Collective Share Quotas and Fishermen Organizations' Role in Ex-Vessel Price Determination [*/]

(Shortened title: *Ex-Vessel Price Determination*)

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July 1st, 2018

Abstract

This paper analyses evidence about atomized fishermen collectively bargaining over ex-vessel prices with a monopsony-like buying sector. Government allocation of collective share quotas to fishermen organizations triggered the voluntary formation of cooperative fishermen's bargaining associations, while a highly concentrated processing sector started behaving as a countervailing monopsony. This drove ex-vessel price determination into a sort of fishing region-specific bilateral monopoly price bargaining. We estimate an empirical model of regional ex-vessel price determination, taking advantage of between-regions regulatory differences to identify the differential effects on ex-vessel prices. Our model estimates the overall impact on regional ex-vessel prices from this process of institutional change. Our results show evidence of policy-shift driven higher ex-vessel prices at only one of the regions studied. This region had more favorable conditions for collective action and it is there where fishermen were able to achieve more stable and better organized fishermen associations.

JEL Codes: *Q22, Q28, L11*

Key words: *Bilateral Monopoly Bargaining; Buyer Power; Collective Fishing Rights; Fishermen Cooperatives; Right-based Fishery Management; Small Producers Associations.*

[*/] This paper has benefited from the inputs provided by M. Smith and two anonymous referees. We also thank S. Tveteras and J.P. Montero for helpful comments. We gratefully acknowledge the support from staff of Subsecretaría de Pesca (A. Gertosio, P. Rojas, D. Rivas, L. Flores) and staff from the Chilean Fisheries Research Institute (IFOP: J. Castillo, L. Chong and E. Palta) for providing us data and information about this fishery. We also thank C. Pérez, L. Pichott and M. Inostroza for introducing us about commercial and institutional details of this fishery.

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Introduction

This is an empirical paper about rent distribution between fishers and catch buyers. It analyses how regulatory reform-driven changes affected ex-vessel prices in the Chilean Austral hake *(Merluccius Australis*) artisanal (small-scale) fishery. This was the first artisanal fishery in Chile[1] that started being managed, since the early 2000s, with collective share quotas assigned, on a voluntary basis, to locally-based Fishermen Organizations (FOs). Regulatory reforms gradually enhanced fishermen's collective fishing rights, inducing the formation of cooperative price bargaining associations within a highly atomized harvesting sector. Meanwhile, a highly concentrated buying sector *de facto* started to behave as a countervailing monopsony.[2] This drove ex-vessel price determination into a sort of region-specific bilateral monopoly price bargaining.

The allocation of collective share quotas proceeded through different paces of fishing-rights consolidation at different fishing regions. Our model focuses on estimating the overall impact on regional ex-vessel prices triggered by this process of institutional change. We expect that time- and regional-differences in the implementation of reforms will allow us to identify the impact of the regulatory shifts on regional ex-vessel prices.

Our case study includes two industry features usually ignored by traditional views about common-pool fisheries (Hardin 1968). First, in many export-oriented fisheries, particularly in those specialized on direct human consumption, atomistic fishers frequently sell their catches to highly concentrated (and sometimes vertically integrated) processing and marketing sectors[3] (Crutchfield and Pontecorvo 1969, Platteau 1989, Geirsson and Trondsen 1991, Doeringer and Terkla 1995, Arnason 1995). Second, atomized harvesters may

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[1] In Chile 'artisanal' sector means more than just having small-scale fishing operations. From a legal viewpoint, it implies not only restrictions on the number and size of vessels that a given fisherman can own but also preferential tax treatments and market informality in the functioning of different transactions (e.g., tax evasion and enforcement weaknesses regarding labor and fishing regulations).

[2] We will see later that in our case study the relevant buyer power is endowed not as much in the processing sector but in the market dominance of wholesale importers to the predominant export market for Chilean Austral hake artisanal catches.

[3] The feature of concentrated demand sectors doing trading with atomized producers is common to many food processing industries, such as agribusiness (e.g., sugar beet, tomato pulp, tobacco or fruit growing production; Glover and Kusterer 1990; Korovkin 1992; Little and Watt 1994) and production chains in the beef, pork and poultry meat industries (Barkema, Drabenstott and Novack 2001; Martinez 2002).

then try to improve coordination among them to strengthen their bargaining position when trading with concentrated catch buyers (Crutchfield 1956; Munro 1982).

Both features can have implications upon the traditional overfishing result but also over the fish resource's rent distribution. For example, the former issue has been dealt with by analyzing whether vertical integration between fishers and processors may lead to harvesting solutions closer to the first-best outcome (Clark and Munro 1980; Munro 1982; Schworm 1983; Stollery 1987); while the second issue has led to discuss the resulting ex-vessel price (Blair and Kaserman 1987; Matulich, Mittelhammer and Greenberg 1995).

Part of the latter literature has analyzed the effect of individual fishing quotas (IFQ) implementation, with catch rights exclusively assigned to fishers, on rent distribution between fishers and processors (Matulich, Mittelhammer and Reberte 1996; Matulich and Clark 2003; Hackett et al. 2005; McEvoy et al. 2009). A basic claim from this literature is that as IFQ management slows down the pace of harvesting, over-capitalized (sunk capital) processors will bid up the ex-vessel price of fish, thus transferring some or all or the IFQ-driven rent gains to fishers. An insight from this literature is that, depending on the industrial concentration prevailing at supply and demand sides and also the specificity of capital invested in the fishery, price bargaining between fishers and catch buyers will determine how much each side gets from IFQ-enhanced rents (Fell and Haynie 2011; Blomquist, Hammarlund and Waldo 2015).

In the case of developing countries, however, scant evidence is available on rent distribution issues resulting from right-based fishery management implementation and even more so about policy-shift driven impacts on ex-vessel prices. Evidence on the economic performance of fishermen organizations in developing countries is equally scarce (Deacon, 2012).[4] In this context we scarcely know about the possibility that

[4] Most of the empirical literature on fisherman cooperatives' involvement in fishery management deals with developed world cases. There are very few exceptions concerning developing-country examples (Ovando et al. 2013). In the U.S., since the late 1990s an interesting policy debate sprang up about the assignment of catch share quotas to harvester groups that exploit fish resources, as a variant to IFQ-based management schemes. Analysis about economic results obtained after the assignment of different types of catch privileges to fishing cooperatives, formed voluntarily in the US, can be found at Larkin & Sylvia (1999), Sullivan (2000), Anderson (2002), Deacon, Parker & Costello (2013), Holland, Pinto da Silva & Kitts (2015), and Abbott, Haynie & Reimer (2015). Other developed-world examples, concerning mobile fish resources with involvement of fishermen's cooperative organizations in fishery management, are the Norwegian Lofoten fishery and the UK experience, since the mid-1980s, with the transferring of regulatory responsibility to fishermen organizations (Jentoff 1989; Hatcher 1996a,b). Further evidence about successful examples of fishermen cooperatives are the *Cofradías de Pescadores* in different regions of Spain and also in Japan; though in the last two cases a

atomized fishermen may collectively bargain over ex-vessel prices with monopsony-like processing or marketing sectors. And yet, knowing more on how ex-vessel prices are determined is related to an important policy issue. Impacts on rent distribution between fishers and catch buyers surely affect the political viability of enclosure reforms for an otherwise common-pool resource.

Our analysis should serve as evidence on how the benefits from sectorial growth are shared between big processing/marketing firms and small producers, and also about the scope for small producers' associations as a way to achieve more equitable welfare gains for smaller producers. Lastly, our analysis also provides evidence about the regulatory reforms made in Chile in the last two decades concerning the management of its artisanal (mobile-species) fisheries.[5] To our knowledge scant evidence is available on this topic (Castillo and Dresdner 2013).

In what follows we first present background evidence about the fishery studied, followed by a description of the regulatory reforms leading to the allocation of collective catch quotas to FOs. Afterwards we specify an ex-vessel price determination model, explain the data and variables considered in the empirical model and analyze the estimation results. Finally, we offer conclusions.

Background on the Chilean Austral Hake Fishery

Austral hake catches occur both in fjord waters and at open seas (within the Chilean EEZ), to the south of 40^{0}SL, by industrial and artisanal fleets.[6] The latter operate in fjord waters and concentrate most of their activities between regions X and XI (see Table 1); region XII is where the southernmost fishing grounds and processing plants of this fishery are located.[7] This fishery's regulations are region-specific. At 2007 the official

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predominant proportion of the examples refer to management of sedentary species, in the context of territorial user rights for fishing (TURFs; Jentoff 1989 and Jentoff & McCay 1995).

[5] This paper does not refer to regulatory reforms in Chile aimed at introducing *Areas de Manejo* (TURFs) for slowly-mobile marine resources, such as *Chilean abalone* --*Concholepas concholepa*. For analysis about these reforms, see Jarvis and Wilen (2015), Gelcich et al. (2010) and Castilla et al. (1998).

[6] According with Chilean fisheries law, industrial vessels are those with more than 18 meters of length and weighting more than 50 tons of registered gross tonnage.

[7] Chile is divided for governmental administrative purposes into 15 regions. The latitudinal limits of the fjords areas of X, XI and XII regions are: X (from 41^0 28.60' to 43^0 44.28'); XI (from 43^0 44.28' to 48^0 49.42'); and XII (from 48^0 49.42' to 55^0 33.2'). If we make a projection of these three regions' latitudinal limits to the corresponding arcs of the earth circumference (surface), region X's arc would cover an extension of about 244 km, region XI about 567 km, and region XII about 756 km. Thus region XII northern limit is more than 800 km further south than region X northern limit; i.e. region XII

registers recorded a total of about 5400 artisanal fishermen and about 1800 artisanal vessels operating, as a monthly average, during the high fishing season in this fishery.

Here Table 1

Most of the Chilean Austral hake production is exported to Spain. The yearly-average exported value during 2008-2010 was US$86.7 million, of which US$37.5 million was fresh-chilled production whose catch supply is mostly provided by artisanal boats. In 2011 the Spanish market bought 97% of the exported value by this fishery, including fresh-chilled and frozen products (the most important product formats). A predominant proportion of the Chilean fresh-chilled exports are sold at Mercamadrid, Madrid's main wholesale fish market.

