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Path dependency, institutionalization and co-evolution: The missing diffusion of the blue revolution in Norwegian aquaculture

Bernt Aarset [a], Stig-Erik Jakobsen [b, *]

[a] School of Economics and Business, Norwegian University of Life Sciences, P.O. Box 5003, NO-1432 Aas, Norway
[b] Bergen University College, P.O. Box 7035, NO-5020 Bergen, Norway

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ABSTRACT

Scholars taking the evolutionary perspective argue that technologies, competence and institutions of successful paths may spill over to related industry initiatives and subsequent industry paths. The notion of co-evolution has been introduced as an analytical category for such interconnectivity. In this article, we investigate the development of salmon farming in Norway as a successful industry path and its linkages with cod farming, a subsequent emerging industry path. In the public debate, there has been an expectation that knowledge and solutions from salmon farming will diffuse to aquaculture for other species. However, this diffusion appears to be missing. Cod farming is an area that should capitalize on the success of salmon aquaculture, and we investigate why cod farmers appear to be unable to utilize the experience and knowledge of salmon farmers and copy their solutions. We found that the development of a specialized institutional arrangement for salmon farming makes these models incompatible with the needs of farming of other species, resulting in limited co-evolution between subsequent aquaculture industry paths. Thus, a situation characterized by strong co-evolution *within* an industry path, facilitating the development of an institutional arrangement tailor-made for the firms of the industry, reduce the possibilities for co-evolution *between* related industry paths.

1. Introduction and research question

Salmon aquaculture is an important part of the Norwegian seafood complex. This complex consists of fish farmers and fishing vessels, processing firms, technology suppliers, sales firms, research institutions, investors, supporting institutions and a regulatory framework. Firms and organizations are often operating within several segments of this seafood complex. The narrative of the Norwegian blue revolution created an expectation that accumulated aquaculture knowledge and solutions from salmon farming would diffuse to other parts of the seafood complex, and contribute to the development of a range of profitable aquaculture species (Report to the Storting, 2004–05). However, this diffusion appears to be missing, or is, at best, relatively restricted. Despite optimistic plans and strategies, the production of other aquaculture species has been modest (Directorate of Fisheries, 2013a, Directorate of Fisheries, 2014). In this study, we demonstrate how salmon farming successfully has utilized available resources, while related aquaculture initiatives, exemplified by cod farming, have failed.

Inspired by the evolutionary perspective and path-dependence theory, we investigate the development of salmon farming in Norway as an industry path, emphasizing the development of its institutional arrangements (Boschma and Martin, 2010). Historical junctures have permitted particular trajectories, which again have provided an institutional framework for the salmon farmers. First, we identify crucial junctures, and demonstrate how a strong industry path has been developed through self-reinforcing processes and institutionalization (Martin and Sunley, 2006; Frenken and Boschma, 2007). Second, we elaborate on the linkages between salmon aquaculture and cod farming, a related aquaculture initiative. Scholars taking the evolutionary perspective argue that technologies, competence and solutions from successful paths may spill over to related industry initiatives and subsequent industry paths (Martin, 2010).

We introduce the notion of co-evolution as an analytical category for understanding connectivity between related subsystems. The literature differentiate between co-evolution within an industry path (e.g. between the firms' subsystem and the institutional

* Corresponding author.
E-mail addresses: bernt.aarset@umb.no (B. Aarset), sjak@hib.no (S.-E. Jakobsen).

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subsystem) and co-evolution between industry paths (Schamp, 2010). Despite the popularity of the concept, there is a lack of literature on the main mechanism by which such co-evolution occurs or not, and how co-evolution is linked to institutional conditions (Murmann, 2013). Our point of departure is the observation that cod farming does not seem to learn from the experience and knowledge of salmon farmers, and we want to identify mechanisms that seems to prevent co-evolution between a hegemonic path and a related subsequent industry path. In relation to this, we also want to investigate how co-evolution within an industry path, i.e. between the firms and the institutional framework in salmon farming, influence on the occurrence of co-evolution between subsequent industry paths. The evolutionary perspective is lacking a "*… detailed account of how these co-evolution processes take place*" (Murmann, 2013: 1). We need to know what is co-evolving with what and why a situation of potential co-evolution between industry paths is not being materialized (Schamp, 2010). Thus, our article contributes to a more nuanced understanding of the different dimensions of co-evolution and its significance for industry development. In light of this, the article will focus on the connectivity between salmon and cod farming, and investigate three areas of potential connectivity; production technology, sales regulation and R&D organization.

Cod is an important wild-fish species in Norway, and there is an established infrastructure for catching, processing and marketing the fish. There are also available solutions to resolve the technical and biological challenges of cod farming. Cod farming and salmon farming are both part of the Norwegian seafood complex and have several similarities when it comes to technology, knowledge and research needed in the production and marketing of the product. Many of the actors have operated within both segments (Aarset, 1999). Thus, they are related industries, and cod farmers have the opportunity to capitalize on the proven successes of salmon aquaculture. Nevertheless, we have witnessed a lack of co-evolution between salmon and cod aquaculture, and the latter has not prospered as an industry path. One obvious explanation for this lack of co-evolution is the difference in market conditions, in various ways formed by the relation between the farmed cod and salmon and their wild caught counterparts. An important 'take-off' factor for farmed salmon in Norway during the 1970s was the price premium gained because wild salmon was a high-priced product. As an emerging path with an immature technological set-up, the salmon farming pioneers experienced high production costs. During the 1980s, the real prices for farmed salmon decreased due to rising production volume, but farmers learned from trial and errors and were able to reduce their production cost correspondingly and still make a profit (Jakobsen, 1999). For the first cod farmers the situation was opposite. While the price premium of the wild salmon market fueled the initial technology development of salmon farming, the price of farmed cod was destined to follow the more modest price level of wild cod and related white-fish products. Cod farmers tried in vain to achieve a price premium for the farmed cod product, but they have failed to make profit due to relatively high capture volumes and low market prices in the wild fish sector.

