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Abbreviations and Acronyms

IVQ	Individual Vessel Quota
FAO	Food and Agriculture Organization of the United Nations
FONCOPES	Fondo Compensatorio para el Ordenamiento Pesquero
IDB	Inter -American Development Bank
IFQ	Individual Fishing Quotas
IMARPE	Instituto del Mar de Peru (Ocean Institute)
ITQ	Individual Transferable Quota
MRAG	Marine Resources Assessment Group
NOAA	National Oceanic and Atmospheric Administration
PRODUCE	Ministry of Production of Peru
RBM	Rights Based Management
TAC	Total Allowable Catch
USD	United States Dollar
WB	World Bank

Abstract

The implementation of rights-based management programs is increasing worldwide yet there are few ex post evaluations, especially in developing country contexts. In this paper we examine changes following the implementation of a catch share system in the Peruvian anchovy fishery, which is the world's largest commercial fishery by volume. After implementation of the Individual Vessel Quota (IVQ) management system, we observe a shift toward higher-value products and a 97% increase in per-unit revenue from 2008 to 2013. We also find that landings are more spread out over the fishing season, with an increase in the number of fishing days. Additionally, fleet consolidation occurs over time with a shift toward larger vessels in the steel fleet. Finally, using cost estimates from a large fishing firm on the cost of steel vessel operation, we estimate variable harvesting profit increased from 34-41% of the ex-vessel price pre-IVQ to 63-65% post.

JEL codes: Q22

Key words: Catch shares, Peru, Individual Vessel Quotas (IVQs), Anchovy

1. Introduction

The use of rights-based programs to manage fisheries has increased over the past 25 years. Accompanying the rise is an increased emphasis on designing programs to address goals related to fishery-specific socioeconomic conditions (see e.g. Kroetz, Sanchirico and Lew (2015)). This is true in both developed and developing country fisheries. For example, both the Peruvian anchovy and Chilean jack mackerel rights-based management programs have unique design features, such as the restriction of trade in a general quota market but allowance for transfers within firms and associations (see Kroetz et al. (2016)) for a detailed discussion and analysis of the Chilean program).

Despite developing countries implementing new rights-based management programs over the past 10-15 years, most performance assessments are on developed world fisheries (Jardine and Sanchirico 2012). This bias is a reflection of both where most of the early adopters of rights based systems are found (e.g., Iceland, New Zealand, Canada), as well as the locations where the data are rich enough to measure impacts (see, e.g., Grafton, Squires and Fox (2000), Shotton (2001), Newell, Sanchirico and Kerr (2005), Newell, Papps and Sanchirico (2007), Chu (2009), and MRAG (2009)).With the number of programs and their diversity increasing, a universal set of indicators was developed to permit comparisons across socioeconomic and biological performance of various fisheries management programs (Brinson and Thunberg 2013). Examples of indicators include measures of the number of active vessels, stock size, season length, as well as total economic profit, per-vessel profit, and per-permit holder profit (see e.g. Agar et al. (2014) and Kroetz et al. (2016)).

In this paper we evaluate the change in several indicators of fishery performance after the implementation of the Peruvian Anchovy Maximum Catch Limits per Vessel System (referred to in this paper as the Individual Vessel Quota (IVQ) system). The first article of the Legislative Decree 1084 states that the program objectives include: establishing a regulation mechanism for the extraction of anchoveta (*Engraulis ringens and anchoa nasus*) intended for indirect human consumption to improve the conditions for its modernization and efficiency and to promote sustained development as a source of food, employment and income, and to ensure its responsible use in harmony with the preservation of environment and biodiversity conservation. In this context, the law 1084 is aligned with the Peruvian Organic Law for the Sustainable Use of Natural Resources (Law 26821).

Although the IVQ title suggests quota is assigned and restricted for use on a vessel-by-vessel basis, the system rules are more nuanced. Functionally, quota can be transferred within firms and through the creation of fishing associations. Therefore, there is the potential for changes similar to those under traditional Individual Transferable Quota (ITQs) programs to occur after implementation. Documenting these changes will provide empirical data to reflect on concerns that ITQs may not be effective in managing highly variable fish stocks such as anchovy. For example, Copes (1986) discusses how difficulties setting TACs for highly fluctuating stocks could result in a mid-season TAC reduction or fishery closure, leading to a diminishing fishermen confidence in their ability to fish their quota allocation in future seasons and a race-to-fish occurring.

We build on several earlier studies that have explored the impact of the anchovy management regime change. Tveteras, Paredes and Peña-Torres (2011) conduct an evaluation of the IVQ system using data from the first two years after implementation. Their results suggest a shift away from low grade fishmeal toward high grade fishmeal and an increase in the landings price with the advent of the IVQ system. The authors also find that the seasons lengthened after the introduction of the IVQ system. In a second paper, Paredes (2012) uses cost data to estimate a 316% increase in variable profit post-IVQ.

Most recently, in 2015 Natividad published an analysis of the impact of the IVQ system. Natividad uses high frequency price data from a large fishing firm and finds evidence of a significant increase in ex-vessel price, on the order of 200% (Natividad 2015). Additionally, using landings data through the first 3 seasons of the IVQ system and calculating productivity as total vessel and firm landings, Natividad models changes in vessel and firm productivity due to the IVQ system. He finds no evidence of an increase in productivity. However, his assumption that the South region of the fishery is an adequate control and that the effect of the change in management is the same for the wood and steel segments of the fleet limit the interpretation of the results, as we find some vessels fish in both regions as well as differences in the wood and steel responses to the IVQ system.

Relative to these earlier studies, we use more detailed data over a longer time period. Using the confidential official government landings database from the Ministry of Production of Peru (known as PRODUCE) containing data on all pre- and post-IVQ landings, we explore changes in the margins over which inputs and outputs can be adjusted and resulting economic efficiency (Smith 2012). We measure revenue changes that may arise from shifts in product form or quality, which in turn can lead to an increase in the per-unit price of the landed fish (see e.g. Smith (2012) and Wilen (2005)). We also investigate other indicators of intensive and extensive margin changes that can impact fishing costs, such as the number of active vessels and vessel capacity. Finally, we develop estimates of harvesting profit pre- and post-IVQ.

Our unique data allows us to provide a detailed characterization of the evolution of the fishery, and generate statistics specific to fishing fleets and regions. Specifically, we treat wood and steel hulled vessels as separate fleets because they receive separate quota allocations and quota cannot be transferred between them. Examining the North-Central and South fisheries separately also mimics the TAC-setting procedure. Because the South TAC only binds in one season due to political-economy reasons stemming from shared fish stocks with Chile, we focus on the North-Central fishing region. We still capture the vast majority of fishery landings, as the South is a small share of total landings (7-18% in the years 2006-2013). Hereafter, when not specified, it should be assumed we refer to the North-Central region. We provide information on changes in the South fishery in the Appendix.

We observe a shift toward higher-value product forms and calculate an increase in the ex-vessel price after IVQ system implementation. Specifically, we compute a 70% increase in the ex-vessel price in the first year of the IVQ system (from 2008 to 2009) and a 97% increase from 2008 to 2013. There is also evidence of changes in capital utilization, potentially the result of association and firm-level transfer provisions. Post-IVQ landings are more spread out over the season, with a greater number of days with at least one landing. In addition to changes in when landings occur, in both the steel and wood fleets we observe a decrease in the number of active vessels and total capacity (calculated as the sum of the capacity of active vessels). This is accompanied by consolidation of landings and trips (measured as a percentage of total landings per season and total trips per season). The steel fleet also experiences an increase in median vessel capacity, suggesting that larger vessels were more apt to remain active in the fishery.

To understand potential changes in economic efficiency we use data from a large fishing firm on cost-per-ton fished by the steel fleet for two pre and two post IVQ years. Comparing seasons 1 and 2 from 2008 (pre-IVQ) to seasons 1 and 2 of 2011 (post-IVQ), we estimate a 138% increase in per-ton profit in season 1 and 196% increase in season 2. This is equivalent to a $265 million and $191 (2013 USD) gain in variable profit, in season 1 and 2 respectively. The total seasonal gains depend on the stock and TAC; in 2011 the TAC and stock were high relative to other post-IVQ years (the lowest post-IVQ season1 landings were 55% of the 2011 season 1 landings and the lowest post-IVQ season 2 landings were 33% of the 2011 season 2 landings), so gains of this magnitude should not be expected to occur in all years. In terms of ex-vessel revenue, the 2011 results suggest an increase from profit comprising 34-41% of ex-vessel revenue to 63-65%.