Historically Austral hake had been mainly used to produce frozen products. However, since the mid-1990s an increasing share has gone into fresh-chilled exports. In 2003 it stood for 40% of the total Austral hake exports and 43.4% in 2011. This reorientation of landings was benefited with the success achieved, since the early 2000s, in rationalizing artisanal fishing efforts (more on this later). Better coordination among fishermen's fishing efforts allowed for catch buyers' better planning of catch supplies, improving the marketing conditions for selling abroad fresh-chilled products. In this business, texture and freshness are key conditionals of buyer price. Because of this, and given different fishing technologies in use by artisanal and industrial vessels, artisanal catches clearly provide better quality for fresh-chilled export products. Thus artisanal catches are overwhelmingly destined for fresh-chilled product formats, while industrial catches during our study period were mostly processed as frozen products (Proyecto FIP 2006-32, henceforth FIP2006-32).

In both frozen and fresh-chilled product segments, a few wholesale importers control a significant market share. In the fresh-chilled segment, during our sample period a single wholesale importer regularly controlled, and traded at Mercamadrid, about 70-80% of the total Chilean fresh hake entering into Spain (FIP2006-32). This dominant importer exerted strong vertical control upon the main Austral hake

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inland waters are at great distances from the main austral hake processing plants which operate at regions X and XI. AS a result of this, region XII's Austral hake catch market operates in a more independent way from the other two regional catch markets.

processing/exporting firms located in Chile.[8] This importer most probably had strong buyer power when demanding Chilean Austral hake artisanal catches. However, the high perishability of fresh-chilled products implies that artisanal fishermen may also have some bargaining power when selling their catch, if they could sell it in a coordinated way.

In Spain the Chilean hake competes with other hake species coming from Argentina, New Zealand, Namibia, South Africa and Spain (the last two are the closest substitutes to Chilean Austral hake). Along our sample period, Chilean hake sales at Mercamadrid show in general an increasing trend. In 2003 there was in total 16,700 tons of fresh-chilled hake that reached Mercamadrid, of which 9,500 tons came from Chile. In 1996, the fresh-chilled Austral hake supplied volume in that market was 4,750 tons. However, since the starting (late 2008) of an economic crisis in Spain, up to the end of our sample period (December 2011), Chilean fresh-chilled hake sales at Mercamadrid started to decline.

Share Quota Allocations to Fishermen Organizations

This fishery has had *de jure* entry restrictions since 1992; but for many years they were ineffective because of enforcement weaknesses. At December 2000 the estimated number of artisanal fishermen regularly operating in this fishery, but not formally registered by the regulatory authority (Subpesca), was around 40% of total active fishermen (Peña-Torres, Bustos and Pérez 2006, henceforth PBP2006). Similarly, annual total allowable catches (TACs) have been in operation since 1995 but a more effective enforcement of them only started since the late 1990s. Additionally, all along the 1990s and up to present times there have been in operation minimum catch-size regulations and seasonal biological closures. Other regulatory adjustments have been introduced to improve compliance with regional TACs: e.g., TACs have been allocated to an increasing number of fishing areas per region; and per-area fishing seasons have been implemented to smooth out fishing effort across time to reduce oversupply pressures on ex-vessel prices.

[8] Strong vertical control was exerted through exclusivity clauses in the supplying contracts with the main vertically-integrated processing/exporting firms and through the provision to these firms of significant ex-ante funding for buying artisanal catches (Peña-Torres, Bustos and Pérez 2006).

Here Figure 1

Despite entry restrictions and TACs, an acute fall in catch yields started since the late 1980s and early 1990s (Fig. 1). Declining yields reinforced fishermen's common-pool incentives to anticipate rivals' catches (e.g. during 1997 monthly quotas were typically fished in only 2 days). This magnified the temporal concentration of fish supplies, diminishing ex-vessel prices. This situation encouraged fishing communities to start coordinating their fishing efforts.

In 1997 representatives of fishermen and catch buyers approached the Government on the concern of implementing a more effective enforcement of entry restrictions and quota regulations. Then it started a process of reforms which gradually led to the allocation of collective share quotas to local FOs. This quota system was thought as an alternative to then politically-unfeasible assignment of individual transferable catch quotas (ITQs) for the artisanal sector (Peña-Torres 2002; Gomez-Lobo, Peña-Torres and Barría 2011). Today this fishery has a well-developed system of collective share quotas, including in several cases a *de facto* operation of per-boat transferable catch quotas, with FOs' co-management efforts being directed to fill in Government's enforcement weaknesses (PBP2006).

Initial reform priorities were put on creating a new regulatory scheme to control the number of boats and fishermen taking part in the fishery: the so-called '*Pescas de Investigación' (PI or 'Research Fishing Trips')* Programs. Under this scheme, and the next one that would follow it, per-area TACs are allocated to FOs.

Once an agreement among Subpesca and participating FOs --each of them representing different fishing areas -- was reached, each per-area *PI Program* defined the boats that would take part in the catch of the TAC involved. Subpesca and the participating FOs decided how to allocate per-area quotas based on historical catch records. They also jointly decided how to divide the use of per-area quotas between intra-year fishing seasons. An agreement between Subpesca and each FO was also reached regarding how to divide each FO's TAC among its member vessels, *de facto* assigning per-boat catch quotas (using different criteria of historical fishing presence). During our study period quota allocations were valid only for the incoming year (in more recent years this has been extended). Therefore, the *PI* scheme, though it formally allocated collective

TACs, *de facto* worked as a per-boat (initially non-transferable) quota scheme (more on this later). However, the fishery regulator still had a detailed involvement in the *PI* scheme, defining who, how and when catch quotas could be used.

There are two distinguishable stages in the development of *PI* Programs. In the first stage, which formally started at September 2000 in regions X and XI[9], quota use control was not fully effective as the official register of operating fishermen, vessels and landings of the artisanal sector was neither complete nor fully accurate. Thus *PI* Programs' initial priorities were on perfecting the artisanal-sector register issue (essential for achieving an effective enclosure). In the X and XI regions the incorporation of FOs to different *PI* Programs was gradual. (Later we describe the case of region XII, the newest fishing grounds in this fishery.)

Private consulting firms became in charge of implementing and partially administering the *PI* Programs. Consultants were responsible for registering active fishermen, boats and quota use in each *PI* Program. Consultants also started to support Subpesca's efforts in monitoring and controlling quota use. However, in regions X and XI the perfection of the register issue was fully consolidated only since September 2002; in region XII this occurred since November 2004. Only from then on per-boat catch quotas started to be fully enforced. This marks the beginning of a second stage in the functioning of *PI* Programs. From then on consultants became fully in charge of registering, monitoring and controlling per-boat quota use. Thus detailed regulatory controls became responsibility of private consultants, while the public-sector enforcement agency (Sernapesca) focused more on a supervisory (auditing-type) controlling role.

Consultants were jointly chosen by participating FOs, Subpesca and catch buyers. Consultants were funded by charging a fixed value per kilogram of catch landed in the areas under their control. Both FOs and catch buyers shared the consultant bill. Each FO also received a fixed payment for providing supporting services. Consultants' contract lasted one year. Contract renewal required agreement from FO's representatives, catch buyers and Subpesca. Despite consultants' work at *PI Programs* did face some initial

[9] During the period 1997-2000 a few *PI Programs de facto* started to operate, first in region XI and later in regions X and XII. However, their functioning was *ad hoc* and informal (there was still no law authorizing this new management scheme) and typically with short or interrupted durations.

problems, during our sample period as time went by contract renewal with the same consultant became the norm (FIP2006-32).

Quota allocation rules, within a given FO, differed depending on the region involved. At regions X and XII, FOs' catch quotas were allocated only on the basis of boat owners' historical catch records. Vessels crew members resented this allocation rule, as in this fishery for long time had been in operation a criterion of dividing catch yields in '*thirds*'.[10] By contrast, in region XI quotas were assigned on the basis of both boat-owners' and crew members' records of historical fishing presence, somehow following the historical '*one third*' distribution rule of artisanal share-contracts. The latter in time led to a more consensual and overall better assessment of the *PI* scheme among region XI's fishermen (FIP2006-32).

Starting from January 2005, 19 FOs of region XI (representing 633 fishermen and having 45.2% of region XI's artisanal Austral hake TAC)[11] joined another new type of fishery management scheme called *Artisanal Extraction Regime* (*RAE* in its Spanish acronym). This regime applies to closed-entry artisanal fisheries and FOs can voluntarily apply to it. Once accepted an application (based on administrative requirements such as certification of fishermen's fishing licenses and FO-membership), Subpesca can allocate annual TACs according to fishing area, FO-membership, fleet size or even on a per-boat or per-fishermen basis. Since its beginnings, most *RAE* Programs have allocated collective share quotas according to fishing areas and FOs' (per-boat) membership. Quota allocation has been based on historical catch records and other historical fishing presence criteria. Since 2006 all region XI's artisanal FOs finally joined the *RAE* scheme and have remained in it until current times.[12] Under the *RAE* scheme, private consultants are again in charge of registering and controlling tasks.

Relative to *PI* Programs, under the *RAE* scheme FOs have greater autonomy for deciding operational matters related to quota use: e.g., how, when and where to use the allocated quotas. Also each FO decides by itself how to allocate its collective quota among its members. In some (FO-specific) *RAE* Programs, the

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[10] 1/3 of the trip's catch for paying the trip fishing costs, 1/3 for the vessel crew and the other 1/3 for the boat owner.

[11] These 19 FOs were authorized to participate in an 8-year *RAE* program. Other 26 FOs (having 49.2% of region XI's TAC) remained during 2005 under *PI Programs*, while other fishermen (having 5.5% of the regional TAC) remained that year under TAC but subject to *Olimpic Race* conditions.

[12] Starting from January 2012, most of regions X's and XII's FOs have also joined the *RAE* regime.

collective quota has been divided on a per-fishermen basis, allowing for quota transferability within the corresponding FO (FIP2006-32).

Regarding quota transferability between different FOs operating under *PI-* or *RAE-Programs*, originally the Fisheries Law did not allow it because of strong political opposition to it (related to fears of quota consolidation). However, informal quota rental trading, among FOs and also between FOs and fishing companies, gradually emerged. Along 2010-2012 Subpesca formally authorized, on a case-by-case basis, short-term quota rental trading (transfers of quota user rights within one year) between different FOs and also between FO and fishing companies.[13]

In the next section we describe how the process of ex-vessel price determination changed once collective quotas started to be assigned to FOs.[14]

Ex-vessel Price Determination: Facts and Theoretical Model

Before *PI* Programs, ex-vessel prices were ex-ante agreed between a given artisanal fleet and catch buyers. When settling price agreements, numerous small artisanal fleets operated in a highly atomized and decentralized fashion, while buyers represented a more concentrated sector (catch buying intermediaries acted as agents of rival oligopolistic processing/exporting firms). Depending on fish abundance at different areas, catch buyers may have competed among them for contracting with several small fleets. However, the supply of fishing effort was often very abundant, implying a fairly elastic fishermen supply that would leave no much room for labor bargaining gains. Hence, all along the pre-reforms period artisanal fishermen were, most probably, price-takers.

