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Globalization and the changing institution for sustainability: The case of the Salmon farming industry in Chile

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Globalization and the Changing Institution for Sustainability:
The Case of the Salmon Farming Industry in Chile

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Abstract
The recent expansion of global demand for natural resources has created a production boom in countries endowed with natural resources. Increasing global trade and investment — globalization — offer an important opportunity for developing countries as the global flow of commodities often accompany knowledge and information to increase productivity to facilitate economic development. This positive feature of globalization has some serious drawbacks when the country is not equipped with an institution to ensure environmental sustainability. This paper sought to demonstrate this through the examination of the Chilean salmon farming case. The Chilean salmon farming industry has grown dramatically since the mid 1980s to become the number two exporter of farmed salmon in the world after Norway. The sector, however, suffered a decline in production volume due to the sanitary crisis in 2007. The case also tries to capture the on-going efforts made by the government to strengthen the institution to prevent further occurrences of environmental and sanitary crises.

Keywords:
Globalization, Environmental sustainability, Institution, Innovation, Chile

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Introduction

Increasing economic globalization through trade and foreign direct investment (FDI) facilitate the transfer of knowledge among nations particularly to emerging countries. The reception of external knowledge can be expected to contribute to their learning process and building competitive production capability. In fact, many so-called emerging countries are now increasing their presence in global trade and much of this is associated to natural resource processing activities, such as iron ore, forestry products, minerals, petrochemicals and foodstuff. Despite the positive aspects underlying such process there can be little doubt that this is putting environmental pressure on these countries and that their institutional and regulatory capability to ensure the sustainable use of resources is not necessarily strong enough. As environmental deterioration is a gradual process while recovery from environmental damage might be difficult once a certain threshold is surpassed the timely detection. The establishment of adequate regulatory practices should be regarded as crucial for sustainability of the environment but also for the long-term sustainability of the production activities themselves.

The rapidly growing countries are currently building capacity to manufacture and produce the exportable goods, responding to an expanding market demand. Their main objective is that of generating domestic employment as well as earning foreign currencies, thus environmental sustainability is not usually among the main priorities. Several studies (Sato, 2011 etc) as well as policy reports from international organizations claim that developing countries' institutional capacity for protecting sustainability is rather weak as they tends to prioritize the economic growth. In this paper, we pretend to illustrate the above looking into the case of Chilean salmon farming which after staging a very successful catching-up process with the world's technological frontier suffered the dramatic impact of a sanitary and environmental crisis which badly damaged their international competitive position. In the short period of two decades Chile became the world's second largest exporter of farmed salmon. Given that salmon was not a native species, the rapid growth of this industry was considered as the model case of catching up through building capability in a non-traditional production activity (for more detail see Katz, 2004, Iizuka, 2007, UNCTAD, 2006, Maggi, 2002, Montero, 2004). This success story came under close scrutiny by the sanitary crisis that started in 2007 and force nearly 60% of the cultivation centres out of business, having to sacrifice the biomass under cultivation. The volume of output fell down to nearly the half of that of previous year.

This paper will try to explain how such environmental collapse happened paying special attention to the fact that concomitantly with production capabilities countries specializing in natural resource processing activities countries also need to develop technological, institutional and regulatory capabilities adequately to monitor the use of the environment, the collective utilization of ' common pool' resources. We argue that making progress in terms of the former – i.e. Production capabilities – might not be good enough if long term sustainability of the resource is to be ensured.

2. Theoretical considerations

2.1 Economic globalization and changing role of emerging countries: new wine in old bottles?

Globalization of economic activities is now opening a new space for emerging economies to engage in new production activities. The role of developing countries at global level has shifted from a hierarchical (and potentially exploitative) relationship with developed countries - where developing countries played a passive role as providers of the low cost natural resource - to a new one of an arms' length supplier as described by the global commodity chain literature (Gereffi and Korezeniewicz, 1994, Gereffi, 1994) and global value chain (Humphrey and Schmitz, 2000, 2002a, 2002b, Gerrefi and Kaplinsky 2001, Kaplinsky, 2000, Kaplinsky and Morris, 2001) and even to more participatory and less hierarchical relationship as claimed by the global production network(GPN) (Ernst, 2001) which expect more active participation of suppliers' relying on their capability to increase efficiency of overall production. Similarly, in the literature on FDI, the role of subsidiaries is also being re-considered as a potential source of knowledge within the MNC global network. (Birkenshaw and Hood, 1998). This concept is also extended to the studies on regional systems of innovation where the headquarter of multinational companies (MNCs) and local subsidiaries can provide (1) mutual technology systems; (2) knowledge spillovers; and (3) joint stimulation of industry/demand connected with local firms (Iammarino and Cantwell, 2003). The above literature suggests that local subsidiaries and suppliers are increasingly being seen as a source of knowledge as well as active partners of knowledge creation processes. This trend is supported by the recent growing consumption in the emerging countries where the local subsidiaries are better positioned in grasping the local distribution channels and consumers' preferences as well as discovering the most efficient local production methods utilizing the locally available factors of production.

The role of local players in 'catching up' countries is also changing. Lim and Lee (2001) identified three different patterns of 'catching up' stories – 'path following', 'path skipping' and 'path creating'—based on experience of Korean firms. The catching up via 'path following' and 'path skipping' are more in line with conventional thinking, in which developing countries would trail along the same path of developed countries despite the variability in the way of combining the resources (Gershenkron, 1962; Hobday, 1995, 2003, 2011). The 'path creating' catching up process goes beyond the conventional cumulative learning phenomena – involving imitation and adaptation of technology (Soete and Perez, 1988) – and identifies a new and more independent style for development process.

The recent findings on the innovation capability literature in emerging economies echoes with the above line of argument by suggesting an increasing role and capacity of emerging countries in learning through internalizing foreign technology through FDI and trade (Fu et al, 2011, Fu and Gong, 2011, Pietrobelli and Rabellotti, 2011) but also developing what they call indigenous technological capabilities pari pasu with internalizing foreign know how. (Fu et al, 2011, Fu and Gong, 2011). Here, the importance of capability is not limited to the production technologies per se, but also to the institutional and government structure (Pietrobelli and Rabellotti, 2011) and the organizational capability (Bell and Pavitt, 1995) to support the domestic absorption process. As Fu et al (2012:1210) state "without the proactive indigenous innovation efforts, foreign technology remains only static technology embedded in imported machines which will never turn into real indigenous technological capability". In another word, these studies claim that flow of knowledge will not be fully integrated to become domestic capability unless there are institutional and governance structure at local level to promote and guide the innovation and learning process.

Having come thus far it is important to understand that much of the above literature looks at catching up process as from the lens of manufacturing activities. The focus, hence, was placed on the technology, particularly on the acquisition of production technology and the associated learning process, extended to local institutions. Our main concern in this paper is to extend the argument to the sphere of natural resource based activities and to the need to pay attention to local efforts trying to develop institutional and knowledge capabilities compatible with the local conditions under which natural resource based sectors are being integrated into the long term development strategies of developing countries.

2.2 Globalization of economic activities and its impact on sustainability of local natural resources

Economic activities based on natural resources such as agriculture and mining are booming due to the increasing demand from rapidly expanding emerging economies, such as China, India and others. A number of reports from international organizations (Bloomstrom and Meller, 1991, de Ferrrati et al, 2001, Maloney, 2002, Sinnoit et al, 2010) state the potential of natural resource based activities for economic growth, contrary to the prior 'resource curse' and 'terms of trade' arguments which casted doubts as to the sustainability of a development strategy based on natural resource based products.