In this article, we want to move beyond the differences of the market as the sole explanatory factor, and discuss the specific solutions and institutions that characterize the two industry paths. We believe that a focus on institutional factors will provide us with additional insight into the missing diffusion of the blue revolution in Norway. We understand institutions as the shared routines, practices and values developed within a system and formal institutions influencing the practice of economic actors (i.e. policy regulations) (Martin, 2010). In the article, we elaborate on the following research question: how does institutional factors influence on cod farmers' abilities to extract useful solutions from the experience and knowledge of the salmon farmers? Moreover, we also have to keep in mind that the biological differences between salmon and cod will influence learning between the industry paths. These differences are especially important when it comes to the attempts to copy production technology. The hatched salmon fry, for example, is relatively big and robust and can feed on industrially processed fodder directly. The newly hatched cod fry are very small, and a higher level of skill and technological competence is necessary to process adequate fodder and feed the fry.

We start by presenting contextual information about salmon and cod as species and as targets for aquaculture (Section 2), followed by our theoretical framework (Section 3), and a run-through of material and methods (Section 4). In the empirical part of the paper, we outline the development of salmon aquaculture as an industry path (Section 5), before we discuss interconnectivity between cod and salmon farming (Section 6). The final section links our empirical observations to the theoretical discussion (Section 7).

2. Salmon and cod as farmed and wild species

Salmon and cod are the main species in the Norwegian seafood sector – salmon as a farmed species, but also as a target species in a very limited professional and a recreational fishery – cod as a main target species in the marine fisheries, but also as a species of a limited farm endeavor (see Figs. 1 and 2). Institutions regulate human behavior, such as the behavior of farmers and firms involved in aquaculture. To identify the evolutionary traits of the institutions that regulate behavior in salmon farming and how they fit – or do not fit – with the requirements of the cod farmers, some biological and historical information will be accounted for here.

The Atlantic salmon, the most common species in salmon farming globally, is an anadromous fish that spawns in fresh water. The egg and the larva are relatively large (small fry 2–3 cm). In the wild, the juveniles stay in the stream for two to six years, until their physiology transforms, and as a smolt (between 10 and 20 cm long), it is ready for departure to the sea. The salmon stays at sea until it reaches sexual maturity and then returns to the river. The salmon is carnivorous and thus adapted to an entirely animal-based diet.

Atlantic salmon farming consists of three stages; the breeding/hatching stage, the production of smolt, and the grow-out stage (Skagemo et al., 2014). Downstream the value chain follows slaughter, processing and packing, transportation, export and trade. The main grow-out technology is open net pens, a relatively simple set-up where the surrounding water flows in and out of the pens. The structure of the firms and the scope of the subsidiaries have developed continuously for four decades, and vertical and horizontal integration is common. In Norway, the number of farm licenses has been around one thousand since the 1990s (Directorate of Fisheries 2013a), but ownership concentration is rising, and the number of firms is reduced from 259 in 2001 to 130 in 2011. In 2011, the 11 largest firms controlled 54% of the total stock of Norwegian salmon (Statistics Norway, 2012). Due to persistent growth, the yearly production of farmed salmon in Norway reached 1.2 million tons in 2013, with a first-hand value of 4.7 billion EUR (Statistics Norway, 2014).

Historically, wild capture of salmon is conducted either by various trapping technologies in the fjords and river mouths, or as a recreational fishery in the rivers. The fishery has had regional value in combination with other sources of income, but in economic terms, the fishery is negligible compared to the salmon farming industry (Fig. 1). The following two aspects have particular importance for our study. First, in the industry's infancy, up to the early 1980s, the high-end luxury market purchased farmed salmon

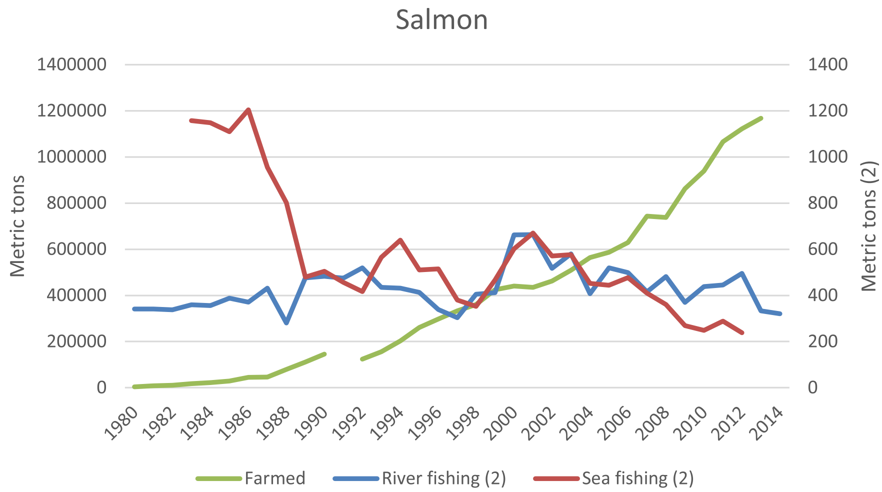

Fig. 1. Farmed and captured salmon, 1980–2014. Source: (Directorate of Fisheries, 2013b, Statistics Norway, 2013; Statistics Norway 2015a,b).