2. Literature on Evaluation of Rights-Based Management Regimes

Arnason (2012) identifies four dimensions of a property right: exclusivity, durability, security, and transferability. In fisheries, gains are often broken out by those that can occur without a transferable right, and those that can occur only when transfer is allowed. Types of benefits associated with ownership, when transfer is not permitted, include a reduced incentive to race for fish that can result in longer seasons, improved worker safety, lower costs, and greater capacity utilization (see e.g. Herrmann (1996), Knapp (1997), Townsend (2005) and Sylvia, Mann and Pugmire (2008)). As the season lengthens, other benefits can occur such as a slower pace of fishing, improved ability to optimize onboard processing facilities, and increased product recovery rates per pound of fish caught (see e.g. Sylvia, Mann and Pugmire (2008) and Pollock Conservation Cooperative and High Seas Catchers' Cooperative (2007)). Additionally, there is evidence of changes in the product mix to a higher composition of more valuable products, such as fresh rather than frozen fish (see e.g. Pollock Conservation Cooperative and High Seas Catchers' Cooperative (2007), Boyd and Dewees (1992), Casey et al. (1995), Herrmann (1996), and Arnason (1993)), as well as improved quality of fish caught achieved through a change in the type of fishing methods (e.g. gear), timing, and location of fishing (see e.g. Knudson (2003), Casey et al. (1995), Agar et al. (2014), Boyd and Dewees (1992), Wilen (2005), Dupont et al. (2002) and Branch (2006)).

Transferability can result in additional changes, such as the consolidation of quota on the most profitable vessels. For example, vessels that have higher costs of fishing have been shown to exit (see e.g. Weninger (1998), Kompas and Che (2005), and Solís et al. (2014)). In many fisheries, the number of vessels and fishing capacity have decreased after the implementation of an ITQ program (see e.g. Townsend (2005), Sanchirico and Newell (2003), Wang (1995), Brandt and McEvoy (2006), Agar et al. (2014), Dupont et al. (2005), Hamon et al. (2009)).

These changes that can accompany implementation of a new management regime can have significant impacts on economic efficiency. Some researchers have estimated the overall economic impact using quota prices (see e.g. Arnason (1993), Newell, Sanchirico et al. (2005), Newell, Papps et al. (2007), Wilen (2005), and Agar et al. (2014)). For example, Newell, Sanchirico and Kerr (2005) found that the value of fishing quota in New Zealand increased over time for fisheries with greater degrees of freedom to change their fishing operations post-ITQ implementation (such as inshore and shellfish fisheries relative to specialized deep-water fisheries).

3. Historical Regulation of the Fishery

In this section we provide a brief outline of the history of regulation in the fishery; more detail is available in the Appendix. The Peruvian government has historically regulated their anchovy fishery as two distinct stocks, the North-Central stock and the Southern stock. The North-Central stock is much larger, with North-Central landings comprising the vast majority of total annual anchovy landings, and resides solely within Peru's exclusive economic zone (Young and Lankester 2013). The Southern stock is smaller and is shared with Chile (Young and Lankester 2013). From 2006-2013 the percent of total catch from the South ranged from 7-19%.

The Southern stock has traditionally been managed with fewer restrictions and regulations due to difficulties in coordinating management with Chile; for example, the Peruvian government has been reluctant to impose seasonal closures or binding catch limits for the Southern stock out of concern that restricting harvest of the Southern stock would benefit the Chilean fishing industry at the expense of the Peruvian industry (Arias Schreiber and Halliday 2013).

In both regions, anchovy is fished by three different fleets: artisanal, small-scale industrial, and large-scale industrial. The artisanal fleet captures anchovy only for direct human consumption and is composed of boats with capacities not greater than 10 m^3. The small-scale fleet is composed of small boats with hull capacities between 10 m^3 and 32.6 m^3 which primarily catch anchovy for direct human consumption in local markets (Arellano and Swartzman 2010).[1] The industrial fleet is made up of purse seiner vessels larger than 32.6 m^3 and the anchovy caught by these vessels are mostly used for the production of fishmeal and fish oil (Sánchez and Seminario 2009). This report focuses exclusively on the industrial fishery, as the artisanal and small scale fisheries do not participate in the IVQ system.

The industrial fleet consists of a steel and wood fleet, based on the hull material of the vessel. The wood vessels are also called Vikingas (Hildago 2002, Suerio 2008). The steel vessels are generally larger than the wooden vessels and are typically owned by vertically integrated companies. These companies often own multiple vessels and process the fish they catch. The wooden vessels are mostly owned by individuals. For more detail on the fleet differences see Tveteras, Paredes and Peña-Torres (2011). In 2007, prior to the implementation of the IVQ system, steel hulled vessels made up approximately 80% of the storage capacity in

[1] For more information also see the first article of the Legislative Decree 005-2012- PRODUCE.

the industrial anchovy fishery while wooden-hulled vessels controlled about 20% of hull storage capacity (APOYO 2008).

Prior to 1992, industrial fisheries for anchovy in Peru operated under regulated open access conditions. The government regulated fishing gear and opened and closed fishing seasons based on fish reproductive cycles in order to protect juvenile fish and spawning fish. A total allowable catch (TAC) in the North Central zone was implemented, but with weak control on access and with new investment incentives due to the privatization process, the number of industrial vessels increased significantly during the 1990s.

The Peruvian government implemented the 1992 General Fishing Law (Ley General de Pesca No 25977). The law created a limited entry system for the North-Central fishery by setting an industry-wide cap of 200,000 cubic meters of ship capacity with licenses granted to specific ships with specific hold capacities. Vessels that wanted to enter the fishery needed to purchase permits from existing vessels and the hold capacity of the new vessel could not exceed the hold capacity of the previous vessel that held the permit. Transfers were allowed within and across fishing companies. The 1992 Law also limited fishing operations to one trip per day and banned industrial vessels from fishing within 5 nautical miles (nm) of the North-central coast (Arias Schreiber 2012). However, the 1992 reforms were unsuccessful at controlling entry and limiting capacity, potentially due to weak enforcement and access to bank financing, and the number of vessels and processing plants continued to increase and the fishing season shortened as the "race to fish" continued (Tveteras, Paredes and Peña-Torres 2011).

Discussions to rationalize the fishery began as early as 2001. The World Bank started providing funding to create a catch share system for the fishery in 2006 (Tveteras, Paredes and Peña-Torres 2011), which lead the implementation of an individual vessel quota (IVQ) system for the industrial fishery in 2008 with Legislative Decree 1084 (Aranda 2009). The change took effect at the start of 2009 fishing year.

4. The IVQ System

The goals of the IVQ system are described in Young and Lankester (2013) and included improving the biologic, economic, and social conditions of the fishery. Stated biological goals included maintaining a healthy abundance of anchovy, reducing discards by at least 10%, limiting bycatch, and managing water pollution at the docks. While non-target species are not directly incorporated into the IVQ, there is fishery-wide bycatch limit of 5% of the total catch and overages of this limit are penalized with fines. The economic goals included reducing capacity and improving the economic conditions of the fishery by, for example, having longer seasons and increasing handling times to improve product recovery rates. The government's social goals included improving vessel safety and assisting crew members with job retraining programs and retirement planning.

The initial allocation of quota was determined using formulas that differed by vessel hull type and vessel fishing zones. Quota was allocated to industrial vessels, which must be over 32.6m^3 in capacity (D.S. No. 005-2012-PRODUCE). Steel vessel quota was allocated based on the vessels' highest catch in the control period of January 2004 through June 2007 and hold capacity. The formula applied 60% weight to historical catch and 40% to hold capacity (Galarza 2010). Wooden vessel quota was based on vessel catch history only (Galarza 2010).[2] Overall, the steel fleet received approximately 80% of the initial allocation of quota (Galarza 2014b). To maintain some flexibility in quota administration, managers reserve 2.2% of the total fishing quota for each fishing season as a "contingency stock" (Salazar 2010).