Nevertheless, it is to be noted that responding to increasing global market demand for energy, minerals and foodstuffs without designing and implementing appropriate regulatory mechanism concerned with the correct use of the environment might easily lead to environmental deterioration. The governments in developing countries are in general prioritizing economic growth and foreign currency acquisition over environmental sustainability (for example Sato, 2010). Hence it is often considered that their environmental regulatory mechanisms are not well designed, less stringent nor fully enforced by the responsible public sector agencies responsible for that. In the 1990s, 'pollution haven' arguments, in which the firms in developed countries move their contaminating production processes to the developing countries due to their less stringent legislation (such as reviewed in Dean, 1992) were extensively discussed. This argument has accused the MNCs for transferring the polluting intensive activities to developing countries and bringing environmental deterioration to the periphery as a result of that. This argument; however, was dismissed as several researches later discovered that environmental factor constituted a small proportion of cost in MNCs and was not the major determining force deciding where a subsidiary was to be located. The case remains, however, that some environmental consequences from FDIs resulted from this process.

A recent study unveiled yet another aspect to the earlier discussion on globalization and environmental sustainability by demonstrating how international trade is affecting biodiversity in developing countries (Lenzen et al, 2012). The study demonstrated that consumption of imported commodities by developed countries—such as coffee, tea, sugar, textile and manufacturing products—is responsible for 30% of biodiversity loss in producing countries. Several studies had already linked the intensive trade of so called commodities—palm oil, coffee and soya (Perfecto et al, 2003, Philpott et al, 2008, Fearnside, 2001, Koh, 2007)—indirectly causing the deterioration of biodiversity in the countries producing these commodities. In order to correct such relationship, creation of a global institutional mechanism to share the environmental/ecological cost between the importer and exporters countries at the global level is called for. At the same time, due to variability and differences of the environmental conditions and local ecological carrying capacity, standardized mechanisms may not be easy to design and implement. Instead, the local stakeholders may need to play an instrumental role in identifying the local 'carrying capacity' of the resource and establishing ecological thresholds as well as creating the new regulatory institutions.

There is a long standing research on how to managing natural resources or common pool resources (CPR)[1] at local level (Hardin, 1968, Ostrom 1990, Feeny, 1990). Managing CPR generates an inner tension between individual user of the 'common', environmental resources, and their benefits maximizing behaviour, and a group of users and its collective performance as each individual actor attempts to maximize its private use of the ´common´, eventually inflicting welfare losses to the rest of the group by depriving others from access (Feeny et al, 1990, Ostrom et al 1999). This situation is described by Hardin[2](1968) as 'tragedy of commons'. Hardin, by identifying the difficulties of

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[1] Common pool resources (CPR) include those property that can have excludability—it is costly to exclude others from using the resources—and subtractability—each user is capable of subtracting from the welfare of other users (Feeny et al, 1990, Ostrom et al 1999) Examples include use of resources such as fisheries, wildlife, surface and groundwater, range and forests.

managing CPR, suggested that environmental resources or CPR should be managed either through government regulation (role of state) or exclusive private property ownership (role of market).

Ostrom (1990); however, considered Harding argument as grossly "simplified" and claimed that in many cases local self-governing institution emerge dealing with the threat of resource degradation. Important to this argument is the fact that stakeholders in the common can 'learn' from interactions and therefore develop institutions capable of preventing the overall environmental degradation. To support sustainability,[3] they have to act collectively for common purposes (Ostrom, 1990) with game theoretical interaction. CPR management therefore brings to the fore the importance of local specific institutions, which can co-evolve with changes in a broader set of global, as well as local forces where CPR is located. (Dietz et al, 2003, Ostrom et al 1999). The institutions need to link the environmental factors with 'location specific' socio economic forces, paying attention to global impact. However, it is also true that such institutions may not emerge naturally and might require intervention from public sector and regulation to induce behavioural change and collective action among stakeholders.

2.3 Role of institution to ensure industry sustainable

Institution is usually defined as the 'rules of the game' following the seminal work of Willamson (1975, 1985, 1998) and North (1990, 1991). At the same time, groups of scholars such as Hogdgeson (1988, 2006), Aoki (2007) and Grief (2006) indentify institution as how behaviours are formed or ways things are done rather than rules or governing structures that constrain behavior. Ebbertsson (2005, 2009), Nelson and Sampat (2001) and Nelson (2008) use the concept of 'social technologies' to make similar distinction as Hodgeson and others. The 'social technologies'—the way work is divided and coordinated—facilitates the understanding of diversity in the way 'physical technology' is implemented under 'conventional' institution such as existing laws, norms, expectations, governing structures and mechanisms, customary modes of organizing and transacting. There is however a much broader contextual sphere as well in which 'institution' involves 'belief', 'culture' and value system which results in Nelson's 'social technologies'[4] (Nelson, 2008). In other words, institution is broadly separated into: 'rule of the game', 'social technology' and historical, social and cultural value system. With this understanding, it is possible to state that all production process involves co-evolution of 'physical and social technologies' in the understanding that we include here 'rules of the game' and 'historical, social and cultural value system' (Ebbertsson, 2009, Nelson, 2008, Nelson and Samphat, 2001).

How does the 'social technology' emerge and change? Ruttan (2005) introduces interesting model which claims that institution[5] is 'induced' by the dynamic interplay between resource & cultural

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[2] Hardin (1968) addressed ´the tragedy of the commons´ with a simple example of 'herder' behavior. By putting one more cow in a limited space of land (common), the individual's maximization attempt– through the eventual overloading of the resource – would cause a reduction of the collective benefits of all users of the common.

[3] Sustainability is defined as "maintaining the capacity of the joint economy-environment system to continue to satisfy the needs and desires of humans for a long time into the future" (Common and Stagl, 2005:8)

[4] Good example is shown by Nelson (2008) and Eggertsson (2009) where they explain the development of biotech industry whose physical technology (biotech) is very much influenced by the IPR regime, laws (Bayh-Dole), code of conduct as well as value system such as public opinions and religious views.

[5] Ruttan (2005) defines institution as follows "Institutions are the rules of a society or of organizations that facilitate coordination among people by helping them form expectations, which each person can reasonably hold in dealing with others. They reflect the conventions and ideologies that have evolved in different societies regarding the behavior of individuals and groups relative to their own behavior and the behavior of

endowments and technical change. He raises historical examples where demand for institutional innovation is created via external forces causing the relative scarcity in the resource endowment—i.e. the increase of demand for rice in 19th century Thailand created by the completion of Suez canal (Feeny, 1982, 2002) generated profit from export and induced the property rights system to manage the farmlands; population growth in Japan during the Tokugawa era (15th century to 19th century)made land scarce property leading to creation of leasing mechanism which laid foundation for modern private property system (Hayami and Kikuchi, 1981) or the population growth created scarcity in land in Philippines while introduction of new technologies—modern high yielding rice varieties, double cropping practice, improved fertilizer and pesticides—improved the productivity and hence allowed to create an institution called subtenancy by dividing the land further (Kikuchi and Hayami, 1980)—all demonstrating the changes in relative resource scarcity and technological change induced the development of new institution because the new institution ensures new economic equilibrium but it 'evolves' in the 'path dependent' manner. His claim is that these institutional developments are very much consistent with modern analytical economics as institution facilitates to readjust the factors of production (resource endowment) to a new dynamic equilibrium, allowing dynamics change along an equilibrium path. Ruttan (2005) goes even further suggesting that "political entrepreneurs" provides resource for the building up of new institutions that resolve the conflicts among interest groups" (ibid: 13).

Botteck and Fink (2011) consider that successful institutional change need to be introduced indigenously, i.e. Homegrown by the citizens of a country, and evolves endogenously, i.e. Results from the interaction of individuals and is not devised centrally by government, is most likely to persist over time. Endogenously evolved institutions are in this sense relatively 'sticky' because they are founded in the existing institutions and beliefs (Boettke et al, 2008). In contrast, "institutional change implemented by agents outside the community is less likely to stick...." (Boettke et al, 2008:502). Boettke and Fink (2011)'s emphasis on endogeniety of institutional change resonates with that of Ostrom (2005) in which she state that the communities can learn to regulate the use of common resource by devising rules. With regards to collectivity, Ruttan (2005) also states that "[i]mprovements in institutional performance are the result of process of collective learning that has passed the slow test of time and its embodied in people's language, culture and institutions.—since collective learning occurs at the level of the community rather than at the individual level, there are severe constraints on the rational design of policies and institutions"(ibid:15). Both arguments point out the importance of institution emerging endogenously to regain the equilibrium at local level.

