. The resits of this trend in 2009 were a loss of small family farms: 0.05ha – 0.2ha and increase in larger farms: 1-25ha.

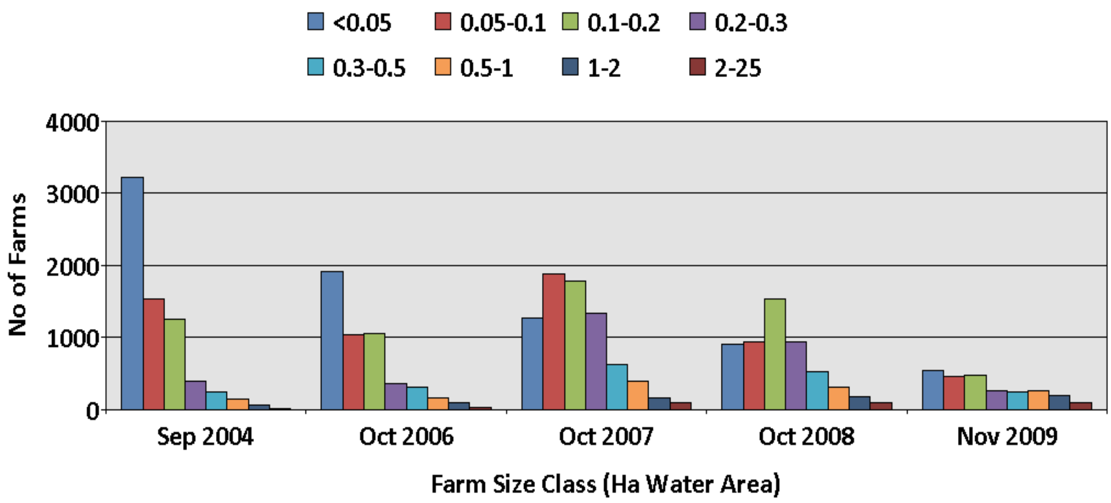

Figure 16. Consolidation of smallholder pangasius farming. An-Giang Province, Vietnam 2004-2009

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The production trends post the 2011 price crash appear static, but a recent price increases (2018 farm-gate prices reaching near all-time highs; up 150% YoY) are attracting new entrants and conversion of land to ponds due to relatively low entry barriers.

Nevertheless, consolidation is likely to continue in the longer terms with larger companies benefiting from greater scale-economies during leaner periods.

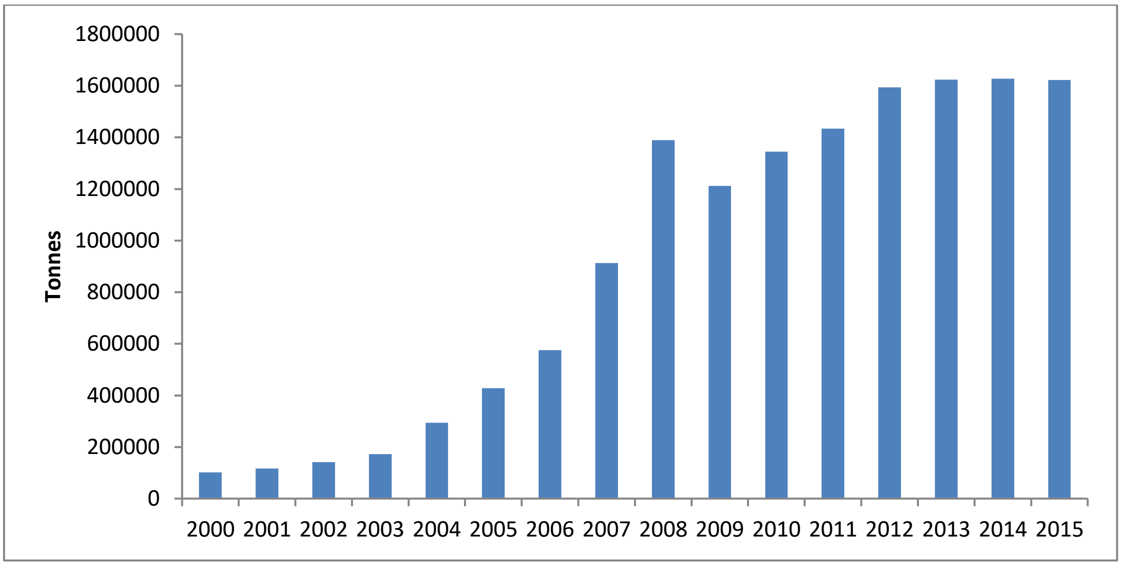

Figure 17. Production volume of Vietnamese pangasius. Source: FAOSTAT

4.2.2 ASC certification

The increased focus on sustainability and food safety results in higher quality standards with respect to production and hygiene. The high level of EU food safety standards compared to the level of standards in markets such as the US, Japan and especially alternative markets such as South Korea or the Middle East, may constitute a barrier for exporters for whom the costs of compliance are too high. If, for whatever reason, the local supply chain in shrimp producing countries cannot meet these requirements or is not able to pass the tests that need to be carried out, this may constitute a reason to export to other countries instead. In recent years it has happened that as a result of rejection by the EU (and also US and Japanese) health authorities, on the basis of the presence of antibiotics, for example, exporters shifted their focus to other markets where health standards are less stringent than in the EU. This ultimately results in different supply chains for specific end markets that each have own levels of quality. Contrary to other barriers, such as import tariffs, this barrier may be eliminated in the countries where shrimp are produced, as institutions can be strengthened and producers can be trained for compliance with EU standards. Traceability is an issue in aquaculture production, as it is used as a means to be able to trace the origins of unsafe seafood.

In 2011 there was an agreement between the governmental organisations VASEP, VINAFISH and ASC (WWF origins), D-Fish to achieve certification rate 30% of production volume of Vietnamese pangasius by 2012 & 2014.This development followed the de-listing of pangasius from WWF red list. However, uptake stalled: from 43 farms May 2012 to only 45 in July 2015 producing 210,210 mt; or less than 15% of total output, Figure 4. The size distribution of ASC certified farms shows that it is ranging from 400 to 21,000 MT annual capacity, of which >90% larger farms >4,000MT capacity and >50% of farms certified for 2-4 years.