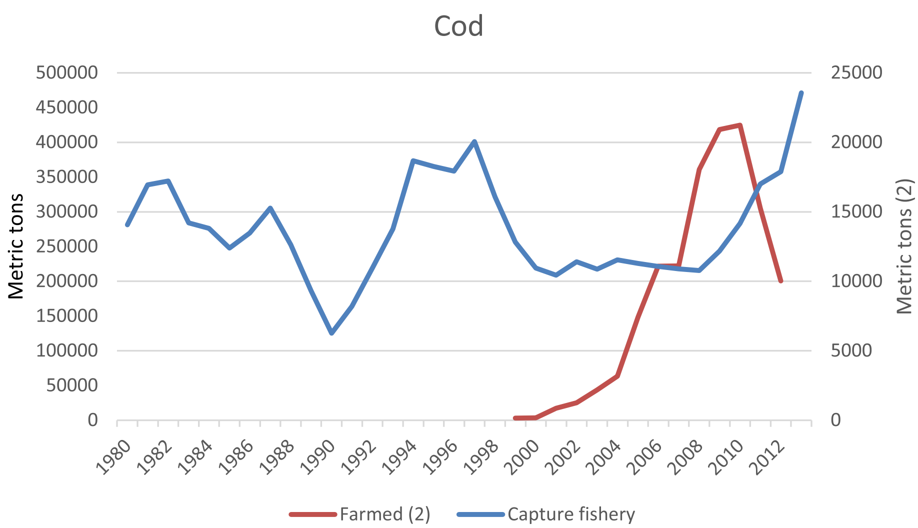

Fig. 2. Farmed and captured cod, 1980–2012. Source: (Directorate of Fisheries, 2013b, Statistics Norway, 2013; Statistics Norway, 2015a,b).

to prices created and maintained by the capture sector, which enabled the farmers to gain experience and still make money (Aarset, 1998). Second, the rising opposition to the salmon industry is concerned with the well-being of the remaining wild salmon stock due to the salmon farmers' battle with a growing salmon lice infestation, and the problems of escapements and admixture of farmed and wild salmon stocks.

The spawning stock of the northeast Arctic cod has increased from 240,000 tons in 2000 to 1,365,000 tons in 2010 (Statistics Norway, 2013). The cod is managed as a shared stock between Russia and Norway (Hønneland, 2007). In late winter, the northeast Arctic cod gather to spawn at the northwest coast of Norway. Cod are recruited to the spawning class at the age of seven to eight years (Nakken, 2008), and return annually to the spawning grounds for many seasons. The eggs are tiny and float in the surface layers, and the distribution of the larvae depends on the ocean currents. The cod is carnivorous and depends on the availability of feed animals.

The history of cod farming has been a roller coaster. The general industrial upturn induced optimistic plans and strategies followed by production declines and recession. Despite the modest production volume, cod has been the second most important species in Norwegian aquaculture since its inception in the late 1980s (Statistics Norway, 2014), a period marked by strong growth in salmon aquaculture. The production peaked in 2009 at 20,924 tons measured by sales of slaughtered farmed cod (Statistics Norway, 2013), which was less than 10% of the wild catches (Fig. 2). By 2011, 329 licenses were issued for cod farming (Directorate of Fisheries, 2013a).

Two aspects of the cod biology challenge in particular the potential for learning from salmon farming. First, the size of the egg and the larvae demand a higher level of skill and technology to start-feed the organisms successfully. Second, the big mouth of the adult fish makes cannibalism a production-related problem.

3. Theoretical framework

In light of the evolutionary perspective on industry development, where the industry system is seen as evolving as a consequence of its history (Martin and Sunley, 2006: 399), we investigate the “particularities” of Norwegian salmon farming and cod farming. Recently, the evolutionary perspective and path dependence theory have been rejuvenated and have gained increased importance in studies of firms and industries (Martin and Sunley, 2006; Scott, 2006; Sydow et al., 2009; Boschma and Martin, 2010; Fløysand

and Jakobsen, 2011). A key issue is that "… the emergence of self-reinforcing effects steers a technology, industry or regional economy along one path rather than another" (Martin, 2010: 3). Some of the early research on path dependence theory has been criticized for emphasizing the ideas of rigidity and lock-in, rather than the processes of ongoing evolution within a system (Martin, 2010). Consequently, it is important to underline that the path-dependent development of an industry is an open-ended process and does not imply historical determinism (Liebowitz and Margolis, 1995; David, 2001; Thelen, 2003; Belussi and Sedita, 2009).

In developing our theoretical framework, we build on recent contributions to path dependence theory (Boschma and Martin, 2010). We begin by defining an industry path. There is a wide array of definitions in the literature (see, for instance, David (1986), Arthur (1989), and Garud and Karnøe (2001)), and the notion has been employed in analyses of industry development, technological system formation and the evolution of political institutions (North, 1990; Thelen, 2003; Pierson, 2004; Boschma and Frenken, 2006; Vergne and Durand, 2010). We adopt the definition of Sydow et al. (2012: 159) of a path as a course of interrelated events "… in which one of the available technological, institutional or organizational options gains momentum in time-space." Hence, a path is triggered by a certain event and driven ahead by specific self-reinforcing mechanisms, such as, for example, the introduction of open net pens in Norwegian salmon aquaculture.