Following the above review the evolution of Chilean salmon farming will be used to illustrate the global-local dimension on environmental sustainability as well as actual difficulties in creating endogenous institution for managing environmental resources.

3. Case of Chilean salmon farming industry

Chilean salmon farming provides an illuminating story of a non-native species being incepted in a highly receptive natural environment and later becoming one of the major exported products, generating employment and rapid economic growth in poor coastal regions of southern Chile. Both the genetic material and the production technology for salmon farming were originally imported and subsequently adapted to local environmental conditions allowing Chile to catch up with the world frontier exporters such as Norway in production terms. While local climatic and geographical

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others" (Ibid, p2). In his footnote (Ibid, p48), he differentiates institutions into: (1) organizations, (2) rules and structure of governance, (3) relationship between firm and regulatory agency (such as innovation system), (4) culture, and value systems. Having distinguished them, he states that he use the term 'institution' in inclusive terms. From this perspective, it is possible to interpret that his 'institution' is closer to 'social technology' of Nelson (2008) and Eggertsson (2005, 2009) rather than narrowly defined 'rules of the game'.

conditions were central to successful salmon cultivation, the dramatic increase in production gradually created a situation of excessive exploitation of the 'common' leading to environmental deterioration and to a sanitary crisis in late 2007. This case is illustrative to capture how global demand contributed the economic growth while also induced the overexploitation of the resource due to lack of 'social technology' at the local level to ensure sustainability of both environment and economic activity. The case also describes on-going efforts made by government to create new 'institution' to find sustainable solution, a sign of induced institutional innovation due to changes in resource response *vis a vis* utilization practices. .

3.1 Rapid catching up Chilean salmon farming industry

In 1994, Chile became the world's number 2 exporter of farmed salmon. This achievement of Chilean salmon industry was remarkable given the knowledge and technology of raising salmon in captivity did not exist in the country in previous decades. The development of the industry dates back to the 1960s when Chilean government (SAG) first signed the cooperation agreement with JICA, the Japanese bilateral cooperation agency, for technological transfer on salmon farming. Since then, the industry had taken off and grew rapidly with the development and diffusion of 'physical technology', i.e. Production capability and of 'social technology', i.e. Institutions and governance technology, facilitated by FundacionChile, Association of Producers of Salmon and Trout (later SalmonChile) and numerous foreign direct investments (Nichiro, Union Carbide) at that time. There were, of course, adaptation efforts to generate 'social technology' amongst firms to facilitate production process. On the other hand, learning by doing and technological adaptation efforts on developing 'physical technology' had the major role on its growth during the initial stages of industry expansion (for more details, see Katz, 2004, Iizuka, 2007, Maggi, 2002, Montero, 2004, UNCTAD, 2006).

3.2 Sanitary crisis and causes

(1) Magnitude of the crisis

In July, 2007, the National Fishery Service (SERNAPESCA) officially confirmed the presence of Infectious Salmon Anemia (ISA) (SERNAPESCA, 2008). The disease, known to be contagious and causes high mortality for Atlantic salmon (but does not harm human health), quickly spread to the nearby cultivation centres. Soon, the affected cultivation sites suspended their operation (Iizuka and Katz, 2011) as the biomass (fish) had to be scarified. By 2009 close to 60 % of the cultivation centres were out of production. In the following year, the production of salmon had fallen to around 200 thousand tons down from its peak of nearly 700 thousand tons in 2006. The impact of the crisis was not limited to salmon farming firms alone as it rapidly reached the intermediate input and services suppliers. Close to 20 thousand jobs were lost in the short period of two years since and numerous coastal villages, where their job depended entirely on the demand for skilled and unskilled labour by salmon farming companies. The dramatic fall in production caused delays of bank loan payment by various salmon firms, resulting to total estimated bank debt of US$1,600-2,500 million by the industry at the end of 2009 causing the chain reaction of bankruptcy (Larrain, 2011). The very much acclaimed Chilean 'salmon cluster' was showing signs of 'de-clustering' due to the environmental and sanitary crisis.

(2) Direct cause of the crisis: ISA virus and sanitary conditions: ecological triad of illness

The ISA virus was believed to be originating from Norway arriving in Chile through imported salmon eggs. Many local specialists believe that a variant of the disease was already present in Chile for some time until combination of environmental conditions triggered its mutation at rapid spread (Bustos 2009, Nieto 2009, Alvial et al, 2008).

In explaining the causes of the ISA epidemic, local biologists and veterinarians we interviewed referred to the 'ecological triad of illness': the interaction between the host (fish), the environment, and the various pathogens acting in the environment. According to them, 'becoming ill' constitutes the process whereby the triad breaks down reducing the self-immunological defence capabilities of the fish. This is when the pathogen acts, infecting one or a few fishes first and then quickly spreading to the whole population in the cultivation tank. In other words, even if it is true that the impact of ISA virus has been quite strong that shouldn't induce us to believe that worsening sanitary and environmental conditions were not present even before the crisis actually manifested itself in the open. In other words, the crisis should not be seen as a consequence of ISA but as the long term, cumulative outcome of sanitary and environmental mismanagement dating back years before the outbreak of ISA.

There is no historical record of water quality at coastal areas where salmon is cultivated in Chile; however, there is a record of sanitary incidents of salmon in captivity by the veterinarians. These data show the sign of gradual decaying of sanitary conditions from the time Chilean salmon export 'take off' in the late 1980s and increase rapidly in its volume exports from the 2000s, long before the ISA epidemic in late 2007 for instance, during the initial years of inception of this industry, i.e. 1980-89, very few episodes of disease were reported. The industry grew rapidly during the 1990s to reach 200 thousand tons per annum by the end of that decade (see figure 1). An independent survey of the sanitary situation carried out in the mid-1990s by local veterinarians confirms that the sanitary situation was worsening even early as in the mid 1990s, almost 10 years before the epidemics actually started(Bustos 2009, Johnson 2008, Nieto, 2009) (table 1).

Insert

Figure 1 Deterioration of sanitary conditions in salmon farming sites and increase of export
Source: Based on SERNAPESCA, various years and Nieto, 2009

Insert

Table 1 Appearance of disease: perception of local veterinarians

Source: based on survey taken in mid 1990s, Bustos, 2008

(3) Indirect causes of spread

a. Absence of regulatory mechanism (rule of the game) with strong developmental approach

Before the crisis in 2007, Chilean aquaculture regulation was not been effectively organized so as to prevent environmental degradation. The national fishery administrations—Undersecretary of Fishery (Subsecretaria de Pesca) and National Fishery Service (Servicio Nacional de Pesca: SERNAPESCA)—did not pay much attention to regulate salmon farming. This is due to following reasons: first regulating the extractive fishery has been their mainstay of business; second , "there was very little to regulate as the scale of production from salmon farming was not so large" (interview with Mr. Sandoval, former secretary of fishery Nov, 2011 and Ms. Saa, official of SERNAPESCA interview, Dec, 2011). Hence, instead of playing the regulatory role they supposedly were created for these institutions gave priority to a 'developmental role' i.e. facilitating the expansion of output during the 1960s, 70s, 80s and much of 90s.

For instance, some regulatory measures were put into place in the 1990s with regards to aquaculture. These are General Law of Fishery and Aquaculture (Ley General de Pesca y Aquicultura: LGPA) of 1991[6], the Supreme Decree no. 475(1994) to define the use of Chile's littoral coastline by

[6] For instance, LGPA of 1991 was mostly dedicated to the extractive fishery and very little reference was made on aquiculture and even within such limited reference to aquaculture, the issues regulated -- clarify the responsibilities of public organization involved in aquaculture and establish the method in identifying the areas appropriate to conduct aquiculture (AAA)-- were to support commercial activities as these two measures allowed simplifying the legal procedures while avoiding the conflict with existing export industry, extractive fisher, respectively.

the Ministry of National Defence, DS. no.499 (1994) the national register of aquaculture and the DS. no. 464 (1995) to disclose the information of fishery and aquaculture activities. In addition to above, the Basic Environmental Law (Ley de Bases del Medio Ambiente) took effect in 1994 (Law no. 19.300) obliging to incorporate Environmental Impact Assessment System (Sistema de Evaluacion Impacto Ambiental: SEIA) before the implementation of any aquaculture activities. In general, the basic legal infrastructure on how to coordinate the aquaculture was established in the 1990s. However, several interviews with the policy makers suggest that these regulations were put in place not to regulate environmental sustainability but more to facilitate business activities.