The quota regime was implemented in the first fishing season of 2009.[3] The quota allocation assigns a vessel a right to a share of the Total Allowable Catch (TAC). Quota is allocated separately for the two fishing seasons in each year and for the North-Central and Southern stocks.

The boundary between the industrial and artisanal fishing grounds has changed over time. From 1992-2012 industrial vessels in the North-Central could only fish beyond 5nm from shore (Arias Schreiber 2012). In 2012, Supreme Decree 005 pushed the boundary out to 10 nm from the coast (Galarza 2014). The Decree also split the artisanal fleet for Anchoveta in two: the small-scale fleet operating from 5 to 10 nm and the artisanal fleet which operating from 0 to 5 nm. The catch from each of these fleets is intended for direct human consumption (however no monitoring mechanism has been established). The following year, Supreme Decree 001-2013-PRODUCE reduced the industrial boundary to 7 nm in the Southern zone. Supreme Decree 011-2013-PRODUCE reestablished the boundary of 10 nm for the zone North-Central after Decree 005-2012-PRODUCE was declared unconstitutional in November 2013.[4] In 2014 Supreme Decree 011-2013-PRODUCE was declared unconstitutional. In 2015, upon recommendation by IMPARPE, Supreme Decree 001-2015-PRODUCE reduced the industrial boundary to 5 nm in the Southern zone. The artisanal vessels are allowed to fish between 0 and 3.5 nm and the small-scale vessels fish between 3.5 and 5 nm.

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[2] The quota for the Southern region was allocated based on the best catch of the vessel between 2004 and 2007, regardless of vessel type (Galarza 2010).

[3] The IVQ program started in the second season of 2009 for the Southern region.

[4] Decree 005 was declared unconstitutional in the Supreme Court. http://peru21.pe/politica/corte-suprema-declara-inconstitucional-decreto-005-2158507

There are three parameters defining the duration and use of the quota.[5] First, each quota share will be renewed after 10 years (Legislative Decree 1084). Second, if a vessel does not fish the quota once every two years (Article 33.8 of the Supreme Decree 004-2002-PRODUCE) or does not catch at least 20% of their individual quota for four consecutive seasons (article 11 of the Law 1084), the vessel can lose its quota allocation. Third, carry-over of unused quota from one season to the next or from one year to the next is not permitted.

The transferability of quota is limited (see Article 16 and the 5th supplementary provision of the Regulation of the Legislative Decree 1084-2008- PRODUCE). Permanent quota allocations are vessel-specific and indivisible; therefore the asset (right to a share of the catch each year in the future) can only be transferred through sale of the vessel. However, the yearly allocations can be transferred among vessels of the same owner (Tveteras, Paredes and Peña-Torres 2011, Young and Lankester 2013). Yearly allocations may also be transferred through the formation of associations; within an association, vessel allocations can be moved to any vessel within the association. To maintain fleet composition, transfers between the wooden and steel fleets are prohibited (Young and Lankester 2013).[6] However, within these fleet and region groups there are no restrictions on the amount of quota that any one firm can own. Finally, the smaller scale nature of the wood fleet is preserved, because wood vessels must be less than 110m^3 in length to be eligible to fish the wood quota (Article 2 of the Regulation of Law 26920 – 1998 – PRODUCE).

Starting in 2004, independent audit companies have been used to monitor and record landings at all landing sites (Schreiber 2012). At any given time, between 5 and 10% of all the vessels fishing in either the North-Central or South carry onboard observers to monitor bycatch, discards, and juveniles (Young and Lankester 2013). These administrative costs are supported by a cost recovery fee charged to the fleet (see e.g. Galarza and Collado (2013) for more detail). The vessels also must have a satellite vessel monitoring systems (VMS) on-board to ensure compliance with the restriction on fishing near-shore (Arias Schreiber 2012).

Despite these protocols, concerns over enforcement and monitoring, initially raised during the pre-IVQ period, persist related to both the commercial fishery and to an even greater extent the artisanal and smaller scale fishery (see e.g. CSA - UPCH (2011), Cuba (2014), and Heck (2014)). An early paper, Aranda (2009), highlights several sources of corruption and illegal behavior by industrial fishery firms and boats, such as illegal fishing within 5 nm of the coast

[5] An additional restriction is that if a vessel owns quota in both the North-Central and Southern regions, the North-Central quota must be fished before a vessel can proceed to fish the Southern region (although this requirement did not bind in the initial season when the IVQ had yet to be implemented in the South).

[6] Transfers between the North-Central and Southern stocks are also not permitted.

(possible because some of the fleet lacks tracking devices) and the influence of powerful interest groups on the formation and implementation of regulations. Other concerns include the allegiance of surveillance companies to industry rather than the government (they are paid by the industry). Corruption may have dissipated over the course of the post-IVQ years we examine because, in response to these findings, the Ministry of Production started publishing the names of vessels with illegal fishing permits and the organization representing the largest fishmeal producers, Sociedad Nacional de Pesquería, prohibited members from purchasing anchovy from these vessels (Tveteras, Paredes and Peña-Torres 2011). Furthermore, the IVQ implementation process improved the quality and quantity of information on active vessels, increased satellite control, and increased transparency of regulations within ports.

5. Data and Methods

In order to measure the economic changes following the implementation of the IVQ system, we examine several indicators identified by NOAA (Brinson and Thunberg 2013) that can influence fishing revenue, cost, or both. To calculate these indicators, we use a unique confidential data set that includes the official Ministry of Production (Ministerio de la Producción, Dirección General de Extracción y Procesamiento Pesquero, known as "PRODUCE") landings dataset, which has a record of all landings from 2006 through mid-2014, anchovy ex-vessel prices from PRODUCE for the same period, publicly available biomass estimates from IMARPE, and TACs. We also have cost information for steel vessels of various sizes for the years 2006, 2008, 2011, and 2013 from a major fishing company that we use to estimate the change in variable fishing profit in the steel fleet pre and post implementation of the IVQ system.

We break statistics down by hull type to consider potential differences between the steel and wood fleets. When generating most of our statistics we also confine our analysis to the North-Central region for two reasons. First, it is the dominant fishing region, with 82-93% of the industrial catch landed in the North-Central from 2006-2013. Second, the Southern TAC only binds in one season, an important factor in determining fishing incentives. For example, when the stock abundance is variable within the season in the fishing grounds, the lack of a binding TAC could result in a race-to-fish while the stock is still large enough to be profitability fished. Therefore, we do not expect significant changes with the IVQ system in the South.[7] More information about the Southern fishery and summary statistics are available in the Appendix.

[7] A race-to-fish could occur for reasons other than a non-binding TAC in either the North-Central or South. As discussed in Costello and Deacon (2007) and Smith (2012), a race-to-fish could occur if the profitability of fishing changes over the course of the season. But it is important to point out that the characteristics of a race-to-fish with secure tenure (right to share of the catch) is not synonymous with the race to fish with insecure tenure. We show later in the paper that the number of days in the fishery with landings increased post-IVQ in the North-Central.

We calculate variable revenue, cost, and profit for trips in two pre-IVQ years (2006 and 2008) and two post-IVQ years (2011 and 2013). Using data on vessel attributes and trips for 2006, 2008, 2011, and 2013, we assign each trip an estimate of total variable costs and total revenue. Costs are available as cost/metric ton, so the total variable cost is calculated by multiplying the cost/metric ton by the metric tons caught. Developing cost estimates specific to the pre- and post-IVQ years is important to account for possible changes in technology or fishing practices, such as the fuel use of engines and trip length. Using monthly ex-vessel price data from PRODUCE, we calculate the revenue as the landings multiplied by the average monthly ex-vessel price.

After calculating the profit for each trip, we sum the revenues and variable costs across all trips, for each of the four years. Because the TACs vary from year-to-year, we calculate an estimate of average revenue per ton landed, average variable cost per ton landing, and variable profit per ton landed, for each year.