In the subsequent process of industry development, after the triggering event, the range of technological options will decrease, but there will also be novelty in the path and new solutions to emerging problems. In salmon aquaculture, for example, there has been comprehensive development of feeding technology and vaccination programs. In addition, there will be changes in the industry population. Some key actors may dominate during the initial phase of industry development, while others may define the market in latter stages (Schneiberg, 2007). Norwegian salmon aquaculture has for instance developed from an industry characterized by local ownership and small firms to a structure dominated by national and global actors (Aarset and Jakobsen, 2009).

The development of an industry path includes the twin processes of continuation and change (Martin, 2010; Jakobsen et al., 2012). The continuation dimension is closely linked to institutionalization; that is, the development of more standardized interaction patterns (routines, norms, values) and formal institutions influencing the way in which economic actors behave (policy regulations). The overall picture is that an industry establish around specific technological solutions, taken-for-granted practices and institutionalized rules.

The concept of co-evolution is introduced to explain how a path change or evolve. Co-evolution refers to the converging processes between different units or subsystems, and concerns how emerging populations or subsystems exist more or less simultaneously and how they are linked through mutual causality in the development process (Sæther et al., 2011; Murmann, 2013). Studies have analyzed co-evolution between technologies and institutions (Van de Ven and Garud, 1994), between firm population and its institutional arrangements (Baum and Singh, 1994; Nelson, 1995) and between different but related industry sectors (Schulz et al., 2006). Thus, we have to differentiate between co-evolution within an industry path (e.g. the firm population and its institutional arrangements) and co-evolution between industry paths (Schamp, 2010).

There is an emerging consensus that firms and institutional arrangements co-evolve (Van de Ven and Garud, 1994; Schamp, 2010). This co-evolution is a striking phenomenon in high-tech industries (Nelson, 1995; Murmann, 2003), but is also identified in other sectors, such as resource-based industries (Sæther et al., 2011). However, the ways in which these processes occur vary between industries. In some cases, policy arrangements and new regulations promote the introduction of a new emerging industry path; in others, policies and regulations constrain the development. Co-evolution between firms and institutional arrangement can also lead to the development of a specialized institutional arrangement that fits the specific demands of an industry. A tailor-made and efficient institutional arrangement represents an advantageous situation for the industry, but this can be temporary. Changing circumstances can eventually make some of these political institutions and regulations less efficient. Further, strong institutional specializations also imply that other industry paths are 'locked out' from learning from their institutional set-up. This may restrict co-evolution between industry paths (Setterfield, 1997; Hassink, 2010).

In co-evolution between industry paths, competence, resources and technologies from successful paths, such as salmon farming, can spill over to related industry initiatives (Martin and Sunley, 2006; Martin, 2010). Thus, the preexisting structure is important for the creation of new industry paths in a region or a nation, and there is often interdependence between subsequent successful paths (Breshnahan et al., 2005; Zook, 2005). New paths may be latent or may spin out from existing paths. There are several examples on how new industry paths build on the knowledge base and the institutions established in already successful industries (Audia et al., 2006; Klepper, 2007; Martin, 2010). Recent contributions from the evolutionary perspective on related variety argues that the more closely related the branches are, the stronger the interaction and the connectivity will be (Frenken et al., 2007; Boschma and Frenken, 2011). Along these lines of thought, it is important to be aware of the status of the industry paths in question. One alternative is a balanced situation, where the paths are more or less on the same level of maturity. This will probably promote a situation characterized by interdependency and a reciprocal flow of knowledge and solutions between the two related paths. Thus, the two paths (or industries) will evolve in close association (Schamp, 2010). Another alternative is a hegemonic situation, where one dominant path influences strongly on the development of the second through the spillover of knowledge, technology and institutions, while the latter has little influence on the existing strong path. Such, 'one-way flow' can often be the case when new subsequent industry paths build on the knowledge base and the institutions established in already successful and related industry paths (Audia et al., 2006).

The hegemonic alternative is probably most relevant for our empirical analysis, where we will study the connectivity, or lack of it, between salmon farming as a successful industry path and cod farming as an emerging related path. In the empirical part of the article, we first elaborate on the development of the salmon farming path and trace elements of within-path co-evolution (e.g. between firms and the institutional arrangement). Second, we look for connectivity between salmon and cod, or co-evolution between industry paths. In the analysis of within-path co-evolution as well as between-path co-evolution, we investigate three areas of potential connectivity between systems; production technology, sales regulation and R&D organization. These areas represent critical features for the development of an industry path, and needs to be investigated in a study of within-path and between-path co-evolution.

4. Material and methods

Both authors have worked with the Norwegian aquaculture industry for more than two decades (Aarset, 1998; Foss and Aarset, 1992; Jakobsen, 1996, 1999; Aarset and Jakobsen, 2009). Our research topic is motivated by within observations of this industry, and by the insight in theory of industrial evolution. This background engage reflexive processes in the researcher team, and we use ourselves as filter in the interpretation of collected information (Haynes, 2012). Archived material was renewed and upgraded. Below we explain how we use different categories of information for the analysis of our research question.