The first regulatory framework specific to regulate the sustainability of aquaculture was enacted in the 2000s. The condition surrounding aquaculture had changed due to; (1) its growing impact on environment with its increasing scale of economic activity; (2) increasing international pressures to equip with environmental regulatory measures at global standards while Chile was going through bilateral trade agreements. As the result, the DS No. 320 on environmental regulations for aquaculture (RAMA) and DS No. 626 of measures for protection, control and eradication of diseases of high risk for hydrobiological species (RESA) were both passed in 2001. These regulations demanded firms to comply with international environmental and sanitary standards; nevertheless, no additional resources were provided for enforcement and monitoring of these regulations (interview with Mr. Norambuena, former director of aquaculture, Undersecretary of Fishery 2011). Furthermore, in the 2000s, there were very strong pro-growth sentiments within the country, especially for exporting sectors, such as salmon. This made the enforcement of the law by public sector agencies quite difficult to pursue. In fact, during this period, government had to rely upon private-public initiatives to control and monitor the environment and sanitary performance by the firms. The clean development agreement (Acuerdos de Produccion Limpia: APL), the agreement so that firms will 'self-regulate' with support from public sector were signed between representatives of public sector in charge of sanitary and environment at regional level and SalmonChile, the representative of private sector in 2001.

The above demonstrates that although there were early recognition of environmental problem and some regulatory measures were in place, much of these efforts did not materialized due to strong sentiment existed in the public sector to promote economic activity based on a *lassies faire* approach.

b. Increasing concentration of cultivation sites (cultivation permits) in limited geographical areas

In Chile any person to start aquaculture in rivers and lakes need to obtain cultivation permits (concessions) from public authorities. The concessions are granted upon requests from the individuals who wish to conduct aquaculture after going through several administrative clearances.

Below is the figure of number of concessions[1] for aquaculture granted from the early 1980s to 2011(figure 2). The gradual increase of concession is observed in the 1980s; the number increases modestly in the 1990s and rapidly in the 2000s. Until the late 90s, most of the concessions concentrated in Los Lagos region (X region, see figure 3), as it was by far the most suitable area for salmon farming with natural fjords, rivers and lakes. This region, as opposed to Aysen(XI) and Magallanes(XII) regions during this period, was equipped with reasonable access to infrastructure that ensured transportation and labour force. The region had a good number of cities with over 5000 inhabitants, and one with more than 100,000 inhabitants (Puerto Montt, the regional capital). In the late 90s, concessions started move southwards, first to Aysen and gradually to Magallanes. This is due to the fact that Los Lagos region had virtually no more space for new cultivation sites while the world price for salmon was quite high justifying the expansion to southern regions with higher unit production costs.

Insert

Figure 2 Map of Chile and locations of aquaculture concessions

Source: based on map of ProChile.

Insert

Figure 3 Transition on the concession right given by Undersecretary of Fishery (1982-2011)

Source: Undersecretary of Fishery, 2011
Note: *2011 is preliminary figure

In the early 2000s, the government started to engage in promoting its growth; the undersecretary of fishery started to promote the industry further with a clear target: double the value of export of salmon in 10 years from US 1200million in 2004 to US2400million by 2014 (interview with Mr. Norambuena, former director of aquaculture in undersecretary of fishery 2011, interview with Mr. Sandoval, former Undersecretary of Fishery, 2011). To facilitate the above, granting of concession rights which used to take 7-8 years from the application to the actual granting of the concession, was speeded up to induce a more rapid growth of the industry. As the result, many concessions were given in the 2003-2005 period. (Iizuka and Katz, 2010**)** (see figure 3).

Currently, 72% of the salmon farming concessions in Chile are located in a small territory covering no more than 300 km2. The concentration of cultivation centre in Chile is striking if compared with the Norway, whose total area of cultivation spread over 1.700 km2 (Infante, 2008) [7]. Despite the limited areas of territories used for farming, there were no regulations monitoring distance between salmon farming centres (currently 2.2778m) until RAMA was enacted in 2001.

c. increasing fish density within the cultivation centre

The production of salmon in Chile increased dramatically as from 1999 onward and by 2006 it had reached an all time historical peak, at just about the same output level than Norway, the biggest exporter in the world. The strong incentive to increase production came from the rapid raise of world prices from 2001 to 2002 resulting from the diffusion of the avian flu which shifted the demand to fish from chicken. This external change in demand – and the expansion of domestic output – occurred without a parallel improvement in the regulatory mechanism, facilitating many firms to increase fish density in their cultivation tanks beyond biologically sustainable levels.

Table 2 compared the volume of fish per cultivation centres in Chile to that of Norway (see table 2). The table clearly shows the larger volume of fish being cultivated in each cultivation site, and this taking place in an already highly densely populated geographical area. Further to consolidate the high density within the cultivation site, EWOS data – a salmon food company – effectively shows that the increase in average number of fish per cultivation centre (see upper part of table 3) since 2003. in other words., salmon farming firms behaved quite similarly to Hardin's herder mentality of increasing the volume of output out of a given cultivation tank by adding 'one more fish' to a fix unit of space to attain higher profits resulting from the raise in world prices for salmon. In this process, the value of the cost of sound sanitary environment—water, CPR—were undermined partly due to the lack of awareness by firms on the importance and cost (sunk cost) and collective behavior (social technology) and partly due to the lack of sound regulatory measures(rule of the game). Once a given threshold of fish density in the pond had been reached, increasing fish density further worsened the 'common' in which the biomass was being reared. Data collected by EWOS provides circumstantial evidence of decreasing biological quality of CPR, the 'water'.

Insert

Table 2 Average salmon Weight per cultivation centre: Chile and Norway

[7] This was confirmed in the recent public lecture by Mr.Pucchi, of AquaChile SA - the largest Chilean salmon farming firm. He confirms this point by saying that: ´production is 50% larger per concession in Chile while total cultivation area is 70% smaller´ (Pucchi, 2009).

Source: EWOS Health,2007.

Table 3 demonstrates the decreasing trend in productivity of firms in relation to 'water' and the volume of fish produced. While the volume of salmon production increased from 2003 onwards, other productivity indicators also show signs of deterioration. For example, the average weight per fish at the time of harvesting declined from 4.4 kg to 4.1 kg, the number of days required for harvesting expanded from 487 days to 543 days, and the weight of salmon produced (output) per unit of input (smolt or egg) decreased from 3.7kg to 3.1kg for the former and 1.3kg to 1.1kg for the latter. These figures indicate that the economic and biological rate of conversion[8] show signs of deterioration, rising from 1.36 to 1.52 and from 1.24 to 1.34 respectively, i.e. More kilos of feed were needed to produce 1kg of salmon. Above loss is created partly by the higher mortality of fish. Table 3 shows that the rate of fish mortality increased from 15 % in 2003 to 25 % in 2007. There are also increasing sunk cost in expenditure on vaccines and antibiotics required to prevent fish from getting ill, and the additional feed meal needed as a consequence of the extension of harvesting time for slower growth of fish[9].

Despite all economic and biological indicators pointing in one and the same direction— falling productivity from 2003 to 2007—we can observe that export in volume and value increased substantially aided by higher price of salmon during the same period (lower part of table 3). The growth of profit enjoyed by most of Chilean salmon firms was actually created by the raising unit world price of salmon but not from the increase in unit productivity per kilo of salmon. In other words, the pressure on the environmental resources at local production sites was augmented by the increasing demand for salmon at global level. The firm re-enforced this activities due to increasing profit caused by high global price of salmon.