Finally, to separate out effects of world demand on fishery revenue from the effects of the IVQ program implementation, we calculate a second set of counterfactual revenues had the IVQ program not been implemented. We calculate this set of revenues under the following assumptions; (1) the ex-vessel price in Peru would be the same percentage of the export price per ton observed in 2008; (2) the product mix in Peru would be the same as that observed in 2008; (3) the total catch in Peru would have been the same as that observed with the IVQ program in place; (4) the world fishmeal export prices for different types of fishmeal are well approximated by Chilean export prices; and (5) the IVQ had no impact on world prices. We utilize Chilean prices for fishmeal, because product-type specific ex-vessel and export prices per ton are unavailable for Peru.[8]

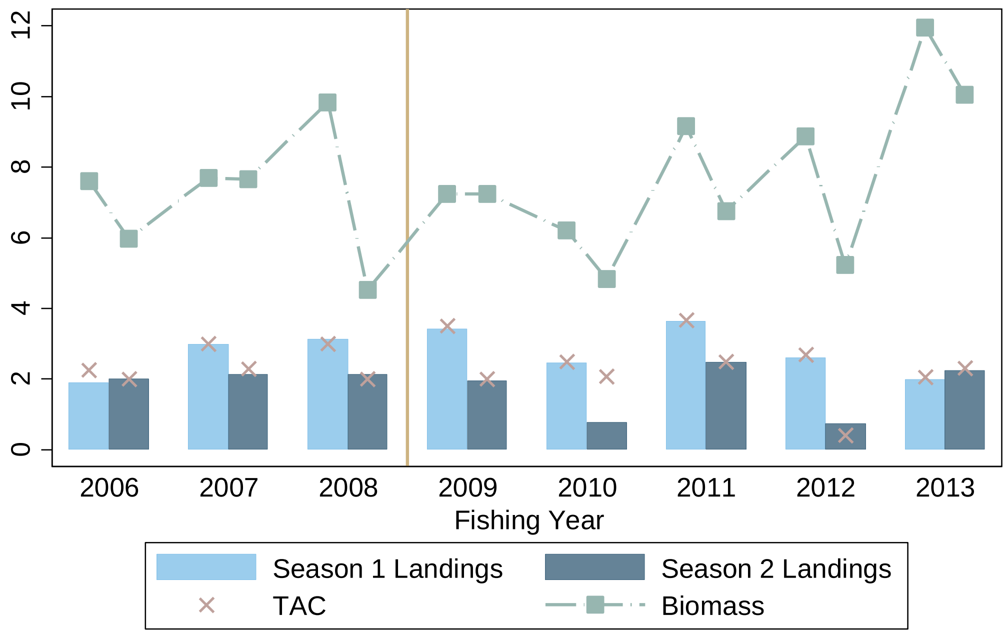
6. Margins of Change

The linkages between the biological and economic systems of fisheries complicate analysis of changes over time. In the Peruvian anchovy fishery, the TAC tends to fluctuate, following the assessed stock size. The anchovy stock fluctuates significantly between seasons within a year and year-to-year, with estimated biomass varying by as much as 200% over the course of the years we have data for (see Figure 1). The TAC generally binds or is close to binding, with the exception of season 2 of 2010. Season 2 of 2010 is the lowest landings year

[8] First we calculate the average real export value per ton implied by the 2008 Peru product quantities and the 2008 Chilean export price data. Next we calculate the average value assuming the same 2008 Peru product mix but 2011 Chilean export values. Then we calculate the percentage increase in export value, for the same product mix, from 2008 to 2011. Finally, we calculate a counterfactual no-IVQ 2011 Peru ex-vessel price, under the assumption that it would have increased by this same percentage. See Kroetz et al. (2016) for information on Chilean export prices.

we have data on, and corresponds to a low-point in the stock abundance and an early closure of the fishery. Fluctuating stock sizes are common for small pelagic species, but questions have arisen in the past about whether ITQ programs can be successfully used to manage these types of stocks (Copes, 1986).

Figure 1: Biomass, TAC, and Landings (Million Metric Tons)



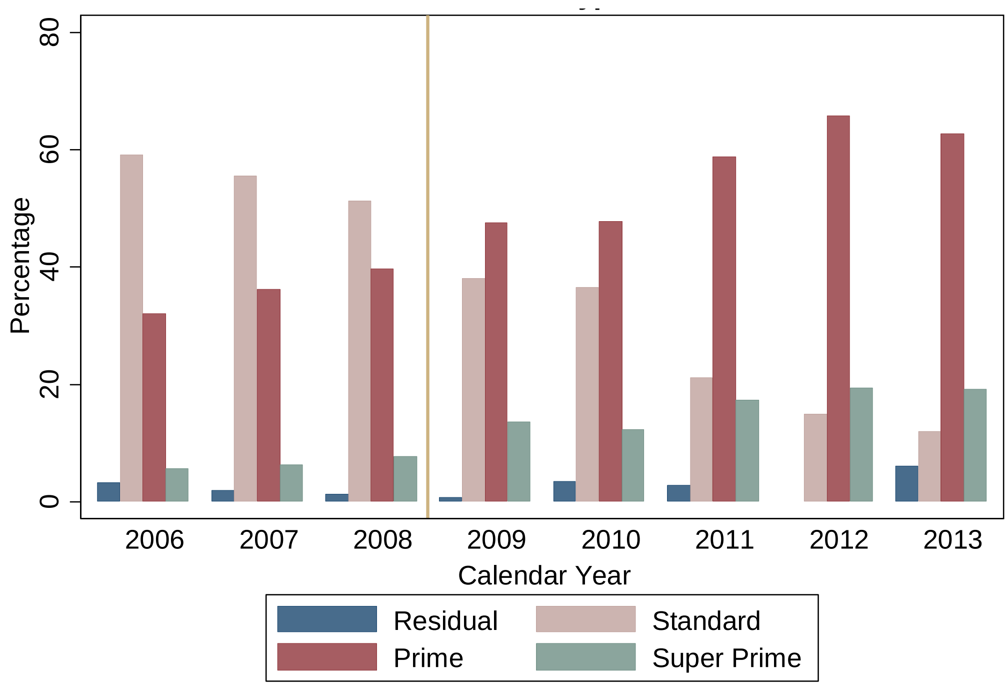
Sources: PRODUCE landings and TAC data. Note: All statistics are for the North-Central region. The solid vertical line corresponds to the start of the IVQ system in the North-Central region.

In the following sections we explore changes that occurred in the fishery that have the potential to impact revenues as well as changes in fleet inputs.

<u>Change in Per-Unit Revenue</u>

Revenue-side changes are an important mechanism that can lead to increases in economic profit. The commercial anchovy catch is used to produce fishmeal, with quality ranging from low-quality residual fishmeal, to standard, prime, and high-quality super-prime. We observe a dramatic change in product type in the fishery (Figure 2) with a shift toward production of higher value products.[9] For example, the share of prime and super-prime fishmeal relative to all fishmeal production increased from around 38% in 2006 to 61% in 2009, to 82% in 2013.

Figure 2: Production of Fishmeal, by Grade, Over Time



Source: Ministerio De Producción - Anuario Estadístico 2010, 2011, 2013.

We also examine the ex-vessel price over time. We calculate a weighted average price for each year, where we use monthly landings as weights for monthly prices (PRODUCE ex-vessel price data). The data from PRODUCE is based on prices recorded for independent market transactions; because of the vertically integrated nature of the steel fleet, most of the ex-vessel price data is based on landings by the wood fleet. We apply this market price to steel fleet landings under the assumption that if the steel vessels were not owned by vertically integrated processors, then they would negotiate the same price as the wood fleet. Because no formal transactions between vertically integrated vessels and processors take place, this is an "implicit" price.

We find that the ex-vessel price of anchovy increased after the start of the IVQ system (Figure 3a). Overall, from 2008 to 2013, there was a 97% rise in the real price of fishmeal. See the Appendix for more detail on monthly price variation. These estimates are higher than

[9] Our data on product type and ex-vessel price is not region-specific. Therefore, to the extent that product quality and prices are lower in the South due to a continued race-to-fish, our estimates here are likely under-estimates of revenue changes in the North-Central.

Tveteras, Paredes et al. (2011), who report that prices rose 37% from 2008 to 2009, but lower than Natividad (2015), who calculates a 200% increase in anchovy prices from 2008 to 2010. If we analyze the same period of time as Natividad, 2008 to 2010, we find a rise of 160%. For more information on daily prices, see Natividad (2015), who obtained and summarized confidential daily-level price data from a single (large) fishing firm.