However, changing fish scarcity and highly perishable fresh-chilled production imply that fishermen may still have some bargaining power when selling their catch, especially if they could sell it in a coordinated

[13] During 2010 and 2011 there were short-term quota rentals between artisanal FO and industrial fishing companies only in the XI region. In 2010 quota transfers represented 18% of the regional artisanal TAC; in 2011 it was 22%. Unfortunately, there is no official record of prices paid in quota rental contracts; so we have no data for analyzing how much of the regulatory-shift driven rent gains may have been captured through higher market values of artisanal quota permits and how much via higher ex-vessel prices. Deacon, Parker and Costello (2013) do provide estimations that show regime-shift driven changes both in ex-vessel prices and quota permit prices.

[14] There is no scope in this paper for describing other changes observed in FO's collective actions, e.g. FOs' increasing involvement in fishery co-management tasks, as *PI* and *RAE* reforms were evolving. For details on this, see PBP2006 and FIP2006-32.

way.[15] This logic likely underlines fishermen's organizational changes that started after collective quotas were assigned to FOs. As a result, ex-vessel price determination evolved into a more centralized procedure. FOs started to coordinate among them, at different fishing regions, to do a more centralized bargaining over ex-vessel prices with catch buyers. As a reaction, the latter also started to negotiate more as regional-consolidated monopsonies.

The starting of *PI* Programs triggered a strengthening of local FO's leaderships. FOs became more numerous (see Table 1) and smaller, but also more local in their representation and more focalized on improving operational productivity and catch marketing issues; e.g., fishermen union leaders started to negotiate directly with catch buyers when selling the catch (FIP2006-32).

Afterwards, and coinciding with the consolidation of consultants' work on registering and monitoring fishermen's participation at *PI Programs*, a new scheme of (usually monthly) price-negotiation assemblies started. These assemblies occurred before starting the next fishing trips, to determine a unique ex-vessel price for all landings under a given *PI Program*. In each assembly it was agreed the ex-vessel price and catch volumes to be bought from the vessels that were participants of that *PI Program*. Each side of the market (buyers and sellers) tended to negotiate as a coordinated single block. Union leaders acted as the fishermen's representatives. The consultants acted as arbiters and witnesses of the agreements achieved. By year 2003 the scheme of periodic assemblies was of general use in regions X and XI. However, from the very beginning of the *PI* scheme, FOs operating at region XI were able to organize as a more stable and more consolidated (regional) collective negotiation block than the more numerous (and more heterogeneous) FOs operating at region X (FIP2006-32). Hence *a priori* we expect to find greater regulatory-shift driven impacts on region XI's ex-vessel prices.

In region XII, expected effects on ex-vessel prices are less clear on an *a priori* basis. Region XII was the last region in this fishery to voluntarily enter into *PI Programs*. Its retarded entry into *PI Programs* was probably due to a less urgent need to rationalize artisanal fishing efforts. Relative to the X and XI regions, region XII had

[15] Deacon, Parker and Costello (2013) present a similar conjecture when they analyze ex-vessel price effects as the result of a harvester cooperative policy implemented in the early 2000s at the Chignik sockeye salmon fishery in Alaska.

less numerous and more homogeneous groups of boat owners and crew members. As a result, even before the consolidation of *PI Programs* region XII's artisanal fleets had managed to self-coordinate, with reasonable success, their collective fishing effort.

Before consolidation of the *PI Programs* at region XII there was in operation a fishing-effort coordinating scheme called *Flotas de Armadores* (vessel owners' voluntary groups). *Flotas* were in charge of distributing the regional TAC among the different artisanal fleets operating at this region. *Flotas* also helped to control quota use. Thus, *Flotas* served as starting point for organizing the FO's collective efforts to contribute to the management of this regional fishery. Given the reasonable success, pre-consolidation of *PI Programs*, of the *Flotas* scheme, *a priori* we expect to find at region XII milder regulatory-shift driven effects on ex-vessel prices, relative to the case of region XI.

A bilateral bargaining model as starting point for our empirical model

Most of the relevant aspects that describe the fishermen assemblies' process of ex-vessel price determination can be captured by the bilateral bargaining model suggested by Blair and Kaserman (1987).[16] We use stylized features of this model to derive basic intuitions about possible determinants of ex-vessel prices and how regulatory shifts may have affected those determinants.

Assume negotiations about ex-vessel prices are region-specific. Suppose fishermen and catch buyers maximize in a per-season fashion their corresponding profits. Let Q be the output of fresh-chilled products and X the catch volume. Assume fixed proportions in the production of Q. $C_X(X)$ denotes the average unit cost of producing X and $C_P(Q)$ the average unit cost of producing Q, excluding the cost of raw fish supply. P(Q) is the fresh-chilled output demand function and $P_X(X)$ is the ex-vessel price.

Assume regional sales of X are monopolized by a centralized block of regional FOs, while catch purchase is monopsonized by a centralized block of regional buyers. Assume both blocks, when confronting

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[16] This model has also been used as starting point by other empirical models analyzing ex-vessel price determination, in market contexts at which both negotiating parties can have market power (Matulich, Mittelhammer and Greenburg 1995; Fell and Hyanie 2011; Blomquist, Hammarlund and Waldo 2015). The last two papers use an estimation technique which allows to decomposing an observable variable (ex-vessel price) into unobservable causal factors (e.g., a time-varying bargaining-power parameter). However, this technique requires assuming that landings are exogenously determined, assumption which does not necessarily apply to our case study.

each other, have some market power due to catch perishability. Suppose the two monopolies do not wish to vertically integrate.[17] Assume instead they agree on signing a contract that maximizes the combined profits $\pi_T = (\pi_F+\pi_B)$, where π_F is the seller block's (fishermen) profits and π_B is the buyer block's profits. The combined profits π_T are given by:

$$\Pi_T = P(Q)Q - C_X(X)X - C_P(Q)Q \qquad (1)$$

In this model a solution that maximizes π_T is to agree on assigning shares of the combined profits, equal to α and $(1-\alpha)$, to the seller and buyer, respectively ($0\leq\alpha\leq1$). Such assignment of profit shares will occur through the negotiated ex-vessel price. Setting $\pi_F=\alpha\pi_T$, hence $\pi_B=(1-\alpha)\pi_T$, and maximizing π_T by choosing P_X, one gets (Blair and Kaserman 1987):

$$P_X = C_X + \alpha \cdot [P(Q) - C_P(Q) - C_X(X)] \qquad (2)$$

Hence the resulting ex-vessel price will range from a minimum value of C_X, equal to the fishermen's opportunity cost (in case fishermen had null bargaining power, $\alpha=0$), up to a maximum of [$P(Q)$- $C_P(Q)$], in case fishermen had all the bargaining power ($\alpha=1$) and so they would capture the whole rent.

Our empirical model is based on the general notion that the combined effect from the introduction of share quotas, the associated enforcement improvements and their potential effect on fishermen's organization and bargaining power, might have shifted the α parameter over time. Unfortunately, we do not have an observable measure of α, neither can we deduce it. Therefore, the focus of our model will be on estimating the overall impact on regional ex-vessel prices triggered by the process of institutional changes[18] associated to the policy reforms under analysis. This will be tested through the use of reform-activated (region-specific) dummy variables. For identification purposes, we will include controls for time-series changes in other relevant variables such as fishing costs, including controls for possible scale-dependent effects, changes in final demand prices, including a proxy for product quality (fish size), and also controls for other changes that may

[17] For example, given costly monitoring of fishing efforts, assume the most efficient way to perform fishing effort is in a highly atomized fashion.
[18] Changes in the ex-vessel price bargaining mechanism are one, among others, of the institutional changes that were triggered by the regulatory reforms under analysis.

have affected the bargaining power between fishermen and catch buyers (e.g. changes in buyer power concentration).

Data, Variables and Empirical Model

We consider monthly data for most of the variables in the empirical model. Our estimation sample covers from January 2000 to December 2011, excluding August each year. During this month there is regularly in force an absolute ban on fishing which coincides with the reproductive period of Austral hake.

We focus on price determination. But prices and quantities are likely simultaneously determined.[19] Thus we define as endogenous variables both the regional ex-vessel prices and the artisanal landings (expressed in tons).

We model regions X, XI and XII as different but interdependent regional markets. The reasons are: (i) as catch freshness is a basic quality aspect of fresh-chilled products, between-regions transport costs[20] produce regional segmentation in catch markets: time lags between catch, processing and exporting can create considerable value differences in fresh-chilled products. However, (ii) given some degree of inter-regional market arbitrage, e.g. via ex-ante decisions on the volumes of regional catch buying, and the possibility of common non-observable environmental shocks on the three regions' fishing grounds, temporal variations in ex-vessel prices and artisanal landings in each region are expected to be correlated with variations in these variables at the other two regions.[21]

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[19] Assuming perfect quota compliance, maximum landings will be constrained by regional TACs. In this fishery, during the sample period it was illegal to obtain catches in one region and then land them in another region. However, landings could be lower than the corresponding regional TACs, as they did along several years of the sample period, as TAC will not always be necessarily binding because: (i) stock-assessment based TACs can overestimate stock abundance and (ii) under some circumstances (weather, market conditions, fish availability) it may be rational for fishing businesses not always to fully catch the corresponding TAC. Additionally, we only had information about annual regional TACs and these will not be binding for most monthly regional landings. In this fishery annual regional TAC has within-year quota divisions, but the latter change from year to year and also frequently within a given year (as the result of vested interest pressures). Unfortunately, we had no access to reliable time-series data for within-year (seasonal) regional TACs. Despite this limitation, in our initial estimations we included annual regional TACs as controls in the corresponding landing equations. However, annual TACs did not obtain significance so they were excluded from the preferred estimation model.

[20] All fresh-chilled Austral hake production that is destined to export markets is airline transported from regional airports to the Chilean capital's international airport and from there to its main export destiny (Spain).

[21] The simple correlation between the ex-vessel nominal prices for regions X and XI is 80% during our sample period. The corresponding correlation between the ex-vessel nominal prices for X and XII regions is 32%; and the correlation between the ex-vessel nominal prices for regions XII and XI is 42%.