The success of pangasius on the EU and USA export markets has attracted a lot of media attention, most of which negative. Prominent NGO's and EU MP's have expressed often ungrounded criticism of pangasius on the basis of its environmental, social and safety credentials (Little et al., 2012). According to the same authors the motivation for this can be linked to industry interests over white fish supply which has been likened to a "war".

A main source of confusion and basis for negative reporting have been import rejections by the Rapid Alert System for food and feed (RASFF) which provides notification of food safety risks before they reach European consumers. Pangasius products have been on the top of product lists that have been refused in the EU market. Pangasius recorded 56 RASFF notifications in its worst year in 2005. The frequency of notifications reduced after but peaked in 2009 and 2010 at 24 and 28 per year, respectively. These later notifications were due to microbial contamination (Little et al., 2012).

Despite some pejorative media polemic – pangasius is demonstrably a high quality/ safe raw material. Improvement in pangasius food safety standards have also come about with consolidation in this industry. This is supported by evidenced by EU-RASSF notification rate of pangasius versus farmed shrimp & capture fishery when normalized by export volume, Figure 18.

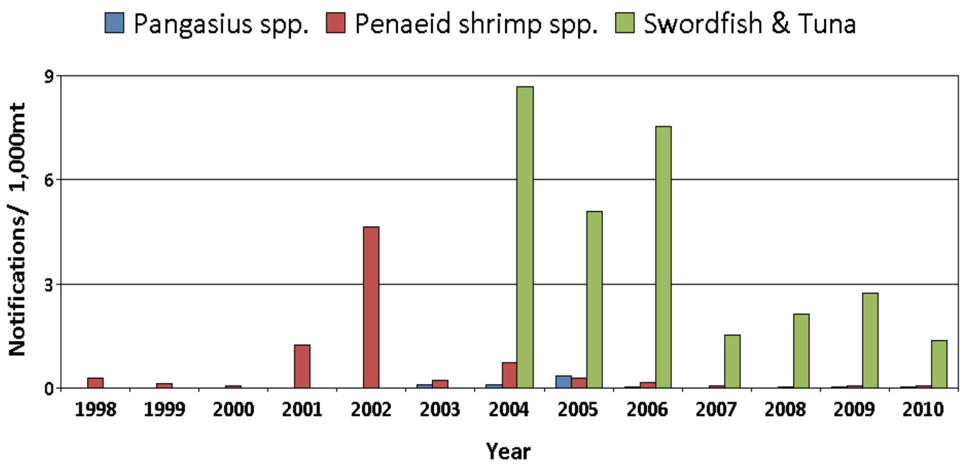

Figure 18. RASFF notifications per 1,000mt imports Vietnam to EU 2001-2010

While quality has improved over time, there is still confusion among consumers regarding food safety and environmental impacts associated with production. Moreover, consumers in those markets are not familiar with pangasius compared to other white fish species, because they have a strong tradition with wild-caught white fish such as haddock and cod, pollock, flatfish. The result has been declining imports in the EU and the US and a shift of exports towards emerging markets.

Pangasius been on and off the WWF's red list of species to avoid over the last decade. In 2017, the pangasius market in EU was strongly affected by the decision of the French retail giant Carrefour to suspend sales of Vietnamese pangasius in all its stores in Belgium, France, and Spain under the suspicion that pangasius farming was polluting the Mekong Delta. This happened despite the fact that a large proportion of Vietnamese pangasius has been certified sustainable by independent third-party certification schemes such as ASC, BAP and GlobalGAP[22].

However, as regards safety of pangasius, (Murk et al., 2016), after analysing contaminant levels encountered in pangasius, collected from the EU Rapid Alert System for Food and Feed (RASFF) database, report that the toxicological risk assessments do not support any of the toxicological risks suggested in the media. They conclude that such mass-mediated risk create confusion, with economic consequences for both seafood exporting countries like Vietnam and for seafood importing regions such as Europe.

However, persistent negative claims about pangasius' safety and environmental issues in the E.U. markets have damaged the fish's image and destroyed the industry's reputation. The image problems act as a barrier to growth in exports, as well as a product upgrading associated with a price premium. Vietnam's pangasius exports were worth USD 1.78 billion (EUR 1.43 billion) in 2017, an increase of 4.3 percent from 2016. However, the export value to the U.S. and E.U. fell 11 percent and 22.3 percent, respectively (Seafoodsource, 2018). Some seafood experts have collectively created a new term for the campaigns surrounding pangasius, calling them the "whitefish wars", which is driving the Vietnamese pangasius away from EU and US markets. China and Latin America has emerged as the strongest market for Vietnamese pangasius.

Carrefour, a major retail grocery chain in Europe, announced in late January 2017 that it would stop selling Vietnamese pangasius fish in some markets (Spain, Belgium, Italy and France, the home country of this supermarket chain) – citing belief about the adverse impacts pangasius farms have on the environment in terms of water pollution from production waste. This happened regardless of the fact that the pangasius products were certified by ASC.

5 Discussion & Conclusions

Third-party sustainability certification schemes are routinely critiqued as being drivers of industry consolidation through higher marginal costs they impose on smaller producers. However, an overly narrow view of certification based on potentials to support a product price-premium neglects wider strategic possibilities. Using two case-studies of success and failure, we position certification within an 'industry dynamics' framework to demonstrate how pre-competitive sectoral strategic objectives can be leveraged. We show how such challenges and opportunities are closely correlated with sector consolidation and concentration trends.

Our preliminary finding point to a growing consensus around the following points (i) other than for earlier adopters, or schemes with in-built premium guarantees (e.g. FairTrade); most voluntary sustainability standards guarantee continued access to certification-centric market segments (linked to reputational issues and advocacy group pressure) over and above any price-premium (ii) the burden of compliance and auditing transaction costs fall most heavily on producers low in the value-chain. Multi-site and group certification, Inter and intra scheme harmonisation and equivalence measures, benchmarking entities such as the GSSI are steps being taken by the certification sector to deal with this problem.