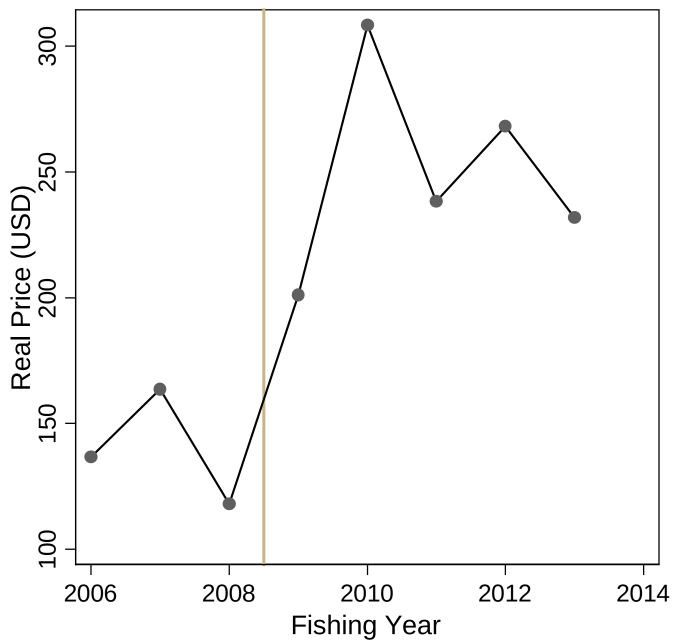
The increase could be due to several factors. First, the increase could be due to changes induced by IVQ- implementation, such as product quality increases due to more careful handling of the fish on-board, less tightly packed fish on-board, a decrease in time between catch and delivery, or spreading out of landings so that processing can be done at a slower rate (Galarza 2014a). These margins of changes are discussed more in the next section.

Another consideration in this fishery is that, with the implementation of the IFQ, bargaining power shifted from processing plants to IFQ-holders. Specifically, under a race-to-fish, processors may have exerted monopsony power, implying that vessels had limited bargaining power in their ability to negotiate prices with processors. Reasons for this might include travel time between processors and/or any time spent negotiating may have been time not spent fishing or time during which catch was degrading. Under an IFQ the scarce resource is the catch, and vessels can bargain with processors, not going out until they negotiate an acceptable price (for further discussion see e.g. Fell and Haynie (2013)). It is possible the IFQ increased vessel negotiation power, particularly of the wood fleet; steel vessels often belong to vertically integrated companies that also process anchovy (see e.g. Galarza (2014a) and Fréon et al. (2013)). Additionally, there may be differences in how changes in bargaining power manifest themselves over the longer run. For example, it is possible that the change to the IVQ program and the increase in number of days fished resulted in some sunk capital in the processing sector, such that some plants may stay open in the short run and pay higher ex-vessel prices than the plants would pay in a long-run equilibrium.

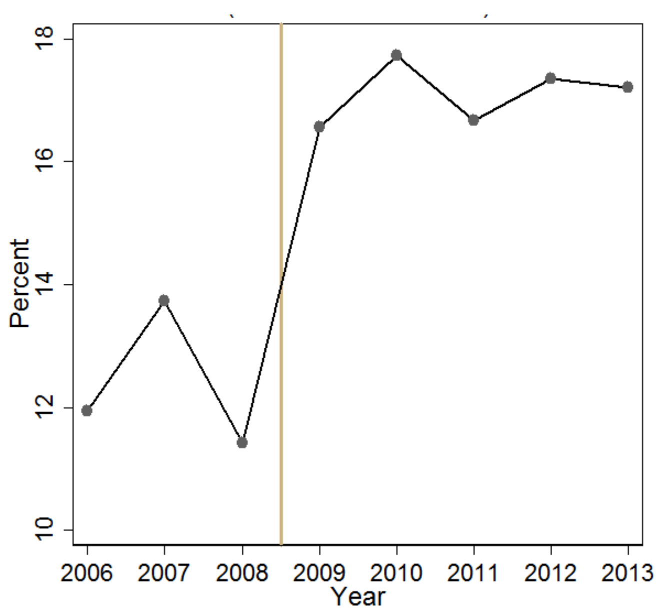
To explore changes in the ex-vessel price over time we graph ex-vessel price as a percentage of the export price (Figure 3b) and the difference between the export price and the ex-vessel price (Figure 3c). The percentage of the export price going to harvesters increased from ~11-14% per-IVQ to ~16-18% after. The first year after the IFQ the real dollar amount per ton going to processors decreased, but in every other year post-IVQ the processors received more per ton than any year pre-IVQ.

Figure 3: Anchovy Ex-Vessel

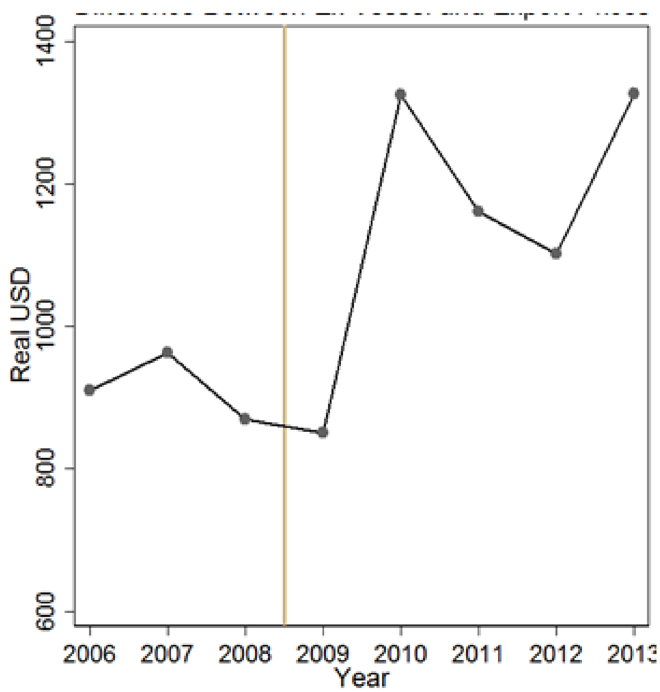
(a) Weighted Average Ex-Vessel Price



(b) Ex-Vessel Price as a Percentage of Export Price



(c) Difference between Export and Ex-Vessel Price



Sources: PRODUCE (ex-vessel price data), World Bank (Peruvian Wholesale Price Index), and UN Treasury (Operational Rates of Exchange).
Note: the solid vertical line corresponds to the start of the IVQ system prior to the 2009 fishing year. The weighted price is calculated using monthly prices and the total monthly catch as the weight.

Finally, the price increase we observe could be due, in part, to a global increase in the demand for fishmeal. Peruvian fishmeal is sold into a global market and over this period the world price of fishmeal increased. Understanding prices in Peru relative to world demand is complicated though, as according to FishStatJ which reports country-level fishmeal production statistics, Peru's contribution to the aggregate global fishmeal supply has ranged from 23-38% over the period from 2006 to 2011 (FAO 2014).

Changes in Fleet Inputs

In this section we examine how fleet input use has changed over time. We consider both extensive margins, such as the number of vessels active in the fishery, as well as intensive margins, such as the number of trips. Incentives to increase revenue, such as the higher prices associated with higher-value fishmeal can motivate changes in inputs. Specifically, increasing product quality often requires slower fishing, shorter trips, and/or less product in the hold per hold capacity unit.

We find a consolidation in the number of active vessels[10] post-IVQ (Figure 4A and 4D, Table 1A, Table 1B). The drop in number of active vessels in the steel fleet is faster and more significant than the wood fleet, with the number of active vessels decreasing by approximately 40% over the period we observe. The wood fleet decrease is smaller, around 25%. However, there are some seasonal fluctuations. The most significant fluctuations occur in season 2 of 2010 and season 2 of 2012, the years with the lowest TACs for the North-Central region.

Accompanying the decrease in the number of active vessels is an increase in the capacity of active vessels (Figure 4B and 4E). This suggests that in the steel fleet, the vessels that remained active post-IVQ were relatively larger than those no longer active. There is a slight increase in the median capacity of the wood vessels, but the trend disappears if vessel capacity is weighted by landings to create a weighted average (see Appendix).