Hence we have six endogenous variables in our model: three regional ex-vessel price equations and three regional landing equations. Denote the regional ex-vessel prices (in logs) by P_X, P_{XI} and P_{XII}; and the corresponding regional artisanal landings (in logs) by Q_X, Q_{XI} and Q_{XII}, for regions X, XI and XII respectively. All (unit) price series are expressed in the domestic currency and in real terms (deflated by the Chilean consumer price index; see Fig. 2).

We made preliminary estimations with the original data; but the results obtained for simple models were unstable and in some cases counterintuitive. After a careful examination of the series we concluded that these issues were related to quality of the landing data. There were some months where the values of these series fluctuated significantly and adopted highly unlikely magnitudes. This could be a consequence of underreporting of landings. Moreover, it was not possible to discern any stable pattern in these fluctuations. We therefore decided to smooth out these fluctuations by using moving quarterly averages (MQA) for all continuous variables. After this change, estimation results became much more stable across different specifications and subsamples. Although this meant we lost part of the monthly variability in the series, since we are interested in the long run effect of regulatory changes on ex-vessel prices, it was a cost we could pay. Therefore, the whole model was estimated using MQA for all continuous variables.

Here Figure 2

The following variables are included as exogenous controls in the empirical model: Fish size, average export price, a proxy for catch buyers' market power and fuel price. We also included some deterministic (seasonal) terms and different dummy variables to capture the effect of regulatory changes.[22] In the following we review each of these variables.

First, the model incorporates a measure of fish unit size (regional average, measured in cm and denoted in logs by *Size*) to control for catch quality. In the fresh-chilled hake trading bigger fish usually obtains higher prices; thus we expect *Size* to be positively associated with ex-vessel prices.

[22] Fishing gears and artisanal boats are homogeneous across the three regional artisanal fleets that we study (FIP2006-32), so they cannot explain differences between regional ex-vessel prices.

The use of the *Size* variable may introduce an endogeneity problem in our estimation model: non-observables affecting the volume of regional landings at month *t* may also affect, in that region, the contemporaneous monthly-average value of *Size* (as the latter is correlated with fish weight). To avoid a potential endogeneity bias in our estimation model, we use a lagged MQA *Size* variable: for each month *t* in the estimation sample, we calculated the corresponding lagged (monthly) MQA value. This variable should be predetermined in relation to our regional endogenous variables. We restricted each regional size variable to enter only at the corresponding (two) regional equations; e.g., the size variable for the X region only entered at the price and landings equations for that region but did not enter at the other regions' equations.

A second control variable is the monthly average export (unit) price of fresh-chilled product formats, as a proxy for the demand price of Austral hake artisanal-catch buyers. Given this fishery's strong orientation to export markets, we expect a non-negative relationship between ex-vessel prices and export prices. The magnitude of the estimated coefficient is expected to depend on the relative bargaining power of supply and demand sides. The lower the fishermen's bargaining power, the closer ex-vessel prices should be to fishermen's reservation prices and the weaker would then be the correlation between ex-vessel and export prices.

The specific way the export price should be included in the model is not evident. One way is the export (unit) fob price of fresh chilled products Austral hake measured in levels. For this we use the monthly MQA of the export (unit) fob price of Austral hake fresh-chilled product formats, expressed in domestic currency (in real terms) and denoted in logs by P_{FOB}. Another way would be to consider the ratio between the monthly average of P_{FOB} (for fresh-chilled products) and the corresponding monthly average of (fob) prices for the Chilean exports of Austral hake frozen products. Call this variable *Ratio.* The conjecture in this second case is that changes in *Ratio* could trigger substitution effects between fresh-chilled and frozen Austral hake products, which in turn may trigger adjustments in the relative allocation of processing capacity to each product format, and through it affects ex-vessel prices. Because of prevailing correlation between P_{FOB} and *Ratio* (simple correlation of 66.5%), we will consider these two variables as alternative controls to identify possible impacts of export prices on regional ex-vessel prices.

Given the existence of high industrial concentration in the Chilean exports of fresh-chilled Austral hake, non-observables might affect both the endogenous variables and the export price variables. This might happen, for example, if Chilean exporters, or the dominant Spanish wholesale importer, of fresh-chilled hake did have enough market power in Mercamadrid, the predominant wholesale export market destination of fresh-chilled Chilean Austral hake.[23] However, despite high industrial concentration in the imports of Chilean fresh-chilled hake into Spain, other countries' supplies of fresh hake (and other white fish) species, also arriving at Mercamadrid, could introduce enough contestability to counteract the possibility of Chilean exporters' market power at this market. During 2004-2010 the exported volume of fresh-chilled Chilean Austral hake sold at Mercamadrid represented between 45-55% of the total volume of traded fresh hake species at this market.

We tested for the possibility that P_{FOB} and *Ratio* were endogenous in our model. We did it in two ways: First, we applied a system long-run weak exogeneity test (the standard exogeneity test used in cointegrated VAR models; Juselius, 2006). Additionally, we applied a Durbin-Wu-Hausman test (Davidson and McKinnon, 2004) to each price and landing equation in the model. This test consists of a two-stage procedure: in the first stage, the variable suspected to be endogenous, P_{FOB} or *Ratio*, is regressed on all exogenous variables used to estimate the first equation (e.g. ex-vessel price P_X). In the second stage, the residuals of the first-stage regression are included as an additional control in the P_X equation, for then testing the significance of this residual variable. The same procedure was also applied to the other regional (price and landing) equations. The results obtained suggest that P_{FOB} could be treated as exogenous in our model, but the results were more ambiguous concerning the exogeneity status of *Ratio*.[24]

To choose a final model specification, selecting between the two export price variables (P_{FOB} and *Ratio*) while taking care of a potential endogeneity problem, we made a series of estimations with different

[23] It was not possible to use, as control variable in our model, the monthly average price of austral hake transactions at Mercamadrid because there was not long enough time-series data of this price.

[24] In five of the six regional equations the exogeneity of P_{FOB} could not be rejected. The only equation where this test was rejected was region XII's landings equation. Moreover, the weak exogeneity hypothesis for P_{FOB} in the cointegrated vector autoregressive (VAR) model neither could be rejected. In the case of *Ratio*, in four of the six individual equations the exogeneity hypothesis could not be rejected (but in the XI and XII regions' landings equations the null of exogeneity was rejected; while the VAR system weak exogeneity hypothesis for *Ratio* was rejected.

specifications in order to check the robustness of our results:[25] we estimated a model excluding both export price variables; two models including one of these variables at a time in a contemporaneous form (assuming both variables were exogenous); and another model using P_{FOB} as an instrument for *Ratio* and then using the instrumented *Ratio* variable (denote it by $Ratio^{EST}$)[26] as explanatory variable in our six-equations model.

In all these alternatives the qualitative results for all other explanatory variables in the model remained unchanged, indicating that there should not be a specification bias in our results. Moreover, the P_{FOB} variable was not significant in all the estimated equations (and in all the specifications considered). At Table 4 we present the results for our two preferred specifications of the export price variable: one considering P_{FOB} (model A) and the other using $Ratio^{EST}$ (model B).[27]

Another control variable in our model is a proxy for industrial concentration at the demand side. We would expect that higher concentration at the demand side implies, *ceteris paribus*, catch buyers' greater bargaining power and thus lower ex-vessel prices (unless the initial price-bargaining context already implied catch buyers' full rent appropriation).

For this control we considered two proxy variables, both based on measures of the Herfindahl-Hirschman Index (*HHI*) calculated at different segments of the wholesale supply chain of Chilean Austral hake exports to Mercamadrid: (a) *HHI* of the monthly Chilean exported value of fresh-chilled Austral hake, denoted in logs by HHI_{export}, and (b) *HHI* of the monthly total regional tonnage of Austral hake catches processed for fresh-chilled product formats at processing plants located at region *R,* denoted in logs by HHI^R. HHI_{export} is region-invariant whereas HHI^R is region-specific. With the latter control, concentration is higher at regions XI and XII, relative to region X. In terms of time-series trends, HHI_{export} first shows a declining phase (until the end

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[25] Another alternative would have been to include the export price variable as a seventh endogenous equation. But this would have reduced much the degrees of freedom in the model and would have made the results harder to assess, so we discarded this option.

[26] To obtain $Ratio^{EST}$ we estimated an auxiliary OLS regression. We regressed *Ratio* on all the exogenous variables included in our model, including all deterministic variables (seasonal, regulatory and impulse dummies), and used P_{FOB} as instrument for *Ratio* (the latter and P_{FOB} are positively correlated while P_{FOB} was tested and resulted exogenous in our model, so $Ratio^{EST}$ is uncorrelated to the residuals of our six equations model). Once we obtained the estimated parameters, we calculated the fitted Ratio value ($Ratio^{EST}$) for each t in our sampling period. We then re-estimated our VEC model, now including $Ratio^{EST}$ as our export price exogenous variable (see the results reported as model B in Table 4).

[27] All other results are available from the authors on request.

of 2002), then a period with short-run variability but no clear trend and afterwards (since early 2008 and up to the end of our sample period) an increasing trend which coincides with a period of economic crisis in Spain. We will later see that HHI_{export} performed better as control variable in our estimation model.

Another control is the domestic diesel price (monthly MQA, expressed in real terms), denoted in logs by P_{diesel}. Diesel costs represent about 50-60% of total operational per-trip costs in this fishery (FIP2006-32). This variable is a proxy for changes in variable unit fishing costs and it shows an increasing trend along the sampling period. However, interpretations about the estimates to be obtained for this control should be careful. First, there are sources of fishing cost variability which are not observed in our model. For example, there is evidence about fishermen's perception that total fishing costs on average increased along the estimation period, because of Austral hake's increasing scarcity (FIP2006-32). If true, this would imply longer fishing trips and higher fishing costs. However, we had no data to control for variability in fishing trips' duration.

Second, during the pre-reform (*Olimpic Race*) period it was predominant that catch buyers (*ex-ante*) funded the diesel costs of incoming fishing trips (PBP2006). In this context an increase in diesel prices could produce two effects: (1) to increase fishing costs, imposing upward pressures on ex-vessel prices; and (2) to reduce fishermen's bargaining power, given their financial dependence on catch buyers' funding, creating downward pressures on ex-vessel prices. There is also evidence that catch quota allocation to fishermen gave them access to formal (banking) credit, especially to the biggest operators (FIP2006-32). This effect would have surely contributed to reduce fishermen's dependence on catch buyers' funding and so it might have favored fishermen's bargaining power. However, we have no data to control for time-series changes in the financial structure of fishing operations. Therefore, *a priori* we do not have an expected sign for the overall impact of changes in diesel prices upon ex-vessel prices.