[22] http://www.intrafish.com/news/1212717/asc-facts-dont-support-carrefours-pangasius-decision

Within this context we use a corporate social responsibility (CSR) case-study of the Global Salmon Initiative (GSI) as an example of industry re-asserting strategic control of the sustainability agenda to achieve a pre-competitive objectives, through a membership commitment to achieving 100% certification of their marine net-cage sites under the ASC salmon standard by 2020. Members also commit to annual disclosure of performance metrics on 9 environmental and 5 social indicator groups over the interim period.

Our analysis indicates the following potential strategic advantages associated with GSI membership. Firstly, by posting of the aforementioned data on the GSI and member websites members direct compliance with requirements of multiple ASC standards for public-disclosure. More significantly by demonstrating collective industry leadership the GSI aims to achieve social license in order to achieve (i) greater market acceptability for global salmon production compared to other animal protein substitutes (ii) improve more local acceptance of the industry which is in turn aligned with growth aspirations in a sector subject to some of the most stringent licensing regulations of any major aquaculture commodity sector.

These observations are affirmed by the evolving GSI membership mix and their certification progress. With 9 operators Chile has the highest number of members, including 3 multi-nationals and the highest proportion of ASC certified production from GSI members, 81% of 147,339 T of certified output (representing 21% of 2016 national output) compared to only 58% of 444,863T of certified output in Norway (35% of national output in 2016). Potentials for organic growth are limited by stringent site-licensing restrictions in many countries; whilst almost uniquely Chile has huge and largely untapped resource in it's isolated Region XII Magellan Antarctic Region. With many of the largest multi-national salmon producers being GSI members with operations in Chile; licensing objectives may provide a particularly strong strategic incentive for membership.

We estimate that 17 current GSI members, with 134 ASC certified sites accounted for 68% of a annualised total of 772,379T (WFE) certified output as Oct 2017, values in turn corresponding to 20% and 30% of an estimated global production of 2,596,700T in 2016. Norway, Chile and Canada lead with 60, 34 and 22 sites respectively. Despite promising progress, we also estimate that 568,129T of GSI annual production capacity remains to be certified over the next 3 years to the 2020 commitment (we estimate 6 GSI members are close to achieving this goal) and presumably this residual also contains sites with more intractable certification issues. GSI membership, currently standing at 17, has fluctuated from 12 to 24 members since it's' inception in 2013. The early withdrawal of major Norwegian multi-nationals Leroy and SalMar was a notable set-back, though both companies remain committed to ASC certification. More challenging to wider reputational benefit could be free-riding effects of (smaller) companies lacking capacity to become certified and the slower certification rate and a greater de-certification propensity for non-GSI members (18% compared to only 3% of GSI sites).

Strategically, the framing of the GSI mission around improved transparency and progressive improvement' provided a means for industry stakeholders to reassert themselves as sustainability leaders whilst accommodating objectives of the WWF. Thus, GSI is an example of industry re-asserting control to achieve strategic precompetitive objectives. This includes a commitment of the membership to achieve ASC certification of all their farming operations by 2020 and the interim publication of annual 'Sustainability Reports' documenting performance against 14 groups of environmental and social indicators.

The Vietnamese pangasius case study indicates that, unlike the certification commitments of GSI which are industry-led, the initiative to achieve a certain certification rate originated from external bodies, with strong links to the government. In addition, the industry structure is substantially different to the salmon industry, although concentration trends mirroring salmon at similar farming intensity, but at much faster rate associated with marginal profits and scale-economies , more fragmented and with a much higher number of small scale operations, who do not have a direct benefit from certification apart from continued access to the market, which, as the case showed, is not always guaranteed. Moreover, the market segments served by the pangasius industry are low-cost, low-value add, suffering where pangasius products suffer reputational issues. The more fragmented structure of the industry prevents strategic action similar to that exhibited by GSI members, and thus makes the industry less able to be pro-active and instead be re-active with regards to the actions of powerful agents along the value chain.

The strategic lessons than can be learned from these case studies are applicable to emerging initiatives such as the Sustainable Shrimp Partnership (SSP) and companies in industries undergoing the trends of consolidation and concentration, where an important element in the nature of competitive rivalry becomes the, or pre-competitive action aimed at the development of the sector as a whole. The success of adoption of certification schemes is thus dependent to a great extent on the origin of initiative (internal or external) and the associated level of ownership of the members and commitment to success the entire industry, which is much more likely to happen in consolidated sectors dominated by a few large international players, than fragmented industries.

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Appendix 1

Testing Governance of Value Chains: Weak Exogeneity of Prices in the Pangasius Value Chain from Vietnam to Germany

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Testing Governance of Value Chains: Weak Exogeneity of Prices in the Pangasius Value Chain from Vietnam to Germany

Abstract. Global value chain analyses are widely used to analyze the governance of food value chains from developing to developed countries. While this analytical framework contributes to explaining value chain organization and governance modes and to identifying incentive incompatibilities as a basis for upgrading, it does not offer a formal testable empirical foundation for identifying governance. This paper proposes a statistical test of the governance of value chains that is exercised through prices by identifying whether a chain is governed by upstream or downstream companies. Weak exogeneity of cointegrated price series between the different nodes of value chains is tested. The test is applied to frozen pangasius fillets, farmed and processed in Vietnam, exported to Germany and sold to German consumers in retail markets. The results identify weak exogeneity of both German retail prices and Vietnamese farm-gate prices over Vietnamese export prices. Hence, German supermarket chains and Vietnamese farmers both exercise price governance over Vietnamese exporters who are pressed from two sides. The test is suggested as one of several standard elements of global value chain analyses to reveal empirical evidence of price governance.

Key Words: Governance test, weak exogeneity, global value chain analysis, pangasius.
JEL Classification codes: L1, M2, Q1.