We now turn to examining the number of days of activity in each fishing season. Under an IVQ system there is considerable flexibility to spread catch out within a season, therefore we focus on the number of days with at least one vessel making a landing. There is an increase in number of days with a positive landing post-IVQ, reflecting landings spread out more over the course of the season (Figure 5). This is true when broken down by hull type as well (see Appendix).

Next we consider changes to the nature of catch concentration, looking at concentration in catch per vessel and trips per vessel. There is significant variability in absolute measures, such as catch per vessel and trips per vessel, over time (see Appendix). However, given the possibility that variability may be driven by fluctuating stocks and landings, we focus on the concentration of vessel catch as a percentage of total landings. Post-IVQ the median catch per vessel (measured as a percentage of the TAC) increases with a relatively smooth trend (Figure 4C and 4F). The trends are similar for the median number of vessel trips as a percentage of the total trips (see Appendix).[11]

[10] We define an active vessel as a vessel with positive anchovy landings.

[11] We also explore with-in trip catch, looking at landings-per-trip and hold-capacity-filled. It is not clear what, if any, direction we would expect these statistics to move post-IVQ. In fact, given the many dimensions of inputs in the fishing production process (see e.g. Reimer, Abbott and Wilen (2014)), the productivity measure of quantity caught per trip is a measure of partial productivity. In other words, it is a measure of output per one unit of a particular input, in a context in which there are multiple inputs. Furthermore, our examination is limited because we are missing an important margin: the length of the trip.

We find there are changes in the distribution from year-to-year, with no clear trend post-IVQ. Therefore, we do not offer a conclusion about changes over these margins.

7. Steel Profitability

The starting point for our estimation is the cost statistics described in the Data and Methods section for the steel fleet and the ex-vessel monthly price data described in detail in the Appendix. As discussed in the previous section, there is a significant increase in revenue per ton of anchovy landed. To get a more accurate measure of cost changes over time, we couple the cost information with our data on fleet trips and landings, matching each vessel to the appropriate year and cost category.

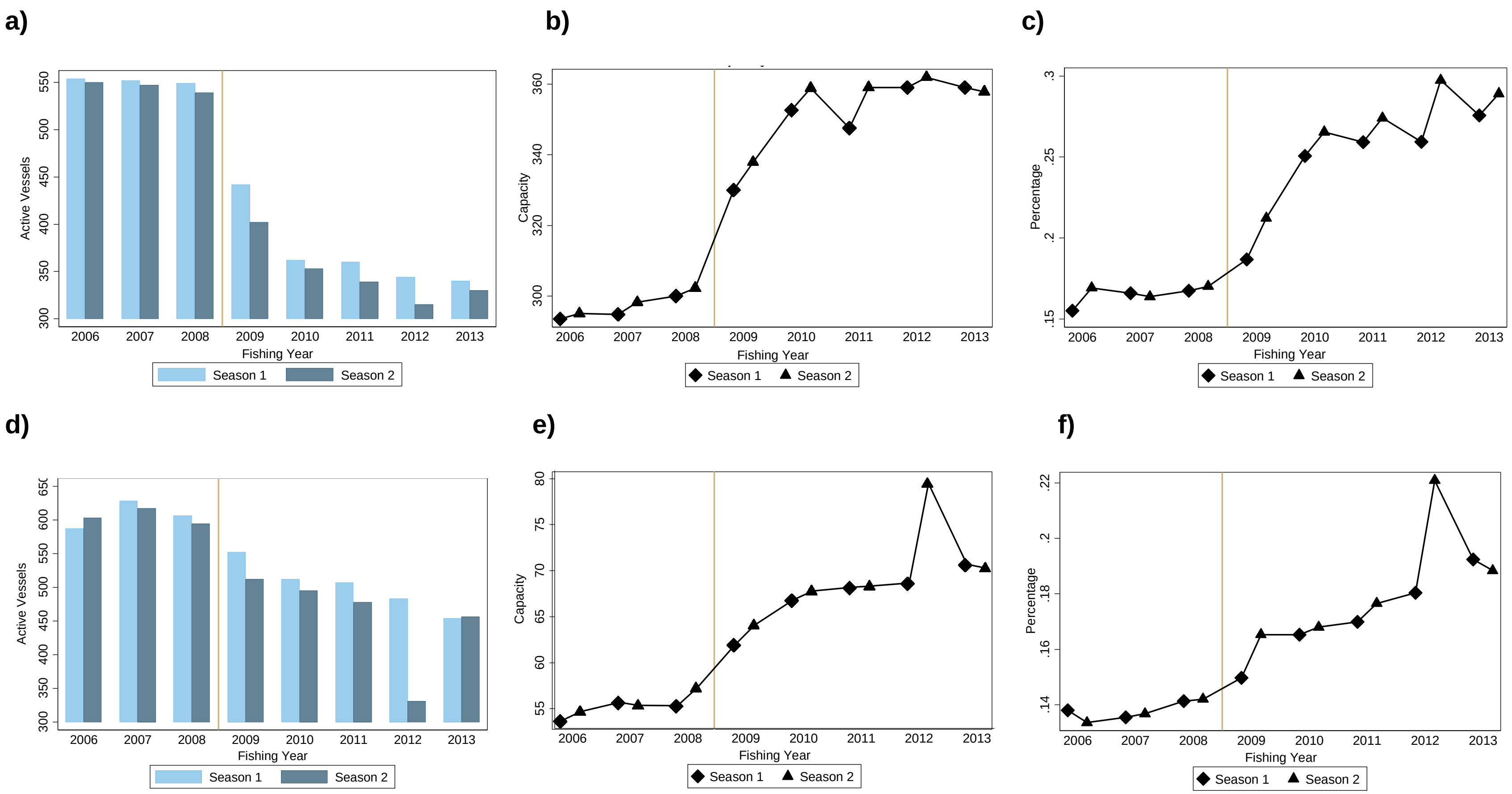
In industrial fisheries, the largest harvest cost components are typically capital and capital maintenance, fuel, and labor. In forage fish fisheries, costs may also depend on how aggregated the stock is and how costly it is to search and find the stock aggregations. Therefore, trip costs may depend on factors including fuel prices, labor rates, capital characteristics, and the stock size. We do not observe details on input quantities used and costs per unit of input. Instead, we have access to average per-ton fishing costs, broken down by vessel category. Therefore, we focus on aggregate and average costs in this section.

In Table 2 we present data on real revenues, variable costs, and variable profit of harvesting, both in total and by average-per-metric ton, for each year and season we have cost data for. To compare across time, we focus on the per-unit costs, revenues, and profits. This helps account for differences in total landings that influence total revenues and costs.

The average per-ton harvesting cost is relatively stable prior to the IVQ system, then decreases in 2011 and increases in 2013. Average per-ton costs are approximately $94/ton prior to the IVQ system implementation, dropping to $84/ton in 2011, and then increasing to around $121/ton in 2013.

Figure 4: Changes in Active Vessels and Vessel Utilization (North-Central Steel Vessel Summary Statistics).

a) Number of Active Vessels; b) Median Hull Capacity of Active Vessels; c) Median Vessel Percentage of Steel Vessel Catch. North-Central Wood Vessel Summary Statistics: d) Number of Active Vessels; e) Median Hull Capacity of Active Vessels; f) Median Vessel Percentage of Wood Vessel Catch.



Source: PRODUCE landings data.
Note: The solid vertical line corresponds to the start of the IVQ system in the North-Central region.