Our estimations also consider different sets of dummy controls: First, eleven region-specific monthly centered dummies to control for seasonal effects (January is the base month).[28] Second, one transitory (May-June 2000) and other permanent dummy variable (December 2000) to control for non-normal residuals in the

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[28] Given the absolute fishing ban that prevails on August each year, our estimation sample contains 11 monthly observations per year. We calculated centered seasonal dummies on an eleven-month basis so that the total impact on the annual series was null.

Q_X and Q_{XI} equations, respectively. Third, to control for potential effects related to the economic crisis in Spain that started in late 2008 and lasted until 2011, and which might not have been fully captured by variations in P_{FOB}, we also included interactive yearly dummies (for years 2009, 2010 and 2011) with the P_{FOB} (or $Ratio^{EST}$) variable. But these interactions were all not significant and therefore were excluded from the final estimations.

Fourth, for testing the effect of the regulatory shifts that occurred during the sample period, we consider the following dummy variables: PI^R (with R=*X, XI* or *XII* region) is a variable that takes the value of one in months when the *PI* regime was consolidated at region *R*, and zero otherwise. In regions *X* and *XI*, this variable starts to be operative from September 2002; in region XII it starts to be operative from November 2004.[29] In the three regions the base regulatory period corresponds to the first years of operation of imperfectly-enforced *PI Programs*. In regions X and XII the *PI* regime remained operative until the end of our sample period.

In the XI region the *RAE Program* started to be operative since January 2005; and by early 2006 all region XI's artisanal FOs had joined the *RAE* scheme and remained in it until the end of our sample period. Thus, a second dummy variable, denoted by *RAE*, takes the value of one, in the case of region XI, since January 2005 and until the end of our sample period, and zero otherwise. Therefore, in region XI the overall estimated effect of the *RAE* regime (relative to the base period), upon the endogenous variables in the model, will be given by the sum of the estimated coefficients for the PI^X and *RAE* dummies.[30]

Some of our estimations also included interactive effects between the regulatory dummies and the controls *HHI* and P_{FOB}. The conjecture was that ex-vessel price effects from these two controls could be affected by the bargaining power of each negotiating side, which in turn might be affected by the regulatory shifts. However, these interactions systematically did not obtain significant results so they were excluded from the final estimation model.

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[29] Before November 2004, the predominant objective for *PI* programs implemented at region XII was to eliminate black-market transactions which produced distortions in this region's official Register about the identity and number of artisanal fishermen and vessels with fishing permits to operate at this region. This objective was achieved from November 2004 onwards. From then on *PI* programs' objective focused on improving TAC setting procedures and achieving effective quota enforcement.

[30] To avoid perfect collinearity among the three regulatory dummies (PI^X, *RAE* and PI^{XI}), in our estimations we dropped off the latter dummy.

Table 2 shows the summary statistics of our estimation data.

Here Table 2

Estimation model

We used cointegration analysis to identify the effect of the regulatory shifts on ex-vessel prices. The potential problem of non-stationary time-series in a multivariate context suggests that the vector autoregressive (VAR) model with cointegration analysis (Johansen and Juselius, 1990) can be an adequate estimation approach. It can deal with non-stationary series, allowing for lagged effects, while also solving the simultaneous determination of different variables.

The estimation model can generically be established as:

$$Z_t = \sum_{i=1}^{k} A_t Z_{t-i} + \sum_{j=1}^{l} B_t X_{t-j} + \Psi D + \mu_t \quad (3a)$$

or in its error correction form (VECM) as:

$$\Delta Z_t = \sum_{i=1}^{k-1} \Gamma_i \Delta Z_{t-i} + \Pi Z_{t-k} + \sum_{j=1}^{l} B_t X_{t-j} + \Psi D + \mu_t \quad (3b)$$

where Z_t is a (*nx1*) vector of endogenous variables, X_t is a *(mx1)* vector of continuous exogenous variables, and *t* denotes the time period. A_t *is* a matrix of coefficients of dimension *(nxn*), B_t is matrix of coefficients of dimension (*mxm*), *D* is a matrix of binary deterministic variables (here is where the regulatory dummies are included), Ψ is the corresponding parameter vector, μ_t is a column vector of *(nx1)* random errors, and *k* and *l* are the number of lags included in the endogenous and exogenous components of the VAR model; Δ is the difference operator, $(\Gamma_i = -I + A_1 + A_2 + ... + A_i)$, with *I* as an identity matrix of order *n* and $\Pi = -(I - A_1 - A_2 - .... - A_k)$; short-run relations are associated with the the Γ_i matrices, while the long-run relations to the Π matrix. In our model: $Z_t^{'} = \left[P_{X,t}, P_{XI,t}, P_{XII,t}, Q_{X,t}, Q_{XI,t}, Q_{XII,t} \right]$ and $X = [Size^R, P_{FOB}\ or\ Ratio^{EST}, P_{diesel}, HHI^R]$, with *R*=*X, XI, XII*.

Since our key focus was to test whether ex-vessel prices had been affected by the regulatory reforms, once all transitory (short-run) adjustments had been completed, we included the policy dummies in the long-run cointegration vectors. These dummies work as breaks in the intercept of the long-run relations and so they do not affect the asymptotic properties of the model under the null hypothesis (Lutkepohl and Kratzig 2004). The impact of the regulatory changes on ex-vessel prices can then be tested by a significance test on the parameters of the regulatory variables in the cointegration vectors.

The estimation model also allows for short-run analysis. Once the long-run relations are identified, equation (3a) can be estimated in the following manner:

$$\Delta Z_t = \sum_{i=1}^{k-1} \Gamma_i \Delta Z_{t-i} + \alpha \hat{\beta}' Z_{t-k} + \sum_{j=1}^{l} B_j X_{t-j} + \Psi D + \mu_t \tag{4}$$

where $\hat{\beta}' Z_{t-k}$ are the estimated cointegration vectors, previously identified. All variables included in equation (4) are stationary and hence classic econometric tests (t- and F- distributions) can be used. Once eq. (4) is estimated we can test for the significance of the parameters associated with the $X_{t\text{-}j}$ variables.

Estimation Results and Discussion

Appendix 2 provides details on the estimation procedure and results. Three cointegration vectors were identified. We interpret each of these vectors as representing a regional catch market. We thus normalize the ex-vessel price coefficient of each region to one in each vector. However, the simultaneous nature of the system implies that these markets are interconnected.[31] Table 3 shows the results for the normalized cointegration vectors.

Here Table 3

Let us now focus on the regulatory changes' effects on ex-vessel prices (Table 3). In the first vector (price equation for the X region) the estimated parameter for the PI variable is not significant. Thus in this region there is no evidence of changes in ex-vessel prices time-connected to the consolidation of the PI scheme. However, in the price equation for the XI region we find a strongly significant and positive effect of the

[31] We made an over-identifying linear restriction test on the parameters of the cointegration vectors for the null hypothesis of no interconnectivity between regional markets. This null assumed that all the parameters of the landing variables not corresponding to the region of the normalized price were zero: e.g., when the normalized price was P_X the coefficients for the Q_{XI} and Q_{XII} variables were zero (under the null). This hypothesis was rejected with a p-value of 0.000 and a LR-statistic of 74.616.

PI variable on ex-vessel prices. Based on the estimated coefficient for the effect of the PI_X dummy on ex-vessel prices in the XI region, monthly average prices in this region were on average 18.2% higher during the consolidated operation of the PI scheme, relative to ex-vessel prices prevailing in the pre-PI period.

This result is consistent with the hypothesis that the set of institutional changes associated to the consolidated operation of the PI scheme did have a positive impact on ex-vessel prices in the XI region. But in this region the regulatory system was later modified to a RAE regime. The ex-vessel price effect of the RAE regime is captured as the sum of the coefficients for the PI_X and *RA*E variables. We made a test of null coefficient over the RAE variable, which is equivalent to testing for equal effects in the consolidated-PI and RAE periods. The obtained p-value was 0,483, which means that the null is not rejected at any traditional significance level. We also tested if the sum of the coefficients for the PI and RAE variables could be zero during the RAE period. The p-value of this test was 0.087, so we can reject this second hypothesis at the 5% significance level. We therefore conclude that, at a 95% of confidence, the positive effect of regulatory reforms on ex-vessel prices in the XI region also prevailed during the RAE period. In the XII region we did not find any significant effect on the ex-vessel prices during the PI period.

Why do we get these differences between regions? From the beginning of the regulatory reforms, fishermen in the XI region were able to achieve more stable and more efficient regional FOs than fishermen in the X region (PBP2006). Better coordination among within-region FOs should help to improve control on fishermen's aggregate fishing effort and also, eventually, to obtain a better bargaining position when negotiating ex-vessel prices. By contrast, at the X region artisanal FOs are far more numerous (Table 1) and heterogeneous in their economic dependence on Austral hake fishing (FIP2006-32). Thus fishermen at region X faced greater difficulties for building and maintaining more compact and stable negotiation blocks. At the same time, during the post-reforms period, greater coordination was also occurring among catch buyers, at both regional markets, to strengthen their own bargaining position. Hence the estimated non-significant effect of PI_X on P_X probably reflects no change in the price bargaining power of region X's fishermen.

In the XII region, before the consolidation of the PI scheme *Flotas de Armadores* already pursued ex-vessel price negotiations collectively, on behalf of each *Flota*'s members, with catch buyers. In the post PI period ex-vessel price negotiations remained this way in this region. Our results suggest that the consolidated PI scheme did not change in a significant way the process of ex-vessel price determination in this region.

There is no space in this paper for a more thorough discussion of the underlying reasons for the more successful cooperative organizational environment achieved post-reforms by fishermen at the XI region, relative to the other two regions. PBP2006 have argued that this outcome was mostly due to factors exogenous to the policy shifts studied at this paper.[32] Nonetheless, one of the probable causal factors was a direct consequence of how share quotas were initially allocated in each region.

At the XI region the Government's initial quota allocation respected the way how catch was historically divided among crew members and boat owners. When the PI and RAE schemes were introduced in this region, both boat owners and crew members got quota allocations. By contrast, in the X and XII regions collective catch quotas were allocated only to boat owners; crew members received no quota at all. As a result, distributive disputes quickly arose, particularly at region X. These conflicts eroded fishermen's perceptions about the fairness of the new management schemes and surely affected the different organizational success that fishermen were able to achieve at each region.