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I. Introduction

Over the last decades, food value chains have globalized, and today many start in developing countries and end in developed countries. With this globalization, the selection of goods offered to final consumers mainly by supermarkets has broadened. Supermarkets in developed countries have opportunities to buy from different suppliers in developing countries, without being dependent on a single supply chain. That has affected the governance power of food value chains, by shifting price setting power from upstream companies in developing countries to downstream companies, such as supermarket chains, in developed countries. A main driver for this development has been improved packaging with freezing facilities during transport and the Modified Atmosphere Packaging (MAP) technology combined with cheaper transport globally. Therefore, the importance of consumer preferences has increased in relation to the technological opportunities in determining the range of supplied food products.

This article suggests the test of weak exogeneity of cointegrated price series between different nodes in value chains as a standard part of global value chain analysis to reveal whether prices are governed by upstream or downstream companies. The purpose is to show how the test can be performed by applying it in the case of frozen pangasius fillets, which are farmed and processed in Vietnam, and exported to and sold in supermarkets in Germany. Furthermore, the purpose is to introduce the foundation of this price governance test in cointegration analysis, testing a non-stationary and cointegrated time series of prices for weak exogeneity.

The pangasius value chain from Vietnam to Germany is selected because the production is growing fast, and therefore, the produce cannot be sold to a fixed set of consumers, so new markets must be continuously built. Aquaculture represents 7 % of the annual production growth globally (FAO 2016, average 1990-2014) and Vietnamese pangasius specifically has annual growth of 11% (FAO 2016, average 1990-2014), demonstrating the growth of food value chains in developing countries. Furthermore, in aquaculture, supermarket chains are better placed than fisheries to take control of the value chain because aquaculture can deliver a stable and uniform supply in large quantities to meet the demand of all the shops of the supermarket chains. This is because fisheries supply what weather and quotas allow, such that aquaculture can take consumer preferences into account. The implication is often that price governance is shifted to downstream companies, but also implies higher prices and better terms for farmers than fishermen.

The fact that Vietnam is the dominating global pangasius supplier delivering 95-98 % of global export (FAO 2016; EPA, 2014; Ponte *et al.,* 2014), indicates that Vietnam may be able to exercise price governance, although competition with other white-fishes, in e.g. Germany (Bronnmann *et al.,* 2016), might prove to be a limitation. Vietnamese pangasius is a selected food value chain because this developing country might have a larger chance of exercising price governance compared to most other food value chains. However, it is shown that German supermarket chains govern prices, indicating that even in a value chain with one developing country dominating global supply, supermarket chains in the developed country govern prices. It is further shown that to some extent Vietnamese farmers also govern export prices.

Global value chain analyses for food produced in developing countries, and in particular for Vietnamese pangasius, are important because developing countries can gain welfare from well-functioning value chains through increased productivity of companies in each node, and through improved organization and coordination between the nodes that provide knowledge on how to increase the efficiency of the chains. Furthermore, global value chain analysis is important to identify incentive incompatibilities and barriers for innovating value chains as a basis for chain upgrading. This paper suggests a method for improving the empirical foundation of global value chain analysis by testing for upstream or downstream price governance.

The horizontal organization of the pangasius value chain from Vietnam to Germany might be characterized as competitive, with competition between farmers, between exporters and between supermarket chains, at least in different developed buyer countries and with the absence of pronounced vertical integration. However, given that all industries in Vietnam were previously state owned (Hakkala and Kokko,2007), the level of competition might not be perfect. The development of international trade in aquaculture products coincides with the transformation of the Vietnamese society since 1986, where market-driven incentives were introduced (Marsh and MacAulay, 2002). In a value chain where the level of competition is not perfectly known, which is the case in several food value chains starting in developing countries, testing whether prices are governed upstream or downstream is valuable knowledge to reveal the nodes that govern price through price leadership. With this knowledge, potential limitation in competition is indicated to the price governing node, although other indicators are needed for confirmation. This knowledge is important to manage competition problems and upgrade the chain. We argue that price transmission analysis adds a more objective measure to the so far primarily qualitative methods used in global value chain analysis to identify lead firms.

The paper is organized as follows. After this introduction, a literature review of global value chain analyses in general and on governance in particular is provided in section two. In section three, the methodological basis for the test of upstream or downstream price governance is presented, and the case of the pangasius value chain from Vietnam to Germany is described statistically in the data section in section four. Section five provides and discusses results, while conclusions are drawn in section six.

II. Literature Review of Global Value Chain Analysis

The term global value chain analysis emerged in the last decade of the 20th century, mainly triggered by the publications of Gereffi and Korzeniewicz (Gereffi, 1996, 1999; Gereffi and Korzeniewicz, 1994) and by Humphrey and Schmitz (Humphrey and Schmitz, 2002a, 2002b). The first publications on global (value) chain analysis (Gereffi and Korzeniewicz, 1994) have been particularly received as a tool to describe and systematize structures and processes in specific, international value chains and to comprehend their complexity by focusing on a few descriptive categories of governance mechanisms. Governance is defined by Gereffi (1994: 97) as "authority and power relationships that determine how financial, material and human resources are allocated and flow within a chain." The governance structures proposed for global value chains are markets and hierarchies, notions established by Williamson (1979), in addition to three particular hybrid forms, namely, modular, relational and network structures, that use both market- and hierarchy-like coordination mechanisms to different degrees (Gereffi and Lee, 2012).

The related categories and concepts have been continuously refined and extended, not only by the seminal authors (Gereffi, Humphrey and Sturgeon, 2005) but also by other researchers, most with a background in development studies. Examples include Gibbon, Bair and Ponte, 2008; Giuliani, Pietrobelli and Rabellotti, 2005; Ponte and Gibbon, 2005; Ponte *et al.,* 2014, and Ponte and Sturgeon,

2014. These developments have contributed to stronger theoretical foundations and a broader set of analytical tools. A focus of recent research on GVCs has been on the impact of standards (Lee, Gereffi and Beauvais, 2012; Ponte and Gibbon, 2005) and more specifically on food chains. These studies have found that smallholders' opportunities for upgrading are considerably narrowed by private quality and safety standards. Other studies on retailers' use of quality standards, which take a more formal approach (von Schlippenbach and Teichmann, 2012), have revealed the strategic usability of standards to exert power and extract rents from dependent suppliers, as well. "Bottom-up" (Gereffi and Lee, 2012) attempts by suppliers or even governments of exporting countries to upgrade their value chains and thereby extract higher rents corresponding to higher efforts are leveled out by "top down" governance through standardization.