Social science analyses apparently often bypass reflections on the biology of the species as cause of the success or failure of industrial aquaculture. Here, we have selected two typical cases that we believe represents features of the phenomenon we want to explore, i.e. mechanisms by which co-evolution occur, or where synergies fail to appear as expected. A typical case exemplifies ' … what is considered to be a typical set of values, given some general understanding of a phenomenon' (Gerring, 2007: 91). Our two selected cases, the salmon and cod farming industries, comprise two characteristics of interest in this study. First, each case (i.e. industry) are defined by its inherent institutional history that add up to distinct industry traits with firms that have adapted to these institutional specifications (Eisenhardt, 1989). Empirical studies use typical cases to confirm and nuance assumptions informed by theory. We define our cases by exhibiting characteristics typical of the phenomena under study. One of the strengths of qualitative case studies is the high-level of conceptual validity that they offer through in-depth examination of descriptive indicators and variables. The use of qualitative case studies is an appropriate method for research that aims to contribute with new knowledge on complex causal relationships or to nuance theoretical assumptions (George and Bennett, 2005; Yin, 2009). When the aim, as here, is to nuance theory the combination of multiple data collection methods is recommended (Eisenhardt, 1989; Jick, 1979; Yin, 2009). Case analyses may combine qualitative with quantitative data, but the selection of cases is based on theoretical and not statistical purposes (Eisenhardt, 1989). Corbin and Strauss (2008) also stress the importance of evaluating the credibility of qualitative case research. The credibility of our paper is attested to by how we have organized the data collection and analysis process, and when the purpose is to build theory, it is legitimate to alter and even add data collection methods during the process (Eisenhardt, 1989).

In the empirical part of the article, we investigate co-evolution within and between paths by analyzing three areas of potential interconnectivity: "Production technology", "Sales regulation" and "R&D organization". More specifically, "Production technology" is covered by policy documents (white papers, regulations, etc) that document the institutional development of the salmon farming industry, and registers of salmon farmers and their technological capacity. "Sales regulation" is covered by official reports prescribing future policies and published analyses summarizing experiences, in addition to production and export statistics. "R&D organization" is covered by policy reports (official reports and other white papers) announcing future efforts and priorities in order to sustain the Norwegian blue revolution, and annual statistics over the allocation of funds to various aquaculture related programs, in addition to observation of the actual situation in the university and research community.

5. Within-path co-evolution: the development of the salmon aquaculture industry path

Self-reinforcing processes and co-evolution between firms and the evolving institutional arrangements have characterized the evolution of the salmon aquaculture industry path. By looking into (i) production technology, (ii) sales regulation, and (iii) the R&D organization we intend to trace how the industry have developed a specialized and tailor-made institutional framework that suits the industry path.

5.1. Production technology

Sydow et al. (2012) emphasizes specific self-reinforcing mechanisms in order to explain why one of the available options gain momentum, and link their definition both to single organizations and to industries. In Norwegian salmon aquaculture, at the industry level, the introduction of the open net-pen technology for use in marine waters in 1969 (Gjedrem, 1992) can be seen as the event that set the development of a successful industry path in motion. The pen technology became the unifying factor and the trigger for finding common solutions to common problems. This technology reduced the search for alternative solutions and set the future trajectory of the salmon industry path. Moreover, in addition to the technology and the firm population, our definition of an industry path includes institutional arrangements such as regulations, industry policy, and public organization. The success of an industry path presupposes the presence of supporting institutions (Schamp, 2010). The development of a unifying technology and a common ground for problem solving was the foundation for the introduction of a new regulatory framework. A license-based model whereby private entrepreneurs produced within frames set by the government was the hegemonic model for resource-based industries such as the agricultural industries and fisheries in Norway in the late 1970s. The dilemma of the government was that it wanted to govern, but it lacked the proper instruments. The newly established open net-pen technology (floating net bags moored to the sea floor) was the opportunity the government needed, and inspired by components of the fisheries institutions, the regulatory principles and instruments of the new industry were formed.

The government decided to use "cubic meter pen volume" to allow only relatively small farm units to be established (Ministry of Fisheries, 1982). This strategy allowed the government to distribute farm capacity along the coast, reflecting overarching political goals. First, the government followed the regulatory principle of conserving a structure of relatively small and geographically widespread farms. The legal definition of cubic meter pen volume became an instrument for the government to distribute farm capacity to newcomers. Later, as the industry matured and the farmers gained experience, the government adjusted their regulative instruments by expanding the capacity of existing farms and the licensed pen volume capacity increased. Subsequently, further legal adjustments distinguished *de facto* from *de jure* pen volume. Finally, the technical definition of licensed pen volume was converted to Maximum Total Biomass January 1st, 2005 (Directorate of Fisheries, 2008). The government attached new intentions and purposes to the regulative principles, and an incremental change in existing institutions occurred. Nevertheless, the basic regulatory principles of pen volume as a defining criterion of firm size remained. Self-reinforcing processes curtailed alternative routes for defining firm size, and public resources have been directed to refining and streamlining specialized regulatory principles for salmon farming that has been advantageous for those that are within the industry. Contrariwise, the license system has made it difficult and costly for newcomers to enter the industry.

5.2. Sales regulation

From early on, the farmed salmon product benefited from the prices set by the exclusive wild salmon niche. Pressing technical problems were solved successively, relatively small farm units were established, and the industry flourished. However, this model left one important issue unresolved — how to bring the farmed product to the market. The policy developers looked again to the fisheries and agricultural sectors for appropriate models, and found various cooperative models to resolve this problem. The demand for a solution to the market issue sparked a debate over the identity of the new endeavor. The various cooperative models with corresponding arguments were compared (Didriksen, 1987; 1989; Official Norwegian Reports, 1977). This discussion became significant in the formation process, where a policy decision with far-reaching consequences was finally made by the establishment of a new mandatory salmon farming sales cooperative under the regulations of the Raw Fish Act. This sales cooperative was a self-reinforcing mechanism (Sydow et al., 2012), further cementing the institutionalization of the pen technology and the distributive power of the Aquaculture Act. The fisheries needed a system that protected them from the insecurity and unpredictability inherent in the capture of wild fish (stock fluctuations and accessibility). The Raw Fish Act provided the fishers with controlling power over the off-the-dock sale of captured fish, and thus a strong hand in their transactions with the fish buyers. Salmon farming, however, has no natural upper limit to production. The system empowered the producers with legal control of the first-hand trade and left them with *de facto* control of the flow of the farmed output. However, a fish-farmer controlled sales cooperative ensured a separation from the (at the time) rather stagnant and subsidized capture fisheries and sustained the attention from entrepreneurs, researchers, investors, suppliers and market actors (Hallenstvedt et al., 1985).