Table 4 reports the results obtained for the short-run adjustment of the system.[33] We estimated a parsimonious (and robust) version of the VECM model using a sequential elimination of regressors procedure based on the Akaike Information Criterion. Effort to increase degrees of freedom was concentrated on the interactions between the endogenous variables: we tested if the endogenous variables could be excluded from the different equations as a way to identify significant links between the regional markets. In the case of exogenous controls, we kept them in the model independently if they were significant or not, since their inclusion is dictated by conceptual considerations. Let us focus on the results for the exogenous controls. All

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[32] For example: (relative to the XI region) at region X the scale of artisanal fishing operations is greater and FOs are far more numerous, more fragmented and more heterogeneous. Along the sample period there were in the X region 6 artisanal fishermen federations (i.e., regional organizations of more atomised fishermen unions) with direct participation in the austral hake fishery. In the XI region, by contrast, there was only one artisanal fishermen federation that enjoyed high cohesion and coordination power over its associated unions (FIP2006-32).

[33] Following Juselius (2006) we calculated individual goodness-of-fit measures for each regional equation, which are equivalent to the coefficient of determination. These results show that the price equations for the X and XI region, and the landing equation for the X region, have a better fit to the data.

qualitative results for the exogenous controls remain unchanged in models A (using P_{FOB}) and B (using $Ratio^{EST}$).

Here Table 4

The *Size* variable was significant only in the P_X equation. The sign of the estimated parameter is positive, as expected. *Size* systematically obtained non-significant results in the other two price equations. This unexpected result may be related to quality issues in the data available to us when constructing the *Size* variable (see Appendix 1).[34]

The export price (P_{FOB} or $Ratio^{EST}$) variables were, in most cases, not significant in the regional price equations. The only exception is region XI, where $Ratio^{EST}$ is significant at 90% of confidence. The predominance of the non-significant result for the export price variables could imply that ex-vessel price determination was, during the sample period, basically independent of international prices. Given that high industrial concentration prevailed all along this period in the wholesale import market to Spain, and given therefore a probable strong buyer power in favor of the dominant wholesale importer, it could well be the case that the price bargaining power of most Chilean FOs was rather weak. The only (partial) exception may have been the case of region XI´s FOs. However, in case P_{FOB} were thought to be a better control for estimating the effect of international prices on ex-vessel prices, then the estimated increase of 18.2% in region XI's ex-vessel prices, associated to the consolidation of the new regulatory schemes, should probably be interpreted (given the non-significance of P_{FOP} in the region XI's price equation) rather as a price-enhancing effect associated to overall better coordination and control of fishermen's aggregate fishing effort in that region.

The HHI^R variables systematically did not obtain statistical significance in the price equations; hence they were excluded from the final estimation models. By contrast, $HHI_{exports}$ showed significant negative effects on ex-vessel prices in the XI and XII regions, and on landings (negative effect as well) in the X region.

The non-significant results obtained for the HHI^R indexes, calculated at the plant-level, could be the result of strong buyer power concentration at the level of wholesale imports to Spain. Recall the dominant

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[34] Missing observations in the original *Size* variables (in levels, not expressed as MQA) were as follows: Out of a total of 132 monthly observations in our sample period, 10 observations were missing in region X, 32 in region XI and 27 in region XII.

wholesale importer exerted strong vertical control in his contracting with Chilean Austral hake processing/exporting firms. And the dominant importer's catch buying decisions were surely taken from a consolidated (multi-plant) perspective. Then, in a fishery where the bigger exporters own multi-plant operations located at different regions, $HHI_{exports}$ could be a better proxy for buyer power concentration.

The negative price effects of $HHI_{exports}$ in the XI and XII regions are consistent with the hypothesis of buyer power, at the export segment, when deciding catch buying from artisanal fleets operating at these regions. However, price effects from $HHI_{exports}$ were systematically not significant in the X region (this result was valid across different specifications). Two issues can help to explain this result.

First, of the three regions studied, the X region is where independent processing plants (i.e., those which are not owned by, or work under full exclusivity for, Austral hake exporters) have a bigger regional market participation. For example, of the 2000-2011 (cumulative) total tonnage of Austral hake catches processed for fresh-chilled production at the X region, 40% was produced by independent plants.[35] By contrast, most of the plants located in the XI and XII regions are owned by, or works under full exclusivity for, big austral hake exporters Thus, at the X region greater market competition, and so weaker buyer power, may have prevailed among catch buyers when contracting with artisanal fleets.

Second, at the X region both the number of artisanal fishermen and the volume of Austral hake artisanal catches are the largest among the three regions studied (Table 1). Also at the X region is where traditionally more conflicts have prevailed among different artisanal fleets. Notice as well that, at the X region, average fish sizes were (consistently) the smallest among the three regions studied (see Table 2). Thus, it could be the case that at the X region ex-vessel prices were closer to fishermen's reservation prices and hence less sensitive to changes in buyer power. In this case fishermen supply curve would resemble a horizontal line. Thus any change affecting demand should be reflected through quantity adjustments. This feature would help to explain the significant effect of $HHI_{exports}$ on the volume of artisanal landings at the X region.

[35] Source: own calculations based on Sernapesca data about plants' processed tonnage, by species and by processing format (see also Subpesca 2003).

Finally, the diesel price variable showed a significant positive effect on ex-vessel prices only in the XI region and on landings (negative effect) in the X region. As in this fishery fuel costs are ex-ante funded by catch buyers, and so risks associated to fuel cost fluctuations can be partially borne by catch buyers, changes in fuel costs could end up affecting fishermen's ex-post (residual) payment. If fuel costs were consistently increasing, as they did during our study period, one would expect that catch buyers and fishermen bargained over how much of these cost increases should be borne by each negotiating side. From this perspective, our estimation results suggest that only region XI's fishermen were able to partially protect themselves against fuel-cost driven reductions in their residual payment. Regarding the negative effect of P_{diesel} on region X's artisanal landings, this is again consistent with the hypothesis that region X fishermen's supply curve would resemble a horizontal line. Thus changes affecting demand prices (as fuel-cost increases do it by reducing catch buyers' profitability) would be reflected through quantity adjustments.

Conclusions

Distributional fears often hamper advances towards efficient right-based resource management (Libecap 1989; North 1990; Grainger and Costello 2016). Our study has shown that allocation of collective share quotas to local FOs can ease the fears of distributional losses traditionally associated to the introduction of IFQs. In our case study the collective quota system endowed FOs with the right to decide how to distribute, use and control the assigned quota among their members. Thus the policy reforms analyzed in this paper not only refer to community-based share quotas but also involve gradual devolution of management and control decisions to FOs, together with improvements in regulatory enforcement. Once a collective quota system is in operation, policy-shift driven rent gains can create incentives to move forward to further evolution of right-based fishery management. Assignment of collective quotas to local FOs can then be thought of as a transition strategy towards the development of gradually self-enhancing right-based fishery management.[36] In our case study,

[36] A similar message is highlighted by Deacon, Parker and Costello (2013) in their analysis of share catch quotas assigned to a self-selected fishing cooperative in a salmon fishery in Alaska. However, in this case a lawsuit first challenged and then three years later ended the cooperative policy. Its demise was related to a distributive clash concerning quota-right allocations between members of the cooperative and harvesters who were independent of the cooperative. Sullivan (2000), on the other hand, has analyzed antitrust concerns regarding the assignment of catch share quotas by associations of fishing companies to their members, in the U.S. Pacific Whiting and Bering Sea Pollock

several of the FOs that participated in the collective-quota system later introduced governance institutions which increasingly rely on the creation of *de facto* individual transferable catch privileges.[37]

Nonetheless, right-based fishery management cannot be separated from its institutional background. Our estimation results highlight the importance of institutional details when implementing policy reforms. We obtained that policy-shift driven ex-vessel price gains were significant at only one of the regions studied. That region was precisely where fishermen were able to achieve, post-reforms, more stable and better organized FOs. This was so because initial conditions in that region were more favorable to cooperative collective action. But also because in that region better policy choices were made: only there initial quota allocations respected the way how catch incomes had been traditionally distributed between boat owners and crew.[38]

Our study should be of special interest for the management of local common-pool resources in developing countries. In this context, small-scale is usually associated to market informality, information costs and institutional weaknesses in regulatory enforcement. Thus, contracting costs for arriving at Pareto-improving enclosure reforms –having to solve in between distributive conflicts and lobbying pressures-- can be even greater than in the developed world. Under these circumstances, our analysis shows that the voluntary assignment of fishing privileges to producer associations can allow user-right enhancing institutional change to proceed forward, particularly if it is done gradually and with the increasing involvement of --and devolution of management decisions to-- local users.

From a methodological viewpoint, we estimated full ex-vessel price effects resulting from the overall regulatory reforms under analysis. We had no data for a more detailed analysis of factors underlying the regulatory-driven price changes. In cases of right-based quota management reforms, to do further analysis of contributing factors to reform-driven distributional effects certainly remains a desirable research challenge. Another challenge is to disentangle how much of the policy-shift driven rent gains may have been captured

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fisheries. In both cases IFQs were unattainable and so fishing companies pursued fishery rationalization through private ordering. Harvesting share contracts were then sent for review to the Department of Justice (DoJ) Antitrust Division and afterwards they got a favorable 'no enforcement intention' letter from the DoJ Antitrust Division.

[37] Holland et al. (2015) describe a very similar result in their study about the harvest cooperatives that started to operate since 2010 in the US Northeast multispecies groundfish fishery.

[38] Here we again coincide with Deacon, Parker and Costello (2013). Quoting from their conclusions: "*…the Chignik experience suggests that reforms enabling self-selected [voluntary] cooperatives can be Pareto improving, provided that they are designed with care*." (p. 114)

through increases in quota prices, in cases with observable markets for quota transferability, and how much via changes in ex-vessel prices.