Insert

Table 3 Key indicators for productivity in salmon firms and some export statistics

Source: based on EWOS HEALTH, 2007 and SalmonChile, various years.

4. **Unbalanced growth of 'physical (production) and social technology'.**

Central to our argument is that production and social technologies – i.e. production capabilities and institutions and industry governance – proceeded at quite different pace opening up a wide space for the sanitary and environmental crisis to emerge. We shall now examine both these aspects at the level of the firm, first, then at the level of the industry and, finally, at the level of the public sector regulatory agencies.

4.1 Deterioration of 'social technology'.

(1) Firm-level circumstances

During the mid-1990s salmon firms became increasingly technologically intensive with use of imported capital equipments such as computers, automatic processing technologies, scientific food formulas, to name a few. The technological gaps *vis a vis* the international 'state of the art' was gradually reduced as far as the large Chilean producers is concerned. As the 'physical technology'

[8] Economic conversion rate is the rate in which KG of feed converted into 1KG of salmon in economic value terms, Biological conversion rate is only in biological terms.

[9] One of the former director of salmon firm estimated total loss of ISA crisis as in total of US$550-600million. This includes overall loss of biomass, loss of less growth, loss of adding treatment cost, operational cost and processing cost (Johnson,2007).

came closer to the frontier, we notice that organizational firm structures became more hierarchical, i.e. a larger ´distance´ appeared between company managers and cultivation tanks (based on interviews with Dr. D. Nieto, Dr. P. Bustos, 2010). In other words, managers became more detached from the fish rearing process. Their tasks became managerial 'routine' to achieve efficiency in operating cultivation centres. This was a big difference from the earlier days of industry inception when most of the pioneer managers started off actually interacting with the fish rearing process in the field. Conventional studies in other industries show that the accumulated impact of many ´minor´ changes in production organization eventually 'explain' a very high proportion of productivity gains at the shop-floor level (Katz, 1984). These also would evolve into capability to transform itself dynamically to a changing situation. It is quite likely that in the present case the same applies to the 'non routine' and possibly not economically efficient activities of veterinary professionals being in touch with fish rearing processes (as it occurred in the initial years of industry inception) may have helped enormously to understand the cumulative changes in fish health and local ecological condition and eventually contributed to the sustainability of industry[10]. Hence, the Chilean firms may have acquired 'competence' in production, namely 'physical technology'; but they did not attain appropriate 'social technology' to deal with environmental sustainability as they proceed into larger production scales.

(2) Inside the industry

In spite of the fact that some individuals – veterinarians, biologists –noticed this trends and gave warnings(Johnson, 2007), collective action did not occur to correct the behavior of individual firms due to deterioration of trust and social norm (social capital) among firms (see Vignolo et al, 2007). Instead, the existing firms opted for an opportunistic behavior of short term profit maximization. Furthermore, we noticed that high profit caused by high global price of salmon also attracted new entrants, who were not before part of the salmon farming community (Iizuka and Katz, 2011). This further complicated the possibility of collaboration becoming more important within the sector.

4.2 Underdevelopment of 'physical technology'

(1) Inside the firm

Salmon farming can be described as a technology intensive activity as scientific and technical knowledge is needed at various levels of the production chain, from vaccines to knowledge about oceanography, veterinary sciences, genetics and wellboats. In the early days of Chilean salmon farming firms acquired knowledge through 'learning by doing' and 'trial and error' processes. Despite the fact the public sector resource for R&D activities became available from the end of the 80s, great deal of knowledge obtained was ´incremental´ knowledge resulting from the in house efforts to 'adapt' technology mostly coming from FundacionChile, a public/private sector organization, from Japanese bilateral cooperation and from some early foreign firms (Nichiro & Union Carbide). During the mid-1990s, salmon firms became technologically more sophisticated but they did so importing capital goods. Very little efforts were made in terms of domestic R&D efforts as can be seen in the low R&D investment in the sector of aquaculture compared to Norway and Scotland.

(2) Inside the industry

Above does not mean that Chile completely ignored knowledge acquisition and creation. In fact, some efforts in promoting innovation and research were done by two public sector organizations that financed R&D after the 1990s. National commission for scientific and technological research (CONICYT) which financed national fund for scientific and technological development (FONDECYT),

[10] Of course, there are also isolated cases of successful local firms who have engaged in more profound and complex process of seeking new process technologies, products and organization of work, more respectful of local conditions. We insist, however, these are few cases in a vast number of situations where technology is copied and imported from countries like Norway, Scotland, USA or Canada.

CORFO (the Chilean Economic Development Agency) which did so through FONTEC & InnovaChile (Bravo et al, 2007; Iizuka and Katz, 2011). Table 4 shows R&D in salmon farming was conducted by universities, technological centres, suppliers and producers, between 1987 and 2005. despite of efforts made to promote innovation and research in this sector, innovation projects supported by CORFO have been focused on short term problem solving issues while the ones financed by the CONICYT was not fully utilized by the industry due to the lack of adequate university-industry linkages (OECD, 2007).

Bravo et al(2007) and Bravo (2009) show[11] that much of the research were conducted to enhance productive technology but did not address more fundamental basic research issues specific to the Chilean context such as the local carrying capacity of different cultivation areas in Southern Chile. (see table 4)

Insert

Table 4 Salmon farming research projects by thematic areas in the period 1987-2008.

Source: Bravo, 2009.

In sum, salmon farming in Chile was capable of developing production *competence* but was not capable for obtaining long term *capabilities* for adequately developing country-specific know how and technology capability for securing the long term environmentally sustainable operation of the industry, using the conceptual differences made by von Tunzelmann (2009). In other words, 'physical technology' and 'social technology' travelled at different speed and along different route. Institutions failed to develop at the needed pace.

From the standpoint of production technology, Chilean salmon farming firms became 'world class'. However, this was achieved without concomitantly developing domestic scientific and technological capabilities –indigenous 'physical technologies'—which are able to integrate external knowledge and provide local solutions to emerging new questions of bio-security, environmental sustainability, control of emerging pathogens and more. Producers established their international competence, importing equipment and production know how from abroad, but did not simultaneously paid attention to the specificity of local environmental conditions. The public sector also paid attention to economic growth by promoting this industry but fail to safeguard the ecological sustainability. This lack of attention to local sustainability is prominent feature for catching up countries such as Chile because most of the advanced countries[12] have institutions that facilitate sustainability of business

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[11] The analysis showed that there was emphasis on egg production, disease control etc; however, none was dedicated to the basic researches for finding out local carrying capacity for instance. For more details about R&D expenditure see the document Bravo et al (2007). Note that the figures give below not distinguish between knowledge of adaptive nature respect knowledge from "major innovations". Adaptive knowledge creation refers when an entity -whether business, university, or other organization- adapted existing knowledge to their particular reality; this means it is not at the level of "science frontier", unlike the major innovations.

[12] For example, Norwegian legal framework explicitly ensures the long-term sustainability of local environment and business. They have two types of sources for the funDS. allocated to finance R&D in aquaculture: the funDS. granted by the government and fund created from the collection of royalties from concessions for the use of the common - or patents – by salmon farMs. The funDS. provided by patents work through payment of royalty by the exporters of fish and fishery products. These funDS. are used in R&D projects that benefit the industry and are distributed in the form of subsidies. In this way, the state ensures creation of knowledge for managing CPR through investing in R&D and research. In other worDS., in Norway, where fishery has been one of the dominant economic activities, institutions balancing environmental and business interests were already systemically implemented. Other countries in which aquaculture plays a significant role –such as UK, Canada,

including the ecological aspect through promoting domestic knowledge generation efforts adapted to local specific circumstances.