5.3. R&D organization

Within an industry path, established regulatory principles are amplified through self-reinforcing processes. The introduction of the mandatory sales cooperative segmented some of the regulatory principles introduced in the Aquaculture Act. It preserved a division between production and sales and marketing, and it empowered the salmon producers.

The licensing system and the sales organization were early on components in an industry policy that relied on the government as an active partner. The ruling policy centered on the premise that the government distributed a measured farm capacity to many small units along the coast. The mandatory sales cooperative achieved the necessary economies of scale in the export market, and the publicly funded research community was set up to provide and disseminate knowledge for the emerging industry (Official Norwegian Reports, 1977). The discourse of this Official Norwegian Report was how the research community could contribute to this new and promising coastal endeavor by pulling together research resources and line up research programs to support the emergent industry (Official Norwegian Reports, 1977; Official Norwegian Reports, 1985; Official Norwegian Reports, 1988). The R&D community again reinforced a path embarked upon by the industry-government partnership.

In the 1980s the salmon segment of the aquaculture industry grew rapidly measured by production volume and value, and one of the explanatory factors for this expansion was the selection of aquaculture as one of four areas for special focus in the government's state budget proposal for 1985 (Report to the Storting, 1984–85). Despite the removal of the sales cooperative in 1991, several institutionalized principles were continued, and traces of the system survived in operations independent of this deregulation. Examples of such institutionalized elements include the maintenance of the production and marketing of salmon as a generic product, volume-oriented production at the expense of specialization and niche-brand strategies, the role of Seafood from Norway (formerly the Norwegian Seafood Council) as the common industry body in trade policy issues, and, finally, a significant publicly funded common R&D.

A significant trait of the within-path co-evolution of salmon farmers and the research community is the willingness and aspiration of the research community to listen to the experiences, challenges and problems of the salmon farmers. This attitude is not always summed up in total agreement, but is based on a mutual understanding and trust (Arntsen et al., 1996, Weir, 1992). The focus of the aquaculture research system shifted towards applied goals (Official Norwegian Reports, 1988), and new strategies for aquaculture research were launched. In 1995, a change in direction of research, focusing more on new species, such as scallop and halibut, as a supplement to the salmon research, appeared (Report to the Storting, 1994–95). The assumption was that there is a connection between the positive industry outcome of salmon aquaculture research and a broader industry outcome of aquaculture research. More recently, biotechnological issues has become more pressing for the industry, and the research community has also moved into this area with relevant research projects (Olesen et al., 2007). New challenges arise, such as intellectual property rights, patenting and other protective measures (Olesen et al., 2008; Rosendal et al., 2013), with consequences for competition, profitability and just management. The direction of development has changed yet again, with research institutions co-evolving with industry partners.

6. Between-path co-evolution: linkages between salmon and cod farming

So far, we have elaborated upon the development of salmon aquaculture as a successful industry path, emphasizing its institutional arrangements. Self-reinforcing processes and within-path co-evolution has developed a specialized and tailor-made institutional framework that fits the industry. According to theory, technologies, competence and solutions from successful paths can spill over to related industry initiatives; that is, co-evolution between subsequent industry paths. This will be investigated through analyses of the cod farming initiative, one of the industries that conceivably could capitalize on the success of salmon aquaculture. In the following, we investigate areas of potential interconnectivity between the salmon and cod industries. We are building on the structure introduced in the previous chapter and investigate between-path co-evolution by tracing the extent to which (i) production technology (ii) sales regulation, and (iii) R&D organization developed for salmon farming have informed the resolution of these challenges in cod farming. These areas have been selected since they represent critical features for the development of a successful industry path.

6.1. Production technology

Many of the early Norwegian cod farmers where more or less experienced salmon farmers (Foss and Aarset, 1992), hence technical solutions developed within salmon farming were easily accessible for them when they diversified into cod farming. However, biological differences between cod and salmon make this exchange a challenge (Jensen et al., 1979; van der Meeren et al., 2003). The production of seed organisms has never been a technical problem within salmon farming. Fertilization, hatching and feeding of fry were well-known processes. The eggs and fry are also of a size that makes them easy to handle. This is different for cod; the size ratio of salmon to cod eggs is 1:68. In a farm setting, fertilized cod eggs are usually collected in particular pens where mature cod have spawned (Rowe et al., 2004). The cod larvae depends on live feed, and one challenge is to correlate the needs of the fry with the cultivation of live plankton, which required the development of complex knowledge about the biology of the cod and the feed organisms(Pedersen et al., 1989). An alternative route to acquire seed organisms is to capture small wild cod and feed them. This alternative model has been tested on several occasions, but other concerns such as quota control, market access, and fish welfare issues have been raised.