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Table 1: Austral Hake Artisanal Fishery Statistics

Region	(1) Number of Fishermen Organizations			(2) Number of registered fishermen (2007)*/			(3) Number of boats in operation (monthly average) 2004-2006	(4) Annual Landings (tons) Average 2000-2011
	2001	2006	2012	# boat owners	# crew members	Total		
X	135	180	208	1952	1654	3606	1535	7268.5
XI	24	60	69	631	758	1389	177	3837.9
XII	n.a.	4	10	120	322	442	45	1767.0
TOTAL		244	287	2703	2734	5437	1757	12873.4

Source: FIP2006-32 and official data from Government agencies (Sernapesca and Subpesca). Regarding data on Fishermen Organizations: 2001 (PBP2006); 2006 (FIP2006-32); 2012 (Sernapesca official data).
Notes: (1): includes Fishermen's Unions, Cooperatives and Guilds; n.a.: non-available; (3) monthly average for the high fishing season, period 2004-2006; */: this fishery is subject to entry restrictions since 1992.

Tabla 2: Data summary (estimation sample; variables in levels, without any transformation –except *Size**)

Variable (unit)	N	Mean	SD	Minimum	Maximum
P_X (CLP/kg)	132	934.1	165.3	669.1	1453
P_{XI} (CLP/kg)	132	1077.3	162.1	562.2	1863.4
P_{XII} (CLP/kg)	132	1011.4	134.4	692.4	1333.2
Q_X (tons)	132	660.8	315.5	1	1587.3
Q_{XI} (tons)	132	348.9	220.4	0.34	1632.4
Q_{XII} (tons)	132	160.6	83.4	0	456
P_{diesel} (CLP/lt)	132	415.9	134.4	174.3	732.3
P_{FOB} (CLP/kg)	132	1677.3	458.3	682.2	2674.7
Ratio (index)	132	0.74	0.14	0.39	1.13
HHI^X *(index)*	132	2240.3	673.2	1439.7	6233.7
HHI^{XI} *(index)*	132	6259.4	2493.2	2532.1	10000
HHI^{XII} *(index)*	132	6690.5	2309.7	2518.9	10000
(MQA) $Size^X$ *(cm)*	130	67.98	2.24	62.8	71.4
(MQA) $Size^{XI}$ *(cm)*	130	71.79	2.69	64.5	76.4
(MQA) $Size^{XII}$ *(cm)*	130	80.95	4.38	71.2	94.1
PI^X	132	0.7803	0.4156	0	1
PI^{XI}	132	0.1970	0.3992	0	1
PI^{XII}	132	0.5985	0.4920	0	1
RAE	132	0.5833	0.4949	0	1

N: Number of (monthly) observations; SD: Stand. Deviation
*: In the case of *Size* we report the MQA value of the corresponding regional variable (details at Appendix 1)

Table 3. Estimated cointegration vectors*

	P_X	P_{XI}	P_{XII}	Q_X	Q_{XI}	Q_{XII}	PI_X	*RAE*	PI_{XII}	*Constant*
Vector 1										
Coefficient	1.000	0.000	0.000	-0.458	0.139	-0.152	0.052	n.a.	n.a.	-3.980
(p-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.003)	(0.024)	(0.330)			(0.000)
Vector 2										
Coefficient	0.000	1.000	0.000	-0.779	0.070	-0.189	-0.167	0.027	n.a.	-1.303
(p-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.202)	(0.015)	(0.012)	(0.482)		(0.040)
Vector 3										
Coefficient	0.000	0.000	1.000	0.100	-0.199	-0.391	n.a	n.a.	0.001	-4.449
(p-value)	(0.000)	(0.000)	(0.000)	(0.295)	(0.003)	(0.000)			(0.985)	(0.000)

* Notes: (1) Endogenous variables are moving averages of the logarithm. (2) All coefficients are presented at the left-hand side of each equation. (3) n.a.: means it does not apply to the corresponding regional equation. (4) The results reported at this Table are valid for both models A and B reported at Table 4.

Table 4: Estimation Results (Parsimonious VECM Model)

Variable	$d(P_X)$		$d(P_{XI})$		$d(P_{XII})$		$d(Q_X)$		$d(Q_{XI})$		$d(Q_{XII})$	
	Model A	Model B	Model A	Model B	Model A	Model B	Model A	Model B	Model A	Model B	Model A	Model B
Endogenous lagged												
$d(P_{X,\ t-1})$	0.487 {0.000}	0.480 {0.000}	0.259 {0.007}	0.248 {0.010}	---	---	-1.163 {0.000}	-1.177 {0.000}	---	---	---	---
$d(P_{XI,t-1})$	---	---	0.421 {0.000}	0.419 {0.000}	0.128 {0.011}	0.127 {0.011}	---	---	---	---	---	---
$d(P_{XII,\ t-1})$	---	---	---	---	0.412 {0.000}	0.400 {0.000}	---	---	---	---	---	---
$d(Q_{Xt-1})$	-0.032 {0.023}	-0.034 {0.018}	-0.065 {0.000}	-0.069 {0.000}	---	---	0.389 {0.000}	0.375 {0.000}	---	---	---	---
$d(Q_{XI,t-1})$	---	---	---	---	---	---	---	---	0.214 {0.006}	0.215 {0.006}	---	---
$d(Q_{XII,t-1})$	---	---	---	---	---	---	---	---	---		---	---
Exogenous												
$d(Size^{X}_{t-1})$	0.831 {0.003}	0.816 {0.004}	n.a.	n.a.	n.a.	n.a.	-0.526 {0.694}	-0.415 {0.755}	n.a.	n.a.	n.a.	n.a.
$d(Size^{XI}_{t-1})$	n.a.	n.a.	-0.232 {0.255}	-0.200 {0.329}	n.a.	n.a.	n.a.	n.a.	1.121 {0.427}	1.147 {0.418}	n.a.	n.a.
$d(Size^{XII}_{t-1})$	n.a.	n.a.	n.a.	n.a.	-0.036 {0.775}	-0.034 {0.789}	n.a.	n.a.	n.a.	n.a.	1.11 {0.130}	1.124 {0.125}
$d(HHI_{exports})$	-0.005 {0.900}	-0.007 {0.862}	-0.148 {0.003}	-0.152 {0.002}	-0.095 {0.018}	-0.094 {0.016}	-0.788 {0.000}	-0.818 {0.000}	-0.198 {0.497}	-0.206 {0.464}	0.075 {0.752}	0.075 {0.747}
$d(P_{diesel})$	0.032 {0.684}	0.039 {0.618}	0.201 {0.032}	0.227 {0.014}	0.016 {0.851}	0.029 {0.730}	-0.68 {0.043}	-0.559 {0.085}	0.354 {0.557}	0.295 {0.619}	0.147 {0.767}	0.106 {0.829}
$d(P_{FOB})$	0.032 {0.605}	n.a.	0.096 {0.194}	n.a.	0.056 {0.412}	n.a.	0.129 {0.622}	n.a.	-0.222 {0.638}	n.a.	-0.186 {0.622}	n.a.
$d(Ratio^{EST})$	n.a.	0.049 {0.472}	n.a.	0.157 {0.072}	n.a.	0.082 {0.260}	n.a.	0.379 {0.213}	n.a.	-0.289 {0.583}	n.a.	-0.294 {0.496}
R^2	0.53	0.54	0.69	0.69	0.39	0.39	0.69	0.70	0.26	0.26	0.29	0.29

Notes: (1) Model A was estimated using P_{FOB} (base model) while Model B was estimated using $Ratio^{EST}$. (2) Notations: variable without *t* subscript denote its contemporaneous value; ---: means the corresponding variable was not significant at 90% of confidence; n.a.: means it does not apply to the corresponding regional equation; d: is the first-difference operator; Value between {.}: p-value. (3) The model also includes seasonal dummies and impulse dummies (not shown in this Table, for parsimony). However, the results for the seasonal dummies indicate that landings on average show higher seasonal values during the second semester of each year; while ex-vessel prices show more seasonality at region XI, with on average higher prices during the 2nd and 4th quarter of each year. (Details about these results are available upon request from the authors). (4) We calculated R^2-alike determination coefficients (last row of this Table), following Juselius (2006).

Figure 1: Artisanal Fleet: Annual (official) landings and TAC (tons)

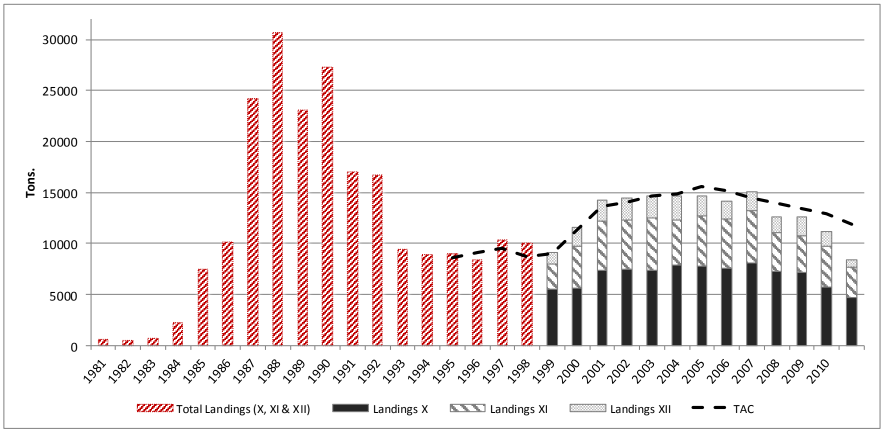
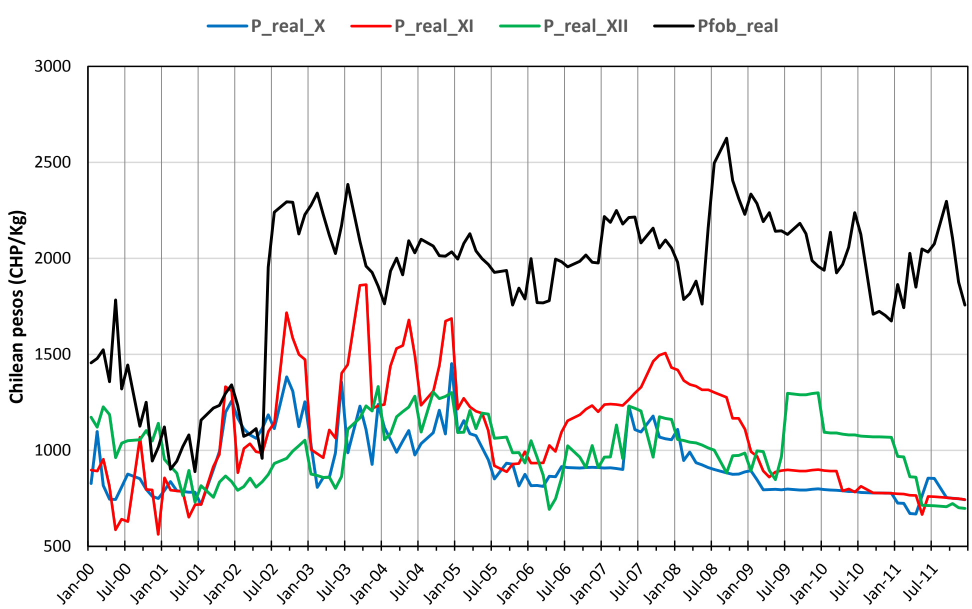


Figure 2: Regional ex-vessel and export (fob) prices (monthly averages)
(Real values; all expressed in CLP/kg)



Source (Figs 1-2): Own elaboration based on data provided by Subpesca.