GVC analyses rely on a methodological mix with a strong focus on qualitative data acquired through interviews, often focusing on the case of one lead firm. At the same time, the goal still is to derive insights into a specific sector in a particular country or region, such as shrimp from Bangladesh (Islam, 2008; Uddin, 2009) or Vietnam (Tran *et al.,* 2013), jeans from Torreon (Mexico; Bair and Gereffi, 2001) or numerous other product categories and countries.

In the following, we propose an empirical model that allows for an objective identification of value chain nodes able to exert price leadership and thus a form of governance.

III. Model

To develop an empirical model specification to test market integration and price leadership between actors in the value chain of pangasius, we start with the traditional price relationship expressed in logarithm to test whether the law of one price (LOP) holds:

$$lnp_t^1 = a + \beta lnp_t^2 + \varepsilon_t \qquad (1)$$

where p_t^i is the price of product *i* at time *t* and the parameter a is a constant term that reflects transportation costs and quality differences between product 1 and 2. The error term ε_t is assumed to be white noise. The parameter β determines the long-run relationship between the prices. If $\beta = 0$, there is no relationship between the price series, while $\beta = 1$ indicates that the LOP holds and there is complete market integration. In case of $\beta \neq 1$ or $\beta \neq 0$ the commodities are imperfect substitutes. Introducing lags into equation 1 accounts for dynamic adjustment pattern (Ravallion, 1986). However, in the case of a non-stationary price series, the results of the econometric analysis are spurious and the log- run relationships can be examined using co-integration (Engel and Granger, 1987).

Whether a time series is stationary is investigated using a unit root test. The unit root test tests the null hypothesis of a unit root against an alternative of stationarity, or mean reversion. If the unit root null hypothesis is rejected, then the series is said to be stationary. The Augmented Dickey Fuller (ADF) test of Dickey and Fuller (1979; 1981) is used here to determine the order of differencing to achieve stationarity and is measured from the following regression:

$$p_t = \pi + \tau T + \sigma p_{it-1} + \sum_{\gamma=1}^{k} \alpha_\gamma \Delta p_{t-\gamma} + \varepsilon_t \qquad (2)$$

where Δ is the difference operator and *T* is a time trend. According to Gordon (1995) and Asche *et al.* (2002) the lag length k is set to achieve white noise in the error term. The null hypothesis that the price series are nonstationary is based on the ratio of σ to its standard error. Testing $\sigma = 0$ is equivalent to testing that p follows a unit root process. Equation 2 may be estimated by restricting both the drift ($\pi = 0$) and trend (τ) terms or only the trend term. The t-statistic from the σ is then compared to the appropriate Dickey-Fuller critical values.

The next step is to determine whether the series having unit root are co-integrated. Co-integration between two time series integrated of the same order can be tested by the Johansen (1988) co-integration test. The vector error correction (VEC) representation of the Johansen (1988) co-integration test is given by

$$\Delta p_t = \sum_{i=1}^{k-1} \delta_i \, \Delta p_{t-i} + \Pi p_{t-1} + \mu + \varepsilon_t \tag{3}$$

where Δp_t contains a vector of I(0) vector of n price series. The parameter μ is the deterministic components composed of the constant, trend and seasonality, δ_i is the short run parameter estimates. The long-run relationship (i.e. the cointegration vector) is captured by the matrix Π.

A cointegration relationship exists if the matrix Π has a reduced rank (r): $0 < r < n$, so that it can be expressed as $\Pi = \alpha\beta'$ where $\beta' p_t$ is stationary. The rank of the matrix Π is tested with modified chi-square tests called the trace and maximum eigenvalue statistics (Johansen, 1988). If $rank(\Pi) = 0$, then no co-integration relationship exists and if $rank(\Pi) = \mathrm{n}$, then there is full rank – indicating that all the price series are stationary. As we conduct a bivariate test, the rank of Π is expected to be 1. The number of k lags selected into equation 3 is based on one that addresses the first moment dependence in the data.

The β matrix contains the co-integrating vectors that define the long-run relationships of the vector of price series, p_t. The LOP is tested in this setting. The parameter α represents the speed with which prices adjust to the equilibrium following disequilibrium. It is used to test for weak exogeneity ($\alpha = 0$) of the respective price vectors. According to Engle and Granger (1987), the existence of a co-integrating relationship between two variables implies that causality exists in at least one direction, hence one of the α's should be different from zero.

A weakly exogenous variable indicates that the variable does not adjust and is used to indicate market leadership. In the current setting of the value chain governance, we illustrate that the leading market governs the value chain. Hence we test for governance along each node of the pangasius value chain from the Vietnamese producers to the German consumers/retailers.

IV. Pangasius Industry and Data Collection

Pangasius catfish *(Pangasius hypophthalmus)* is one of the fastest growing aquaculture species globally (FAO, 2010), with annual production of over 1 million tonnes (FishStatJ, 2014). Vietnam is the major producer, representing more than 75% of the global production. Pangasius catfish is raised popularly in freshwater bodies in the Mekong Delta, along the Mekong River. Previously, the fish were raised in cages and pens. Since Vietnam began to experience globalization, Vietnamese farmers have farmed pangasius in ponds with pellet feeds, yielding a very high productivity of up to 500 tonnes/ha. In 2012, the total pangasius farming area of Vietnam was 3.586 ha, of which households account for

48.7%, farming companies for 49.1% and farmer collectives for only 2.1% (Tung *et al.,* 2014). Recently, the farming area has increased significantly, peaking in 2015 at 5.900 ha (Mard, 2016). However, the farming area owned by households has diminished dramatically, and farming companies currently account for approximately 80% of the total farming area in the delta.