There are also biological differences between cod and salmon in terms of feeding. The small size of the cod fry required specialized technology compared with the rather simple solutions available for salmon farming in the introductory phase of this industry path. Nor does the subsequent intense development of feeding technology in salmon farming provided cod farmers with appropriate technological solutions. However, we believe that lack of co-evolution in technology development between cod and salmon cannot be explained only by characteristics of the lively bodies of the fish. It also seems likely to contend that the cod farming pioneers were unable to adjust the technological solutions developed for salmon farming and tailor them for cod farming. In the grow-out phase for instance, open net-pens in saltwater is an adequate technology for both species. However, biological differences call for specific solutions when it comes to the organization of the production. Cod have a much larger mouth relative to the body size compared to salmon, and thus, the size variability of the fish in the pen must be much more even for cod than for salmon. This means that the cod must be sorted by size more often otherwise the farmer will experience a problem of cannibalism. Sorting and cannibalism are both potential cost drivers of cod farming. However, an ability to transform the technological solutions of salmon farming into a technology that fits the conditions of cod farming seems to be lacking within the cod industry (Aarset, 1999).

The absence of a unifying production technology for cod implies a lack of dedicated projects for the production of useful knowledge, such as veterinary issues, fodder, nutrition, and further refinement of an appropriate technology. Cooperation between producers is critical in the introductory phase, and the lack of technological agreement and uniformity implies that the necessary cooperation is not in place.

6.2. Sales regulation

For the first cod farming entrepreneurs, it was important to find a model of organizing the trade of the product to ensure a predictable outcome. This proved difficult. As illustrated in the previous section, salmon farming arrived at a model where the farmers established their own sales organization with mandatory rights to the first sales of all farmed fish, mandated by the Raw Fish Act, but outside of the established sales organizations in the fisheries (Hallenstvedt et al., 1985). The sales organization for the trade of (wild-caught) cod (Norges Råfisklag) is one of the most powerful institutions in the Norwegian fisheries. This organization is a mandatory fisher-owned sales organization with statutory rights to the first trade of all cod. In this way, all fishers are assured equal bargaining power and price for their product. This sales organization saw itself as the natural unit for the trade of farmed cod. In the salmon sector, the sales organization for farmed salmon (Fiskeoppdretternes Salgslag) took the job of organizing the trade of salmon off the shoulders of the farmers during a period when the farmers had to concentrate on the technical aspects of farming.

In 1989, the trade of farmed cod was removed from the portfolio of the Fish Farmers Trade Association (Soldal, 1990), and after some controversy, the farmers of farm-hatched cod were allowed to sell their product directly in the market. However, this experience was of marginal use for the cod farmers, where the massive presence of the sales organization for wild-caught codfish curbed cod farm initiatives. To sell the product outside any organization and thus without any organizational resources is not necessarily a prosperous option. The lack of supportive institutions implies a lack of structures that collect, organize and utilize information. The cod farmers lack such institutions, and their situation is thus different from that of the salmon farmers who were supported by a designated sales association. In the end, farmed cod will not be easily distinguished from wild-caught cod and will be confronted by the market price set for the wild fish.

The cod sector is regulated and institutionalized. “Who does what and when” is decided along the historical path of the cod fisheries. Politically, historically and economically, cod is one of the most important fish species in Norwegian waters. The cod product is well known and in good demand. As a wild caught fish, cod is managed according to politically sanctioned resource management institutions. Due to the huge market volumes of wild cod, farmed cod is not distinguished from wild cod. Farmed cod have so far failed to develop distinct markets. The experience from salmon farming demonstrates the significance of available models – acquired either by luck or by skill – at critical junctures of the development. The requirements of the farmed salmon drove the development of salmon farming. Farmed cod never achieved a defining or constitutional power. Initially, all cod were traded through the fish-farmers sales organization. This obligation was lifted, but cod as a farmed product remained hard to distinguish from the wild fish, and it was thus difficult to demand a price premium. Farmed cod can thus be sold directly from farmer to high-end markets, but lacked the resources to develop the necessary relations. Hence, the price of farmed cod was destined to follow the wild fish price of cod and related products. As mentioned earlier, an important take-off factor for salmon was the relationship with wild salmon and the price premium gained in the market. For cod, the situation was different. Cod farmers tried in vain to achieve a price premium for the farmed cod product, but the price-setting power of the wild fish sector kept the prices for farmed cod too low.

6.3. R&D organization

Within salmon farming, the research community and the salmon farmers cooperated over core topics for the advancement of the industry. Even at a time when the industry still was small, it consisted of entrepreneurs eager to refine their skills and to develop their industry further. The research problems were extracted from the hands-on experiences of these entrepreneurs, hence a bottom-up drive for appropriate solutions. The economic success of this industry path indicates that it has been a feasible solution for the R&D organization.

The question is then what the cod farming entrepreneurs has gained from the R&D model of the salmon farmers. The immediate answer is “not a lot”. In cod farming, a top-down R&D model has been developed. The cod researchers could not refer to a group of cod farmers to back up their choice of research problems, and consequently research problems were generated by the researchers themselves – not to solve practical problems in the industry, but to expand the level of research knowledge. This is not necessarily a wrong model, but it presupposes mechanisms for the commercialization of research-based knowledge and bridging the discrepancy between the research community and industry actors (Njøs et al., 2014), otherwise it will not stimulate innovation and industrial development. Considerable public funding has been poured into the research of cod as a farmed species (Aarset, 1999; Steien, 2003), but the lack of product identity conveys no guidance for the research community on what to do. Several alternatives for production such as feeding of live-caught cod and sea ranched cod have been tested, but with modest success. The sum of these projects does not add up to industrial development.

One of the reasons for this top-down model for R&D in cod farming is the historically strong position of cod within the

Norwegian fishing industry and a long tradition of cod research (both wild and farmed). In 1978, the publicly funded Institute of Marine Research established an aquaculture research station in Western Norway, and the bulk of the cod research took place at this location. The research station was originally established to accommodate the growing salmon industry. Despite this co-location of aquaculture-related research on cod and salmon, the effect on the salmon industry was considerable, and that on cod was marginal. Thus, the overall picture is of diversity in R&D models and lack of interconnectivity between the salmon and cod industries.