4.3 Efforts made by public sector to induce institutional change

(1) Attempt by the Chilean public and private sector to facilitate emergence of new institution

Shortly after the ISA incident, government established an institution called MESA DE SALMON (roundtable for salmon: hereafter roundtable) among members of public sector to resolve the 'crisis' swiftly as possible. The roundtable had several tasks: first, modifying the existing sanitary norms and the rules for environmental protection and; second, creating new 'routines' i.e. operational protocols capable of ensuring sustainable future growth of this sector. It is noteworthy that strengthening the 'salmon cluster ' was still contemplated as their tasks at the beginning while the roundtable was required to take on various other additional tasks due to series of events happened subsequently. These are: (1) unemployment in regions; (2) restriction on use of chemicals and antibiotics; (3) bank debt of salmon firms; (4) concession rights and (5) land/coastal use in the regions. Additional tasks made mandatory for the roundtable to go through the legal process to modify the LGPA. The draft modification of LGPA was prepared in 2009 and finally passed by congress in March 2010[13]. It is possible to say that from its creation to the completion of modification of LGPA, the roundtable was a crucial coordinating institution of different stakeholders. Below highlights some efforts made by public sector to; (1) strengthen 'rule of the game' and (2) induce institutional innovation to allow industry sustainability.

(2) Attempts made by the government to induce new institution

The modification of LGPA (law no 18.892) in 2010 created changes in the following areas: (1) concession right; (2) strengthening of sanitary and environmental regulations; (3) introduction of collective management of the 'common' via 'barrios' & 'macro zones' and; (4) strengthening the role of government, particularly the authority of national fishery service to enforce environmental and sanitary regulations. All of these changes concern the new institution, both in terms of 'rule of the game' and 'social technology'.

a. Concession right

Three changes took place concerning concession right. First, concession right was to convert it into a transferable property or an asset that can be used to guarantee a bank loan. The change was made with the purpose to resolve the bank debt problem acquired by salmon firms to replace their conventional collateral, the biomass (fish), which was destroyed by the ISA crisis. Second, the payment for concession right was increased from 2-4[14] UTM per ha per month to 10 UTM per ha per month to finance the enforcement of regulatory measures as well as basic scientific research for better regulatory rules. Third, granting new concessions for the 12th region (Magallanes) is frozen for 2 years similarly for 11th region for a year in order to integrate salmon farming with the coastal zoning plan.

Spain—also have institutions to promote research agendas focusing on environmental impact, health management and food safety (Bravo et al, 2007).

[13] Right after the establishment of law in March, 2010, the government changed from President Bachelet to President Pineara, the opposition party.

[14]The law establish the payment of aquaculture concessions monthly payment of 2UTM per ha of cultivation center until the first 50 ha and 4UTM per ha for the area exceeding 50ha. 1UTM (Unidad de fomento) is equivalent to US $ 46.58 as of March, 2012. After the enactment of law, in 2012, the fee is expected to go up further to 35UTM per ha. The increase of revenue from concession (patente) will be used to finance the research and enforcement of regulation (SERNAPESCA, interview with Mr. Burgos).

b. Strengthening sanitary and environmental regulations

Existing sanitary regulations were strengthened. These are appropriate areas for aquiculture (AAA), regulation on sanitation for aquiculture (Regulamento Sanitario para la Acuicultura: RESA) and regulation on environment for aquiculture (Reglamento Ambiental para la Acuicultura: RAMA). The AAA is an area that shares common epidemiologic, oceanographic, operational or geographic characteristics that has complied with both environmental and sanitary regulations before granting concessions. The identification of AAA require examining diverse information including alternative uses of the site such as natural reserves, touristic attraction, indigenous population, harbour and natural habitat for other hydro biological resources.

The existing regulation on sanitary (RESA) and environmental regulation (RAMA) was revised to strengthen the measures of enforcement. For instance, the modification plans to develop specific regulatory measures to control fish density in the cultivation site, restrict the imports of eggs & movement of fish stocks and monitor the rate of fish mortality. The new reporting system for environmental information (Informacion Ambiental: INFA) was established to make necessary information available to the government. The important new developments are the integration of comprehensive zoning plan for coastal areas with the sanitary and environmental measures. The specific regulation and norms on use of chemicals and antibiotics were also established. Most importantly, for the first time, measures/ methods and standards for implementing sanctions and punishment were clearly stipulated. It is now up to the judiciary system to see that sanctions are being abided for.

c. Creation of 'barrios' (neighbourhood): collective management

The 'barrio (neighbourhood)'[15] or 'a group of concessions' was created as a new institution to collectively manage production among the firms whose concessions are located in similar geographical zones. Concessions located close to each other are grouped into 'barrios', the designated area determined by similar operational and geographical characteristics with oceanographic and epidemiological consideration so that sanitary management of aquaculture can be effectively executed. All of these 'barrios' are grouped into macrozonas (macro zones) also determined by the geographical characteristics.

The purpose of establishing 'barrio' was to synchronize the production calendar among the concessions located in similar geographic areas as a way to diminish the risks of sanitary crisis. The coordination of production calendar within the concessions in the same 'barrio' means different owners of concessions have to agree to one production calendar including fallowing period, a resting period for the environment to regain its biological properties. Firms also needed to agree on jointly programming their navigation services as navigation is singled out as one source of pathogen transmission. The producers in the same 'barrio' are also obliged to jointly implement regulations on fish escapes and placing appropriate distance between the cultivation centres.

The 'barrio' is a new instrument that encourages the owner of different concessions to collaborate to find effective collective solutions. The decision making process within the 'barrio' is to follow the democratic rule of one concession one vote. At the initial stage in 2010, geographical areas for salmon cultivation in the sea and coastal areas of 10^{th} and 11^{th} regions are divided into 7 macro-zones (4 in 10^{th} region and 3 in 11^{th} region) and 58 'barrios' (neighbourhoods)(24 in 10^{th} region and 34 in 11^{th} region) according to the zoning established by the RS. No 450 in 2011, this was modified into seven macrozones and 61 barrios in the 10^{th} region (24 barrios) and 11^{th} region (37barrios) (Subsecretaria de Pesca, 2011 res, extebti 18.96).

[15] The original proposal for dividing fish farming areas into barrios in the 10^{th} and 11^{th} regions is made by the SalmonChile.

d. Strengthening of public sector, National Fishery Service and Undersecretary of Fishery for the enforcement of modified LGPA

The modification of law entailed enhancement of government authority on aquaculture matters by the Undersecretary of Fishery (SUBPESCA) and National Fishery Service (SERNAPESCA)[16]. The Undersecretary of Fishery now can establish resolutions with specific details with regards to implementation such as determining the indicators (e.g. density of fish in cultivation by species) through consultation with experts. The National Fishery Service (SERNAPESCA) now can enforce regulations set by the undersecretary. For instance, prior to the modification, the national fishery service had limited authorization for inspection; however, after the modification; it is entitled to inspect all registered property related to aquaculture[17]. In addition to that, they have now an authority to stop any transit of vessels between macrozones as well as between 'barrios' when they decide that there is a sanitary emergency.

(3) Initial challenges faced by the public authorities

The modification of LGPA of 2010(Ley 18892) has outlined the framework for controlling the sanitation and environmental condition for salmon industry. The effective implementation depends on converting the framework into measures and actually enforcing them. One way to do that was to strengthen the 'rule of the game' by specifying the indicators to be controlled by the regulatory agencies. Another was the interesting attempt made by the public sector to induce institutional innovation through introduction of 'barrio' and 'macrozones'.

a. Trial and error process for creating for better 'rule of the game'

After the modification of LGPA various resolutions[18], were issued one after another in an attempt to make the law operational. Both SUBPESCA and SERNAPESCA are currently going through a trial and error period of learning and identifying the better indicators through interacting with experts and firms. Despite the rapid learning curve, much of the measures taken are still focused on short-term problem but not on the fundamental long term issues. This would require a scientific research to create the regulations that would take into consideration the actual carrying capacity of the environment. As the study by Bravo et al (2007) indicated, much of the research conducted in aquaculture has been aimed mainly at the improvement of production capabilities and did not address the fundamental issues related to the specificity of the Chilean production environment and carrying capacity resulting from its oceanography, biology and geography. For this reason, the public sector is currently trying to strengthen research capacity to fit the regulations to the local natural environment and biological conditions. It is contemplated to strengthen the role of Instituto de Formento Pesquero(IFOP) to collaborate in these topics. IFOP has been actively involved in the formulation of regulations and norms (such as decision over fishing quota and prohibition period) in extractive fisheries. However, details of IFOP's involvement are not being clearly stipulated, yet.