In 2015, Vietnam produced nearly 1.12 million tonnes of pangasius, and over 97% of the production was used as raw materials for over 140 processing plants (EPA, 2014; VASEP, 2016). Most processed products are used for export, and Vietnam represents over 95% of the global export value of pangasius (EPA, 2014), with an export value in 2015 of $1.55 billion. The United States and the EU are the two largest export markets of pangasius, accounting for approximately 65% of the total export volume. EU countries have become increasingly important importers for pangasius, with annual growth of approximately 10% (VASEP, 2014).

Pangasius products are exported mostly as frozen fillets, accounting for 98% of the total export values (EPA, 2014). Spain, the Netherlands, the UK and Germany are the major retail markets in the EU. In the period of 2007–2012, Germany imported approximately 2,355 tonnes of pangasius fillets per month (Table 1). Pangasius frozen fillets are sold in the most popular retailers in Germany such as Aldi, Schwarz Group (Lidl) and Edeka. Pangasius has the advantage of low price, and the taste is comparable to other white fishes such as cod or haddock.

[Table 1. Summary statistics of prices and quantity exported to Germany, monthly average 2007-2012]

For this study, four different sources of data are used. The farming data were collected in Vietnam from the Vietnamese Association of Seafood Exporters and Producers (VASEP). VASEP obtains quantity and prices of pangasius products supplied by farmers to processors per month in different locations. The farming price used in this study is the monthly average farm-gate price of pangasius in the Mekong Delta over the period of 2007–2012.

Monthly export data for Vietnamese pangasius are available from the website of the International Trade Center (www.trademap.org), WTO. Recently, pangasius products, i.e., frozen fillet, have been classified by two separate codes: HS030429 (frozen fish fillets) for the period 2007–2012 and HS030462 (frozen fillets, pangasius species) after 2012. Although the product code HS030429 applied to all types of frozen fish fillets, cross checking the data prior to 2012 revealed that more than 95% of frozen fish fillets exported from Vietnam were pangasius (the rest were other fishes such as tilapia and carp). The monthly data on exported value ($) and quantity (kg) distributed to import countries were obtained, and the average export price was calculated for the period 2007–2012. All prices were converted to euros, and the analysis was conducted using nominal values (EUR) per kilogram.

The retail data consist of two proprietary sets of data. In both datasets, the European Article Number (EAN) Code identifies each item. The first dataset was obtained from the Consumer Scan of the GfK Panel Service Germany for the year 2007. In this dataset, households record the total expenditure (EUR) on and volume purchased of a specific EAN in one purchase trip. From this, the price per unit is calculated. The second proprietary dataset consists of scanned sales data (SymphonyIRIGroup 2012) containing sales data from the 1st week of 2008 to the 52nd week of 2012.

In this dataset, each observation consists of the scanned EAN, the paid price (EUR) and the number of bought units. For our analyses, we focus on price series for frozen natural pangasius fillet.

All prices are converted to EUR/kg and are aggregated to monthly averages. Figure 1 shows the price movements of the three different price series.

[Figure 1. Price series along the supply chain for pangasius]

The Vietnamese producer and export prices are much lower than the retail prices in the German market. On average, retail prices are twice as high as the producer prices of pangasius. The export and retail prices appear to show a decreasing trend, while the producer price shows an upward trend. Except for the producer price, which shows significant variation in early 2011, prices are generally stable in all periods. Causality between prices cannot be identified through the price patterns in Figure 1. This must be analysed during the estimation procedure.

V. Results

As the test for co-integration depends on the time series properties of the data, we first conduct the ADF test to ensure that all prices are integrated of the same order. The ADF test results are shown in Table 2. Two specifications of the ADF test are used. The first specification includes only the intercept (constant), while the second contains a deterministic trend in addition to the intercept. The tests are conducted on both levels and first differences of the logarithm of the price series. Optimum lag lengths for each price series are chosen to be two lags, based on the Akaike Information Criteria (AIC).

[Table 2. T-Statistic for ADF test of stationarity]

Comparing the ADF t-statistic in Table 2 to the appropriate Dickey-Fuller critical values at the 5% level of significance, we cannot reject the null hypothesis that three prices in levels have unit roots in both specifications. That of the first difference is rejected at the 5% significance level. The results of the ADF tests on the first differences of the prices provide sufficient support that the three prices are stationary. We conclude that the pangasius prices along the value chain are integrated of the first order; I(1), hence providing the precondition for the co-integration test.

The co-integration-based test of market integration is used to uncover causality among prices along the value chain that are not visible in Figure 1. One may run a multivariate or bivariate Johansen (1988) test to reveal the rank co-integration. If the three prices share a common stochastic trend, it must be that all prices in the system are pairwise co-integrated (Asche *et al.,* 1999). However, three bivariate tests are carried out first, and we found that only two paired prices are co-integrated, and therefore the multivariate test is not necessary. The bivariate tests are carried out with the optimal lag chosen based on the AIC statistic. The results are presented in Table 3.

[Table 3. Bivariate Johansen tests for rank co-integration]

Johansen (1988) suggests two statistics for the number ranks of the cointegration vectors in the system; these are the maximum eigenvalue and the trace value. At the 5% significance level, trace and maximum eigenvalue statistics reject the null of zero rank (i.e., no cointegration) between export and farm prices and between export and retail prices. However, the null of no cointegration between the farm and retail prices fails to be rejected. At the rank of one indicating the existence of a cointegration relationship, the eigenvalue and trace statistics fail to be rejected for the farm and export prices as well as for the export and retail prices. As the test for full rank (rank=2) also fails to be rejected, we conclude that a cointegration relationship exists between the farm and export prices and the export and retail prices. However, we are unable to uncover a relationship between the farm and retail ends of the value chain.

Having established cointegration relationships, we test for the LOP to uncover the degree of price transmission between the two bivariate links. If markets are integrated but the LOP is rejected, the markets are said to be partially integrated (Nielsen *et al.,* 2009) or price transmission incomplete. The results of tests for the LOP are presented in Table 4. At the 5% significance level, we reject the hypothesis that the LOP exists between all paired markets. The results indicate a partial integration or incomplete pass-through of price changes between farm and export and between retail and export markets.