7. Concluding remarks

In this article, we have elaborated upon the assumption of the evolutionary perspective that technologies, competence and institutions from successful paths may spill over to related industry initiatives (Martin, 2010; Schamp, 2010). Co-evolution between subsequent industry paths has been analyzed by investigating the interconnectivity between the mature and successful salmon aquaculture path and the emerging cod farming path. Salmon and cod farming are both part of the Norwegian seafood complex and have, despite some species related biological differences, several similarities when it comes to technology, knowledge and research needed in production and marketing. Many industry actors have also been operating within both industry segments. Still, we found a lack of evidence concerning how solutions and institutions developed for salmon farming were useful for the cod farmers. In other words, salmon farmers have apparently not offered the cod farmers with viable production technology, sales regulation, and R&D organization models to solve pertinent issues, nor has cod farming managed to construct its own set of efficient institutions.

Through self-reinforcing processes and strong linkages between salmon firms, authorities and public actors, the salmon aquaculture industry has refined and adjusted its existing institutional arrangements according to its needs. Such co-evolution within a path has resulted in a specialized and tailor-made institutional arrangement that meets the demands of the salmon industry very well. However, strong institutional specialization leads to a tendency to institutional lock-in and the obstruction of the diffusion of models and competences across industry segments or related industry paths (Setterfield, 1997). Thus, institutional specialization within salmon farming makes the models incompatible with the needs of farming of other species. The momentum of salmon farming constrains rather than encourages expansion in other segments of aquaculture, and in this article, we have demonstrated limited co-evolution between subsequent aquaculture industry paths. The salmon industry has developed models for production, sales regulation and R&D organization that have become too specialized, resulting in fading opportunities to transfer knowledge and experience to emerging aquaculture industries. The knowledge developed in areas such as fish physiology and nutrition, veterinary medicine and salmon breeding programs are of little relevance to other species. Moreover, the specialization of salmon farming inhibits the transfer of knowledge and fruitful development processes between industries, undermining the diffusional aspects of the blue revolution. In other words, cod farming is 'locked out' from the knowledge, institutions and resources of the salmon path. It is increasingly difficult to meet the expectations of 'seamless diffusion' of efficient solutions from salmon farming to other aquaculture species. The upside of such institutional specialization is a tailored arrangement that suits the prospering salmon farms, while the downside is a lack of co-evolution and interconnectivity between subsequent and related industry paths.

Our article contributes to the theoretical debate in evolutionary inspired research on industry development by elaborating upon the notion of co-evolution. Despite the popularity of the concept, there is a lack of discussion of how co-evolution occurs, the main mechanism by which it occurs and why, and conversely, why it does not occur (Murmann, 2013). It is important to move on from the rather bold statement that everything is co-evolving with everything (Schamp, 2010). Instead, we need to know what is co-evolving with what. We add to this discussion by identifying institutional mechanisms that seem to prevent co-evolution from occurring. We found that a situation characterized by strong co-evolution *within* an industry path and the development of a specialized institutional arrangement reduce the possibilities for co-evolution *between* related industry paths. Strong institutional specialization within a prospering path implies that emerging related paths are being locked out from the institutional arrangement of the former.

Our study has some limitations. We have elaborated upon a specific case of co-evolution, i.e. the linkages between salmon as a successful industry path and cod farming as an emerging path. In this hegemonic situation, we have looked for 'one-way flows' from the dominant path (salmon) to the emerging path (cod). We have also emphasized to which extent cod farming has copied the institutions and technology of salmon farming, while other forms of spillovers and connectivity has not been analyzed in our case study (for instance the flow of capital, and the mobility of human resources). We know for example that capital from salmon farming companies has been invested in cod farming initiatives (Aarset, 2006). It is also important to underline that we have only analyzed the linkages between salmon farming and one related industry path. Further empirical investigations are needed in order to map the broader picture and investigate how knowledge and capital from salmon farming has been important for other parts of the Norwegian economy. In further developing our understanding of co-evolution as a theoretical concept, there is also a need for more reflections on the notion of interdependence and mutual causality. Many studies, like ours, seems to be restricted to analyses of how one dominant system influences a second system, while a more thorough understanding of interdependence and the second system's influence on the first seems to be missing. In this respect, Giddens' (1984) idea of structuration may be a fruitful point of departure (see, for instance, Sydow et al. (2012)).

Our study has illustrated the significance of bottom-up processes in salmon farming in successful economic development, but it also emphasizes the ambiguity of this process. Salmon farming demonstrates a process of rationalization over three decades. All information, experience and research have been conducted, collected or made available according to one single aim, for someone to harvest a considerable rent of the farming of salmon. The sociopolitical project of developing and employing a broad platform for aquaculture production is difficult to see. The farming of cod seems to have benefited little from the farming of salmon. Our analysis has provided a novel understanding of the forces involved in the streamlining of the value chain of salmon aquaculture, with its set of intended and unintended consequences. The world's fisheries have reached their maximum yield, and aquaculture is predicted to supply the demand from an increasing world population. This considerable task require careful design in order to utilize available but limited resources such as water of high quality, the coastal zone and capital in a sustainable way. The diffusion of efficient institutions must be enhanced to reduce the vulnerability of monocultures in aquaculture. From a wider perspective, it can be argued that a carefully designed policy at historical trigger points can guide an industry path in appropriate directions to improve the applicability of its knowledge and institutions for related aquaculture initiatives. In other words, a more distinctive industry policy could have facilitated a stronger diffusion of the blue revolution.

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