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[16] On 3 August, 2012, Law (Ley No. 20597) was passed the congress to further strengthen the authority of above two institutions with regards to aquiculture. The Law officially changed the Undersecretary of Fishery to Undersecretary of Fishery and Aquiculture and upgraded the department of Aquiculture to Division, making it the same legal status as National Commission. In the similar manner, the National Fishery Service was changed to National Fishery and Aquiculture Service (Aqua, Crean Nueva Subsecretaria de Pesca y Acuicultura, 06, August, 2012).

[17] Farm, stores, warehouse, slaughter facilities (processing plants), fish nurseries, ships, aircraft, train, vehicles, boxes, packages and packaging items.

[18] Resolutions (Ley extenta) are a form of law that specifies the details within the framework law (Ley general). This does not require political approval through the Congress. This form of law can be issued by the authority of Undersecretary of Fishery alone.

b. Inducing better institution for sustainability

The purpose of establishing 'barrio' was to synchronize the production calendar among the concessions located in similar geographical areas to reduce sanitary risks by having better monitoring and control. This means various different owners of concessions in the 'barrio' have to agree on jointly programming their production calendar of either 21 to 24 months including when to implement sowing, harvesting, give medication & vaccinations and harvest, all of which is to be followed by a 3 months resting period.

Currently, each 'barrio' consists of diverse type of concessions of different owners and each concession may produce different types of salmon—salar (atlantic), coho and trout—with different production calendar with different numbers of months to grow. Furthermore, some small firms which does not have concessions in different 'barrios' and 'macrozones' face the problem of having no cash flow during the fallowing period, as they do not have many alternative cultivation sites under operation. For the above reasons, the coordination of production calendar within the barrio confronts difficulties. Historical lack of trust and social capital among the industry (Vignolo et al, 2007) made the collaborative efforts within the barrio even more difficult.

The effectiveness of 'barrio' is still being discussed among the stakeholders. While some (general manager of INTESAL, the association SalmonChile) criticize that current 'barrio' was not created with good understanding of oceanography and epidemiology, others evaluate positively as the one step forward towards managing the sanitary and environmental information (AQUA, en Puerto Mott: expertos analizaron efectividad de los 'barrios' salmonicultores, 10 Aug, 2012). Overall, the stakeholders seem to agree that: 1) understanding of local environmental specificity is necessary for controlling diseases--that same measures to control caligus (sealice) in 10th region cannot to be applied to the 11th region; 2) collective actions is needed to ensure biosecurity; 3) the 'barrio' can at least be a good coordination instrument, particularly to prevent the incidence of sanitary emergency episodes. 4) further research in oceanography, animal health and production organization conditions is needed to identify the sanitary logistical path necessary to improve the current system. (AQUA, en Puerto Montt: expertos analizaron efectividad de los 'barrios' salmonicultores, 10 Aug, 2012).

As can be seen from above, currently there is a struggle to set appropriate 'rule of the game' and induce emergence of appropriate institution to ensure sustainability. The dialogue to improve the situation is still continuing as we can see that the public-private roundtable (MESA DE SALMON) was re-established as the permanent institution by the Minister of Economy to maintain a negotiation space amongst various agents from both private (including representatives of two associations (SalmonChile, ACOTRUCH, large private firms) and public sectors(the Ministry of Economy, Animal Health Unit, Subdirection of Aquiculture, National Fishery Service) to define effective enforcement measures. This is perhaps the more significant step towards institutional innovation for sustainable management of this industry that has resulted from the 2007 sanitary crisis.

5. Conclusion

Recent expansion of global demand for natural resources—food and energy—has created a production boom in countries endowed with rich natural resource. Many of countries that seek to develop via the exploitation of said resources might not be equipped with the institutions to ensure the environmental sustainability 'path creating' development with sound indigenous capability—'social technology' and 'physical technology'. This paper sought to demonstrate through the examination of the Chilean salmon farming case how such situation could led to environmental and economic crisis, if social and production technologies proceed along separate and incommunicado routes. The case also tried to capture the on-going efforts made by the government to strengthen 'rule of the game' as well as induce the development of new institutions, i.e. 'social technologies'.

The Chilean salmon farming sector was capable to expand production gaining large economies of scale and experimented a sustained process of ´technological deepening´ and growth in productivity in very short period of time. As from this point of view it is possible to say that the industry managed to attain sound production capabilities. However, 'social capabilities – institutions – did not develop sufficiently to ensure the sustainability of the industry. As a result of that, the country myopically neglected the long term sustainability of the common pool resource.

The firms increased production volume and became top producer next to Norway; nevertheless, collective and local institution to manage environmental endowment—'social technology'—did not develop *pari pasu* with the above. Furthermore, firms did not understand that they needed to spend more on R&D activities in order to adequately manage local production conditions and the technological specificity of the domestic environment; as the result, they fail to develop indigenous 'physical technology'. The joint impact of a lack of local knowledge on the local carrying capacity of the resource in different locations and adequate institutions to enforced regulations designed adequately to manage the environment eventually developed in this new version of the tragedy of the commons. Nor the firms, neither the government were able to stop what could a priori be expected to develop into a social failure to exploit in a sustainable way a rich national endowment of natural comparative advantages.

After the crisis, public and private stakeholders are trying to establish institutions both in terms of 'rule of the game' as well as in terms of 'social technology'. It is true that there are still many unresolved questions that demand detail consideration, but we have to admit that changes cannot be achieved overnight; it is the continuous process and outcome in aligning interests of agents involved in a dynamic manner over the years that eventually make countries capable of better management. The change in 'social technology' via change in the 'rule of law' in Chile is a step in the right direction; nevertheless, whether current speed of institutional change can catch up with the speed of biological and ecological deterioration to sustain this industry long term expansion still remains as an open ended question. We must not forget however, that the changes that are taking place in the salmon farming sphere are but a small fraction of the more global changes the Chilean society is undergoing in the search for a fairer distribution of wealth and adequate democratic governance. [19]

[19] Some changes can be observed from the recent student movements in Chile starting from 2011.

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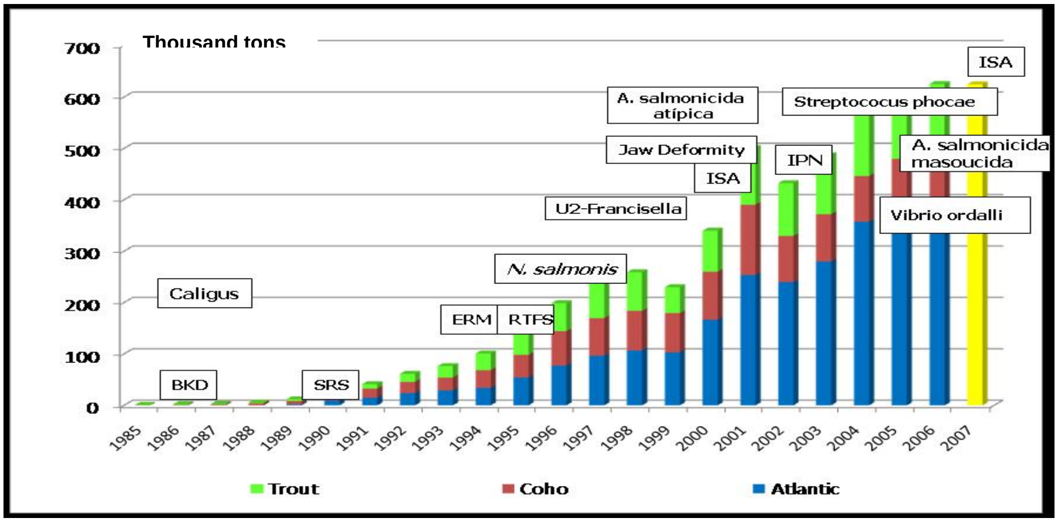