Table 1A: Summary Statistics – North-Central Steel Fleet

Fishing Season	Number of Active Vessels	Total Landings (MT)	Trips	Ave. Capacity (MT)	Ave. Landings per Vessel (MT)	Ave. Landings per Trip (MT)	Biomass
S12006	554	1,542,560	7,262	305	2784	212	7,613
S22006	550	1,638,134	7,263	308	2978	225	5,979
S12007	552	2,335,485	10,534	308	4231	222	7,690
S22007	547	1,597,964	8,316	311	2921	192	7,667
S12008	549	2,499,692	12,313	313	4553	203	9,840
S22008	539	1,720,507	7,263	315	3192	237	4,525
S12009	442	2,721,530	12,387	325	6157	220	7,248
S22009	402	1,565,834	8,753	335	3895	179	7,248
S12010	362	1,968,326	7,656	345	5437	257	6,202
S22010	353	629,348	4,812	348	1783	131	4,830
S12011	360	2,920,129	12,643	348	8111	231	9,158
S22011	339	1,989,777	7,603	355	5869	262	6,753
S12012	344	2,104,536	11,581	355	6118	182	8,880
S22012	315	613,921	5,693	359	1949	108	5,225
S12013	340	1,603,388	6,955	353	4716	230	11,948
S22013	330	1,819,614	8,645	351	5514	210	10,047

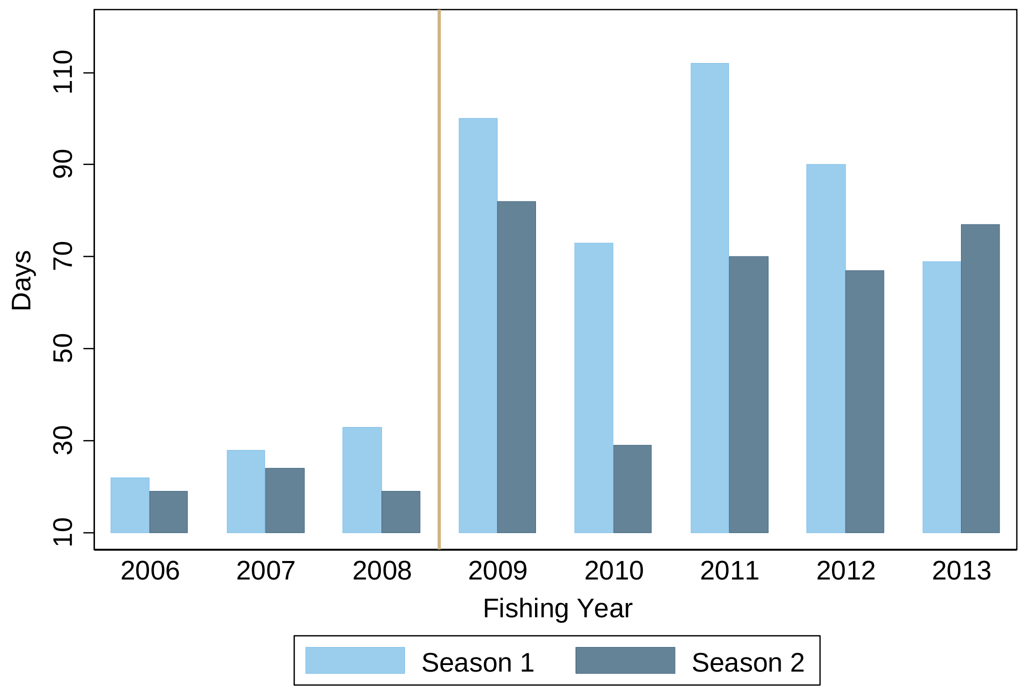
Source: PRODUCE landings data.
Note: the IVQ program began in the first season of 2009 in the North-Central region.

Table 1B: Summary Statistics – North-Central Wood Fleet

Fishing Season	Number of Active Vessels	Total Landings (MT)	Trips	Ave. Capacity (MT)	Ave. Landings per Vessel (MT)	Ave. Landings per Trip (MT)	Biomass
S12006	587	359,595	7,694	64	613	47	7,613
S22006	603	367,937	7,623	65	610	48	5,979
S12007	628	644,996	12,569	66	1,016	51	7,690
S22007	617	540,921	10,814	66	868	50	7,667
S12008	606	634,755	13,061	66	1,030	48	9,840
S22008	594	415,702	8,410	66	700	49	4,525
S12009	552	697,849	14,897	68	1,264	47	7,248
S22009	512	395,615	10,351	69	773	38	7,248
S12010	512	497,910	8,688	69	972	57	6,202
S22010	495	150,019	3,884	70	303	39	4,830
S12011	507	725,873	14,447	70	1,432	50	9,158
S22011	478	487,773	8,293	70	1,020	59	6,753
S12012	483	502,237	11,939	70	1,040	42	8,880
S22012	331	128,775	3,367	78	389	38	5,225
S12013	454	382,592	6,529	71	843	59	11,948
S22013	456	429,770	7,006	70	942	61	10,047

Source: PRODUCE landings data.
Note: the IVQ system began in the first season of 2009 in the North-Central region.

Figure 5: Number of Days per Fishing Season with at Least One Landing Record in the North-Central



Source: PRODUCE landings data.
Note: The solid vertical line corresponds to the start of the IVQ system in the North-Central region.

Table 2: Steel Variable Profit (2013 USD)

	North-Central							
Fishing Year	**2006**		**2008**		**2011**		**2013**	
Season	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Total Revenue (million USD)	191	249	310	191	707	458	378	469
Total Variable Cost (million USD)	144	154	236	162	248	168	194	220
Total Profit (million USD)	47	95	74	28	459	290	184	250
Revenue per metric ton	124	152	124	111	242	230	235	258
Cost per metric ton	94	94	94	94	84	84	121	121
Profit per metric ton	30	58	29	17	157	145	115	138
Per-Ton Profit as % of Ex-Vessel Revenue/Ton	**24%**	**38%**	**23%**	**15%**	**65%**	**63%**	**49%**	**53%**

Note: the ITQ system began in the first season of 2009 in the North-Central region.

The cost change is relatively small compared to the revenue changes. Aggregated to the year level (see Appendix), post-IVQ revenue per ton is more than 75% greater than pre-IVQ revenue per ton. The large revenue increases combined with relatively small cost changes result in an increased profit-per-ton post-IVQ. Pre-IVQ profit-per-ton is 33% of ex-vessel revenue in 2006, 20% in 2008, and 64% and 51% in the post-IVQ years 2011 and 2013, respectively.

Although we convert the revenues, costs, and profits to a per-ton basis to facilitate comparisons across years, we do not account for potential changes in revenues and costs that may be associated with varying stock characteristics. All else equal, we expect the per-ton fishing costs to be the same or higher when the stock is lower. Additionally, assuming upward sloping marginal costs curves, we expect the per-unit cost and the average cost per unit to increase as total landings increase. Comparing the biomass estimates for season 1 and 2 of each year we have data for, we observe that 2006 is a relatively low stock year and 2013 a relatively high stock year. However, 2008 and 2011 have similar stock levels. Additionally, the landings are similar, but slightly higher in 2011. All else equal, and assuming increasing marginal costs, we expect the slightly higher landings would increase per-unit costs post-IVQ and decrease profits.

Table 3: Counterfactual Steel Variable Profit (2013 USD)

North-Central				
	No-IVQ Counterfactual		**2011 Observed**	
Season	**1**	**2**	**1**	**2**
Revenue per metric ton	160	143	242	230
Cost per metric ton	94	94	84	84
Profit per metric ton	66	49	157	145
Per-Ton Profit as % of Ex-Vessel Revenue/Ton	**41%**	**34%**	**65%**	**63%**

Note: We compare the observed 2011 revenue, cost, and profit to our estimate of what the 2011 revenue, cost, and profit would have been had the IVQ not been implemented.

Under the assumptions that costs would have remained the same (in real terms) had the IVQ not been implemented, that world fishmeal prices would have still increased, and that the ex-vessel price is a constant percentage of the export price, we calculate a conservative counterfactual revenue per ton. In Table 3, we present the counterfactual 2011 revenue, cost, and profit per ton, had the IVQ not been implemented. To give a sense of the absolute magnitude of the change in terms of overall fishery harvesting profit we calculate per-unit increases in profit and multiply this difference by the total harvest. We focus on 2008 and 2011, the years with the most similar stock levels and landings. We calculate a $91/ton higher profit in season 1 of 2011 relative to season 1 of 2008 and $96/ton when comparing the profits for season 2. Multiplying the gain in profit per ton by the total 2011 seasonal landings, the aggregate gain is $265 million in season 1 and $191 million in season 2. If all conditions present in 2008 remained the same, but the landings were equivalent to 2011 landings and the IVQ were not implemented, these amounts would represent the gain in profit from the introduction of the system. The total seasonal gains depend on the stock and TAC; in 2011 the TAC and stock were high relative to other post-IVQ years (the lowest post-IVQ season1 landings were 55% of the 2011 season 1 landings and the lowest post-IVQ season 2 landings were 33% of the 2011 season 2 landings), so gains of this magnitude should not be expected to occur in all years. In relative terms this equates to a 138% increase in profit for season 1 and a 196% increase in profit in season 2. In terms of ex-vessel revenue, this represents an increase from profit comprising 34-41% of ex-vessel revenue in 2008 to 63-65% in 2011.