[Table 4. Test for the Law of One Price and Weak Exogeneity in Bivariate models]

To identify the directions of causality and magnitude/speed of adjustment between the prices, the vector error correction model estimation is presented in Table 5.

[Table 5. Vector error correction and cointegration estimation]

In Table 5, the parameter α represents the speed of the adjustment parameter. The parameter is significant for the export price equation in model 1 but not for the farm price (a likelihood ratio test of the adjustment parameters is also presented in Table 5, the weak exogeneity test). In model 2, the speed of adjustment parameters is significant for the export equation but not for the retail equation. This implies that the export prices do adjust to the farm/producer prices, hence the farm price is weakly exogenous to the export price. Additionally, the retail price is weakly exogenous to the export prices. The Vietnamese producer and German retail prices are therefore acting as the market leaders to the exporter along the pangasius value chain. It further reveals that exporters adjust faster ($\alpha_2 = -0.390$) to retail price changes than to producer price changes ($\alpha_1 = -0.261$) following a shock. The cointegration links identified in the value chain reflect the fact that over 90% of pangasius production is exported; therefore the price transmission between farmers and retailers is via the exporters. Finally, we examine the robustness of the model fit. Tests for misspecification conducted include normality, autocorrelation (AR), and autoregressive conditional heteroscedasticity (ARCH). These tests are presented in the bottom of Table 5.

Normality is only rejected at the 5% significance level in the retail equation for Model 2. Autocorrelation and ARCH effects are absent indicating that the model is well fitted to the data.

In summary, the identification of market integration in the value chain in this study follows the flow of pangasius commodities along the nodes of the chain. Price transmission is identified to be incomplete. Market leadership or governance in the chain occurs at the two extreme nodes, namely, the producers and the retailers, with exporters adjusting faster to the downstream price changes than to the upstream price changes.

VI. Conclusions

In this article, the weak exogeneity test of cointegrated time series of prices between different nodes in value chains has been suggested for testing upstream or downstream price governance, thereby providing empirical evidence as a basis for global value chain analyses. The cointegration methodology is introduced, fitted to global value chain analysis and applied to the case of pangasius to demonstrate how it works empirically. In the pangasius value chain starting in Vietnam and ending in Germany, it is shown that German retail chains govern export prices from Vietnam, as German retail prices are weakly exogenous to Vietnamese export prices. It is further shown that to some extent, Vietnamese farmers also govern the prices of exporters.

This result indicates that Vietnamese exporters are squeezed between farmers and strong German retail chains. Hence, the retail chains in the developed country, Germany, govern the export price in the developing country, Vietnam. Even in the case of pangasius frozen fillets, where Vietnam is the major global supplier, the retail chains in the developed country govern prices, which may be due to the low reputation still a result of the low reputation of the product (Bush & Dujif, 2011; Little et al., 2012). Simultaneously, farm-gate prices govern Vietnamese export prices. While the reasons for this remain speculation, it might be due to the fragmented organization of exporters (VASEP, 2015). Here, the importance of other methods from the portfolio of global value chain analysis becomes apparent for the detailed identification of reasons for the exporters' weaker price position vis-à-vis both retailers and farmers. Belton et al. (2011) provide a network perspective on Vietnamese pangasius production and claim that larger operators might be endowed with superior networks. Such insights can only be gathered from key informant interviews, and it is likely that the small number of cases prohibits more quantitative approaches to gain more objective indicators. However, this finding might indicate successful upgrading attempts of those farmers that actively participate in the global value chain between Vietnam and Germany. If they have achieved a superior level of sustainability in production and thus successfully differentiated themselves from other producers, they may be able to extract higher rents. Exporters then are squeezed between retailers, who only buy the upgraded pangasius, and the farmers, who have multiple options to market their fish, including local markets and neighboring countries (VASEP, 2015).

To the extent that this result can be generalized to other food value chains from developing countries, supermarket chains in developed countries seem to govern the prices downstream, leaving exporters in developing countries in a position where they can only accept prices. They must also fulfill other demands, such as delivering large lots, and adhering to protocols for producer responsibility, environmental protection and other corporate and social responsibilities, which the consumers in developed countries might demand.

The position of Vietnam as the largest global exporter country of pangasius with its exporters fragmented in organization also proposes the option of increased horizontal cooperation in the Vietnamese pangasius exporter node. Through such cooperation, the node may become able to match the price leadership role in relation to supermarket chains in Germany and other developed countries, on one hand, and Vietnamese pangasius farmers, on the other.

Global value chain analysis has gained widespread recognition as a framework for identifying upgrading options of global value chains, not least in food value chains from developing countries. Issues such as explaining value chain organization and governance modes and identifying incentive incompatibilities as a basis for value chain upgrading have been investigated. While the global value chain approach is well founded theoretically and studies of real-world cases are statistically based, the methodology lacks a testable empirical foundation to be used among more standard elements for analyzing governance. This article suggests testing for price governance using weak exogeneity tests. Other elements of governance in addition to prices remain for future study. Testing the efficiency of value chains can also improve the empirical foundation of global value chain analysis, but this too remains a field for future study (e.g., combining knowledge of profit allocation in the value chain with price transmission tests between nodes).