Figure 1 Deterioration of sanitary conditions in salmon farming sites and increase of export

Source: Based on SERNAPESCA, various years and Nieto, 2009

Table 1 Appearance of disease: perception of local veterinarians

Disease	6-7 years ago	Mid 1990s
Bacterial kidney disease	X	X
Piscinketsiosis		X
Infectiouspancreatic necrosis	X	X
Vibriosis (v.ordeli)		X
Vibriosis (v.angillarium)		X
Ulcerative vibriosis		X
Streptococosis		X
Franciseltosis		X
Atypical furunculosis		X
Kudoa		X
Jandrice syndrome		
Nucleospondiosis	X	X
Flavovacteriosis	X	X
Columnaris	X	X
Yersimiosis	X	X
Saprolegiosis	X	X
Caligus	X	X
ISA (infectious Salmon Anemia)		X
Amoebic gill disease.		X

Source: based on survey taken in mid 1990s, Bustos, 2008

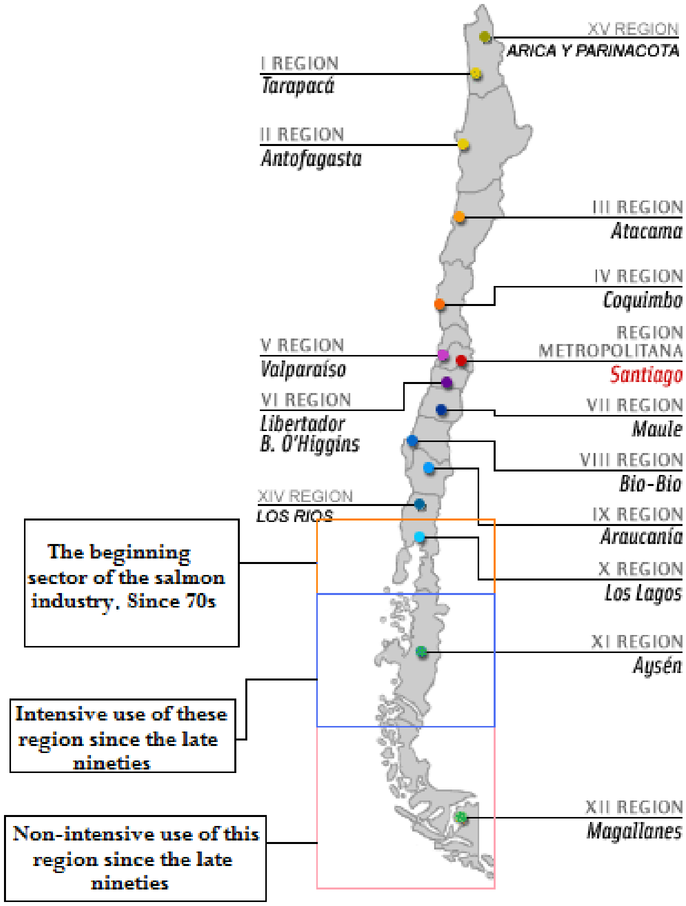

Figure 2 Map of Chile and locations of aquaculture concessions
Source: based on map of ProChile

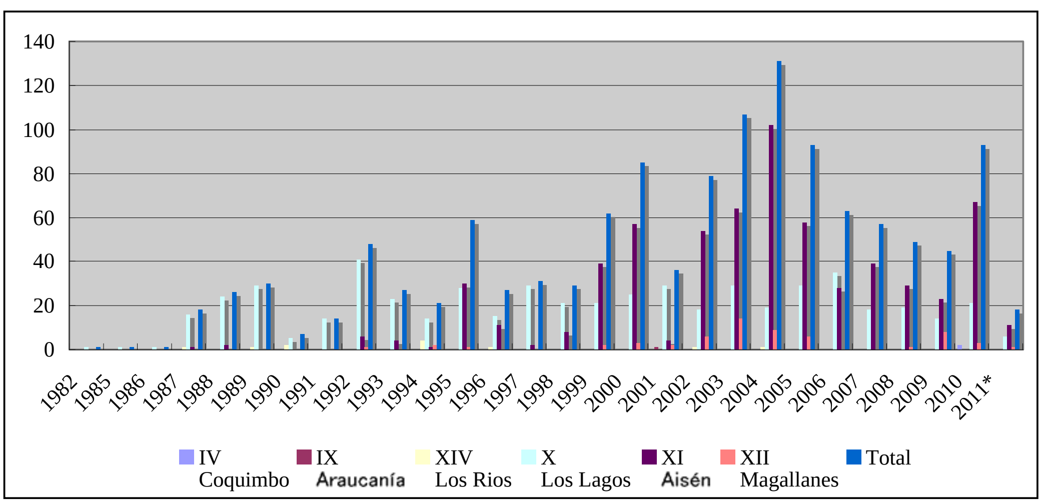

Figure 2 Transition on the concession right given by Undersecretary of Fishery (1982-2011)
Source: Undersecretary of Fishery, 2011
Note: *2011 is preliminary figure

Table 2 Average salmon Weight per cultivation center: Chile and Norway

Chilean cultivation site	Average tons/center
Chiloe centro	1,136
Melinka	1,106
Chiloe sur	859
Estuario reloncavi	1,142
Aysen	757
Hornopiren	1,079
Cisnes	892
Seno reloncavi	1,076
Total	**1,021**
Norwegian cultivation site	**Average tons/center**
Finnmark	255
Troms	499
Nordland	528
Nord-trondelag	518
Sor-trondelag	522
More og fjordane	424
Hordaland	374
Rogaland	506
Ovrige fylker	689
Total	**474**

Source: EWOS Health

Table 3 Key indicators for productivity in salmon firms and some export statistics

	2003	2004	2005	2006	2007
Kg/smolt	3.71	3.66	3.57	3.34	3.14
Kg/egg	1.3	1.28	1.25	1.17	1.1
Average weight at the harvest time	4,444	4,555	4,342	4,219	4,130
Economic factor conversion rate	1.36	1.4	1.38	1.42	1.52
Biological factor conversion rate	1.24	1.27	1.28	1.3	1.34
Days required unitl harvesting	487	497	484	488	543
Number of fish per cultivation center	650,000	700,000	670,000	825,000	945,000
Mortality rate (%)	16	18	17.5	20	24
Volume of production net (000)tonnes	286	355	384	387	397
Export US$(million) FOB	1,146	1,439	1,721	2,207	2,245
Price US$ per kg	4.0	3.6	4.5	5.9	6.0

Source: based on EWOS HEALTH, 2007 and SalmonChile, various years.

Table 4 Salmon farming research projects by thematic areas in the period 1987-2008.

Thematic Areas	**No. project**	**%**	**Chilean pesos M$**	**%**
Pathology and Sanitary Management	77	26,8%	12,140,701	28,9%
Genetics and reproduction	38	13,2%	7,752,516	18,4%
Nutrition and Food	29	10,1%	6,327,948	15,1%
Environment and Clean Production	33	11,5%	3,842,839	9,1%
Technology centres	5	1,7%	3,736,752	8,9%
Engineering and Technology	44	15,3%	3,489,769	8,3%
Cultivation and Production	14	4,9%	1,573,375	3,7%
Training and y Transfer of Technology	18	6,3%	1,026,484	2,4%
Processing and Quality control	13	4,5%	877,022	2,1%
Recreational Fishery	10	3,5%	829,549	2,0%
Administration and regulations	4	1,4%	346,458	0,8%
Small scale aquiculture	1	0,3%	46,874	0,1%
Biology and Ecology	1	0,3%	43,043	0,1%
Total	**287**		**42,033,331**	

Source: Bravo, 2009.

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