Appendix 1: Data sources

Landings data was provided by Sernapesca (the enforcement agency) and ex-vessel prices by Subpesca. Our control variable *Size* is a lagged monthly MQA value of fish (unit) size. This variable is based on the Chilean Fisheries Research Institute (IFOP)'s sampling data on fish sizes.[39] As we had some missing observations at each of the three regional fish size monthly series, in our estimations we used MQA *Size* data. For the period January.2006 up to December.2011 we had access to IFOP's estimated (population projected) monthly averages of fish unit size, per region and for most of the months involved. In the case of few missing monthly data in this period, we completed the series by doing linear extrapolations from the contiguous monthly average values to each missing month. For the period January.2000 up to December.2005 we only had access to IFOP's sampling fish size data (at the level of each sampled fish) and no data for a few months. To complete the corresponding regional time-series, we again did linear extrapolations, for the missing months, from the contiguous monthly data.

Regarding our export price control P_{FOB}, we used the monthly MQA of the export (unit) fob price of Austral hake fresh-chilled product formats, expressed in real terms. It results from multiplying the monthly average international export price (expressed in Euros/kg.) by the monthly average of the nominal currency rate (CLP/Euros) and deflated by the Chilean consumer price index. All these values were obtained from the Chilean Central Bank. Export data was provided by IFOP. Equivalent calculations were made for obtaining the other export price variable (*Ratio*).

Information about diesel prices was obtained from the Chilean Energy Commission. In search of parsimony, our estimations use the monthly regional average of diesel prices in region X as the common control variable for diesel prices in the three regions (diesel prices in all three regions were highly collinear).

Appendix 2: Estimation of the VECM model

We first tested for the number (*r)* of cointegration vectors associated with the long-run relations. To determine *r* we used the reduced-rank method (Johansen 1988). Once the number of cointegration vectors was obtained, we tested if the obtained cointegration relations corresponded with the expected theoretical values (over-identifying linear restrictions tests, Lutkepohl and Kratzig 2004). To do this we first made tests to identify the integration order of the variables. This information was used to specify how the different variables should be included in the model (first differences or levels). Then we made tests to specify the lag order *k* and the introduction of non-stochastic components in the VAR model. Once a proper specification was obtained we applied the restricted rank tests to identify the number of cointegration vectors supported by the data.

[39] All along the study period, IFOP regularly carried out a sampling-trip program designed to collect information about fish unit sizes, at each region studied in this paper.

When $0<r<n$ (n denotes the number of endogenous variables), r cointegrating vectors exist. In our case, at most five cointegration vectors may exist (long-run relations). When this happens, one can factor Π such that $\Pi = \alpha\beta'$, where both α and β are $(n \times r)$ matrices. Matrix β contains the cointegrating vectors or the long-run relationships and α encompasses the adjustment parameters. Once the number of vectors is identified, we can test whether ex-vessel price determination should be treated as separate processes between regions. If the latter were the case in the long-run, the data should be consistent with the existence of three cointegration vectors, one for each region, and each region's variables should only participate in the corresponding region's vector.

In what follows we present the results. We first present the unitary root tests. Then we look at the optimal number of lags for the VAR model. Afterwards we show the results for the Johansen's restricted rank test for identifying cointegration vectors. Finally, we present the uni- and multi-equation specification tests.

We made several unit root tests for all variables in the model (in levels, logs, first differences and first log differences). We also checked different specifications with deterministic terms (without constant, with constant, with trend, with seasonal centered dummies, and combinations). This helped to specify the VECM model. Table A1 reports selected results for the endogenous variables in logs calculated with MQA.

Table A1. Augmented Dickey Fuller Unit Root Tests for Endogenous Variables in logs calculated with data in moving quarterly averages (in a model with a constant as deterministic term)

Variable	*Deterministic terms*	*Optimal lags*	*Test value*	*5% critical value*	*10% critical value*
P_X	constant	5	-2.16	-2.86	-2.57
P_{XI}	constant	4	-1.79	-2.86	-2.57
P_{XII}	constant	4	-2.45	-2.86	-2.57
Q_X	constant	4	-4.91	-2.86	-2.57
Q_{XI}	constant	4	-3.92	-2.86	-2.57
Q_{XII}	constant	4	-3.45	-2.86	-2.57
d(P_X)	constant	5	-5.41	-2.86	-2.57
d(P_{XI})	constant	5	-7.13	-2.86	-2.57
d(P_{XII})	constant	5	-5.27	-2.86	-2.57
d(Q_X)	constant	5	-8.91	-2.86	-2.57
d(Q_{XI})	constant	5	-7.37	-2.86	-2.57
d(Q_{XII})	constant	5	-7.11	-2.86	-2.57

d(.): Indicates first-differences

The results suggest that the price variables should be *I(1)* while the landings variables could show a *I(0)* behavior. However, the tests for cointegration vectors (reported later) show that there should be common stochastic trends for these variables.

To specify the VAR model we first tested for the optimal number of lags to be included. Table A2 reports the results. Since the number of optimal lags differs between alternative standard tests we decided to select the Hannan-Quinn and Schwartz Criteria.[40]

Table A2. Optimal number of lags for the multivariate model

Test	Optimal number of lags (in differences)
Akaike Info Criterion (AIC)	2
Final Prediction Error	2
Hannan-Quinn Criterion	1
Schwarz Criterion	1

We estimated different versions of the model and controlled for their statistical specifications. We made specification tests for normality, autocorrelation and autoregressive conditional heteroskedasticity which we discuss later. We finally selected a model that included one lag (in first differences) in the VECM for endogenous variables and zero lags for exogenous variables (except *Size* which enters 1-month lagged, without contemporaneous term), a constant term restricted to the cointegration space, three cointegration vectors, and centered seasonal dummies. Table A3 reports the results for the Johansen's test over the cointegration rank.

Table A3. Johansen's trace test over the cointegration rank

			Critical values at different levels of confidence		
r	*LR*	*p-value*	*90%*	*95%*	*99%*
0	164.3	0.0000	98.98	103.68	112.88
1	86.1	0.0075	72.74	76.81	84.84
2	51.0	0.0909	50.50	53.94	60.81
3	21.3	0.6468	32.25	35.07	40.78
4	10.2	0.6269	17.98	20.16	24.69
5	3.1	0.5671	7.60	9.14	12.53

r: cointegration rank tested*; LR*: Likelihood ratio statistic value. The number of lags in levels is two. Seasonal dummies were included.

The tests suggest at the 90% confidence level that three cointegration vectors exist. This confidence interval should be appropriate given the relatively small sample available. In the main text we interpret these vectors as {price, quantity} quasi reduced-equations for each region. However, since we include regulatory

[40] It is known that the AIC asymptotically overestimates the optimum order with positive probability and that the Hannan Quinn and the Schwartz Criteria estimate the order consistently under quite general conditions (Lűtkepohl and Krätzig 2004).

periods in the cointegration vectors, in the form of shifts in the intercept, we also report in table A4 the results of the tests for the cointegration rank with these shifts included in the model.

Table A4. Johansen's trace test over the cointegration rank
(with breaks in levels at the moment of initiation of new regulatory regimes)

			Critical values at different levels of confidence		
r	*LR*	*p-value*	*90%*	*95%*	*99%*
0	214.18	0.0000	125.89	130.79	140.31
1	126.78	0.0001	95.64	99.96	108.41
2	77.62	0.0190	69.28	73.02	80.40
3	43.16	0.2020	46.88	50.05	56.38
4	15.08	0.8511	28.35	30.94	36.21
5	6.58	0.6387	13.70	15.76	20.14

r : cointegration rank tested; *LR*: Likelihood ratio statistic value. The number of lags in levels is two. Seasonal dummies were included.

Here the tests suggest at the 90% and 95% confidence level that three cointegration vectors exist. Tables 3 and 4 (in the main text) reports the results obtained for the estimated coefficients of the cointegration vectors and the parsimonious VECM model, respectively. To obtain the final (parsimonious) models we tested sequentially with F-tests for the exclusion of non-significant variables. While doing so we additionally checked for consistency and robustness in the sign of the estimated effects. Tables A5 and A6 report the specification tests obtained for the final parsimonious models (models A and B in Table 4).

Table A5. Univariate tests with 16 lags
(All ex-vessel prices are expressed as the log of the corresponding MQA value)

Residuals from equation:	Jarque-Bera[1/]		ARCH-LM[2/]	
	Model A	Model B	Model A	Model B
$d(P_X)$	0.096	0.088	0.124	0.138
$d(P_{XI})$	0.425	0.320	0.094	0.104
$d(P_{XII})$	0.192	0.194	0.112	0.117
$d(Q_X)$	0.473	0.811	0.389	0.145
$d(Q_{XI})$	0.273	0.298	0.368	0.373
$d(Q_{XII})$	0.337	0.352	0.434	0.443

[1/]: Normality test; [2/]: Non-autoregressive heterocedasticity test; reported numbers are *p*-values; d(.): denotes first-differences

Table A6. Multivariable tests

Test	Model A	Model B
Autocorrelation:		
Breusch-Godfrey LM (1 lag)	0.566	0.620
Breusch-Godfrey LM (2 lags)	0.313	0.317
Normality:		
Doornik & Hansen	0.233	0.233
Lütkepohl	0.262	0.275
Autoregressive Heterocedasticity:		
ARCH-LM	0.218	0.240

LM: Lagrange-multiplier; ARCH-LM: Autoregressive conditional heteroscedasticity LM test; reported numbers are *p*-values.

Both the univariate and multivariate tests suggest that the residuals do not suffer from autocorrelation, non-normality or heterocedasticity. We had evidence of non-normality in our initial results. This non-normality was generated by the existence of outliers in different months. We corrected it by introducing impulse dummies. In the final parsimonious models the normality null hypothesis could not be rejected.