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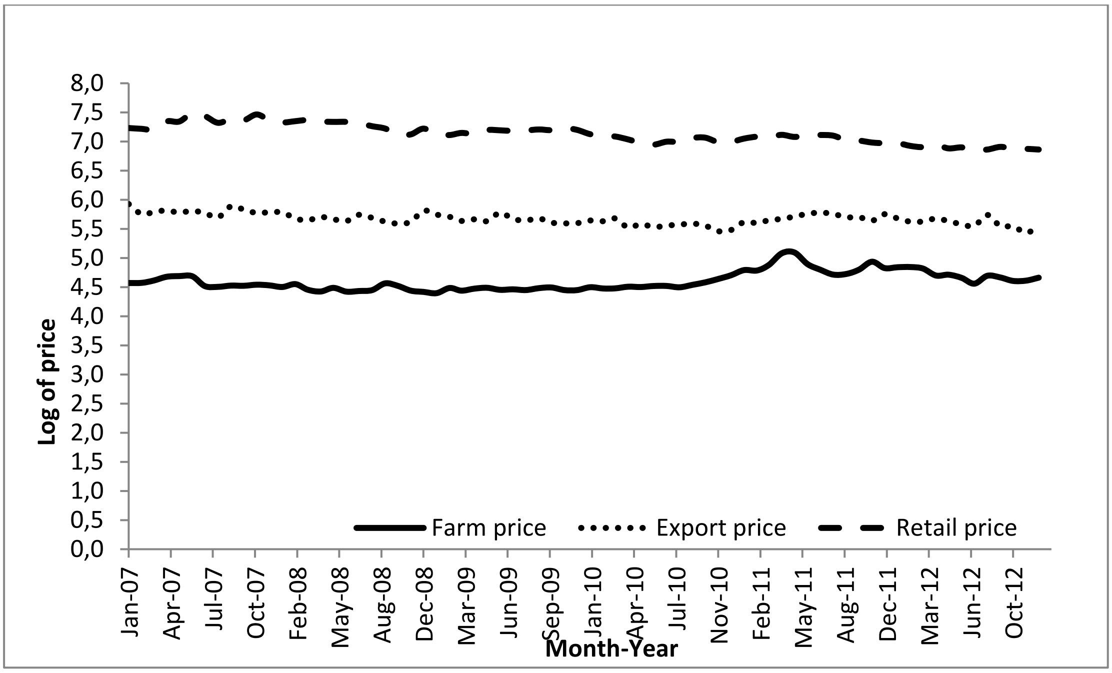

Fig. 1. Price series along the supply chain for pangasius

Table 1. Summary statistics of prices and quantity exported to Germany, monthly average 2007-2012

	Mean	Std. Dev.	Min	Max
Farm price (€/kg)	0.74	0.14	0.53	1.13
Export price (€/kg)	2.03	0.22	1.64	2.76
Germany's retail price (€/kg)	9.19	1.25	7.24	13.14
Export to Germany (tonnes/month)	2,355	764	1,030	4,268

Source: VASEP, Trademap, SymphonyIRIGroup

Table 2. T-Statistic for ADF test of stationarity

	Intercept Only	Intercept and Trend
***Log of farm price* (lags 2)**		
Level	-1.651	-2.226
1st Difference	-5.185**	-5.155**
***Log of export price* (lags 2)**		
Level	-2.143	-2.734
1st Difference	-7.410**	-7.351**
***Log of retail price* (lags 2)**		
Level	-0.506	-3.888*
1st Difference	-5.256**	-5.206**

[a)] *Critical values at 1%, 5% & 10% are -3.551, -2.913 & -2.592, respectively*

[b)] *Critical values at 1%, 5% & 10% are -4.104, -3.479 & -3.167, respectively*

*&** *significant at the 5% level and the 1% level, respectively*

Table 3. Bivariate Johansen tests for rank co-integration

Rank	eigenvalue	λ_{trace}	$CV_{(trace, 5\%)}$	$CV_{(trace, 1\%)}$	λ_{max}	$CV_{(max,5\%)}$	$CV_{(max, 1\%)}$
Export and Farm (lags=1, constant)							
r=0		20.36^{**}	15.41	20.04	16.92^{*}	14.07	18.63
r<=1	0.21	3.44	3.76	6.65	3.43	3.76	6.65
r<=2	0.05						
Export and Retail (lags=1, constant)							
r=0		25.59^{**}	15.41	20.04	24.83^{**}	14.07	18.63
r<=1	0.30	0.76	3.76	6.65	0.76	3.76	6.65
r<=2	0.01						
Farm and Retail (lags=10, constant)							
r=0		6.50	15.41	20.04	5.71	14.07	18.63
r<=1	0.08	0.79	3.76	6.65	0.79	3.76	6.65
r<=2	0.01						

** & * *significant at 1% and 5% level, respectively*

Table 4. Test for Law of One Price and Weak Exogeneity in Bivariate models

	LOP (χ2)	Weak exogeneity	
		First	Second
Farm-Export	9.83 (p<0.0017)	**0.16 (p=0.689)**	12.52 (p<0.001)
Retail-Export	17.62 (p=0.0001)	**0.98 (p=0.322)**	20.62 (p<0.001)
Retail-Farm	4.55 (p=0.0329)	0.00 (p=0.969)	4.89 (p=0.027)

Table 5. Vector error correction and cointegration estimation [a]

	Model 1 Export-Farm		Model 2 Export-Retail	
	Coef.	Std.Err.	Coef.	Std.Err.
α_1 (adjustment)-export price	-0.261**	0.096	-0.390**	0.124
α_2 (adjustment)	-0.108	0.096	0.031	0.094
γ_1 (constant)	-0.001	0.008	0.000	0.008
γ_2 (constant)	0.003	0.008	-0.006	0.006
δ_{11}	-0.213*	0.117	-0.163	0.124
δ_{12}	-0.130	0.123	-0.012	0.166
δ_{21}	0.059	0.117	0.042	0.094
δ_{22}	0.075	0.123	-0.152	0.126
Cointegrating parameter				
β_1 (Normalized)	1.000	.	1.000	.
β_2	-0.035	0.184	-0.337**	0.116
μ (constant)	-5.495	.	-3.252	.
Model fit statistics	***χ2***	***p-value***	***χ2***	***p-value***
Normality-(eq.1)	4.65	0.10	3.10*	0.04
Normality-(eq.2)	3.52	0.17	3.099	0.212
AR(1/7)-(eq.1)	4.45	0.73	4.099	0.768
AR(1/7)-(eq.2)	6.86	0.44	5.510	0.598
ARCH(1)-(eq.1)	0.20	0.65	0.472	0.4921
ARCH(1)-(eq.2)	0.02	0.90	0.714	0.3981
AIC	-4.92		-5.65	

*[a] Difference in log of prices are used & the export is endogenous variable; ** & * significant at 1% and 5% level, respectively.*