Our estimates are consistent with previous estimates of the quota lease price. We expect our estimates of average profit to be higher than the quota lease price.[12] Our estimate of average profit per ton in 2011 is $157 (2013 USD) in season one and $145 in season 2. In 2013 the North-Central steel estimate is $115 in season one (2013 USD) and $138 in season 2. These are higher than the Paredes (2012) estimated quota price of approximately $100/metric ton and Galarza and Collado's (2013) estimate of $103/metric ton.

8. Conclusion

In analyzing the Peruvian anchovy fishery, we find evidence that changes have occurred in the fishery that are consistent with the economic goals of the management system, including lengthened seasons, production of higher-value products, fleet consolidation, and increased per-ton variable profit. Although an IVQ system in name, allowances for within firm transfers of

[12] Under the assumption that the profit of each vessel is maximized, the profit maximizing condition is: $0 = P - VC_i(q_i)' - m$, where m is the implied quota lease price and P is the ex-vessel price. Therefore, the implied quota lease price, which is the per ton resource rent, is: $m = P - VC_i(q_i)'$. We expect a vessel to take a trip if the expected trip profit per ton $P - VC_i(q_i)'$ is greater than or equal to the quota lease price. For this fishery we consider an "implied" lease rate given that the markets are informal and movement of quota occurs through firms or the associations. Under the assumption of increasing marginal costs, vessels will continue to add trips until the expected value of an additional trip is less than the quota price. In equilibrium, we expect the return to the final unit of catch by each vessel to equal the quota price; we expect equalization of the marginal return, not the average.
Given an increasing marginal cost curve, the marginal cost would be greater than the average and the average cost per ton would be a lower bound on a measure of the marginal cost per ton. The higher the cost per ton, the lower the quota price, suggesting our estimates of average profit should be an upper bound on the quota lease price.

quota and the formation of associations through which quota can be transferred to vessels of other firms appear to have provided sufficient flexibility for some changes to occur.

Relative to earlier studies our scope is broader as we analyze more margins of change and examine these changes over a longer time period. We also break our analysis down by the hull-type and region. In the North-Central region, we find some heterogeneity between the steel and wood fleets. Specifically, the contraction in fleet size and the shift toward larger capacity vessel is much more pronounced in the steel fleet. This highlights the importance of conducting separate examinations of each group of participants that receives a quota allocation.

In our analysis of the changes to harvesting revenues and costs coinciding with the IVQ system, we find that revenue-side gains are significant and large relative to cost-side changes. This finding emphasizes the importance of revenue-side changes that can occur due to ITQ implementation. This finding is consistent with observations in other fisheries. For example, there is evidence of fishermen investing in less-efficient gears after the race to fish is eliminated with an ITQ as a means to increase the quality of the output. Red snapper quota holders in New Zealand went from using trawl gear prior to the introduction of ITQs to longlines to eventually relying on traps after the ITQ, as their product type shifted from frozen to fresh to live fish that were shipped to Japan and China (Dewees 1998).

Furthermore, these findings should allay concerns that IVQs and ITQs may not be able to successfully manage fluctuating stocks (Copes 1986) and concerns over excessive corruption in the fishery. Specifically, that industry has reduced the number of active vessels through firm or association level transfers suggests that quota transfers can still occur with fluctuating stocks and that there is some confidence in the government's ability to set TACs, enforce, and monitor. That being said, there are two seasons each year with separate TACs; potentially a modification from a one-TAC-per-year design that helps address the Copes (1986) concern that regulators would have difficulties predicting future stock levels to set TACs for variable stocks.

The relative success of the North-Central anchovy IVQ system raises questions about related management schemes including the anchovy IVQ system in the South and management of the artisanal and smaller scale anchovy fisheries. Although in our most recent year of data (2013) the Southern catch is only 12% of the total industrial anchovy catch in Peru, the ex-vessel value of the approximately 575,000 metric tons landed is ~$134 million USD. If the South and North-Central were considered separate fisheries, then the Southern anchovy catch would be the second-largest species catch by volume in Peru (Servicio Nacional de Pesca y Acuicultura 2013). Without a binding TAC, a race-to-fish will likely continue (see the Appendix for information on how days of active fishing do not appear to increase post-IVQ as they did in the North-Central) and stocks will likely remain lower than maximum economic yield. Furthermore, around 40% of active steel vessels fish in both regions. Understanding how the fishing management regime in the South affects the optimal fishing strategy and potentially the profitability of fishing in the North-Central region warrants further investigation.

Another important management question with implications for industrial North-Central IVQ profitability needing further study is management of the small-scale artisanal fleet. The artisanal and small scale fleets operate outside of the IVQ system in essentially an open-access regime (Galarza 2014). The industrial and artisanal fleets fish the same stock, and so overfishing in the artisanal fleet can impact the stock and thus profitability of the industrial fleet. The artisanal fleet also delivers some product for fishmeal (see e.g. Fréon et al. (2013)). Furthermore, as described in the "IVQ Program" section, the fishing grounds of the fleets are spatially delineated with the artisanal fleet fishing closest to shore, then the small-scale fleet beyond that, and finally the industrial fleet fishing furthest from shore. This has essentially created an open-access regime operating from nearest to shore where the artisanal and small-scale fleets fish and an IVQ system in the region beyond the zone for the small-scale fleet to the Exclusive Economic Zone. Because the spatial distribution of the stock with respect to distance to the coast has historically been influenced by El Niño events (appearing closer in El Niño years) this change has the potential to increase the conflicts between the two fleets and undercut the potential security of the quota asset (and hence reduce its value) (see e.g. Costello, Quérou and Tomini (2015)).

Our analysis also helps highlight the need for more standardized collection of indicators in catch share fisheries. No government-collected cost data are available. Compared to another source of cost information we are aware of, Paredes (2008), our reported costs are higher, and therefore our profit estimates may be conservative. There is also no trip departure and arrival information, limiting our ability to identify increases in handling times and improved product recovery rates, one of the IVQ system goals (Young and Lankester 2013). Given the data limitations, we leave establishing casual inference for future work. Specifically, attributing the increase in profit to the IVQ system would require isolating the impact of the IVQ system from other confounding factors, such as changing labor markets or biomass, that could lead to changes which would have occurred in absence of the IVQ system (see discussion in Gertler et al. (2011) on counterfeit counterfactuals).

We also leave for further investigation the performance of the program beyond impacts related to the economics of harvesting anchovy. This includes evaluating outcomes relative to other program goals including the use of anchoveta for sustained development as a source of food, employment and income, and to ensure its responsible use in harmony with the preservation of environment and biodiversity conservation. Additionally, given the vertically integrated nature of the firms owning most of the steel vessels, a more extensive evaluation of the economic impact of the program would include evaluation of profit along the entire value chain from harvest, to processing, and then sale.

Finally, the difference in degree and speed of consolidation across hull types is an important source of variation that can have economic and social impacts, but has yet to be fully explored. Steel fleet crew members and wood vessels owners, which controlled the minority of vessel and processing capacity, were initially opposed to the IVQ system implementation (see e.g. La Republica (2008)). One reason for opposition by wood vessel owners was their concern their production would be reduced (see e.g. La Republica (2008)). Owners of processing plants and vessels, primarily from the steel fleet, committed to a landings tax to finance a social support program in response to the controversy. To that end, the government created a social fund, FONCOPES, to provide a benefits program for early retirement of crew, training in technical careers, and assistance for crew to start small businesses. Vessels in the IVQ system supported the fund though a mandatory fee based on the amount of quota per vessel and the number of crew members (Galarza 2010). Young and Lankester (2013) report that during its first three years FONCOPES collected $10 million (USD), assisted in the voluntary retirement of 350 fishermen, and helped 400 workers transition out of the fishery. Furthermore, Galarza (2010) reports fewer accidents following the start of the IVQ system. We leave for future work understanding the political economy questions related to support by stakeholders for catch shares, the mechanisms through which consolidation occurred, and the economic and social costs and benefits of association and firm transfer provisions and the fleet-specific allocation structure of the system.

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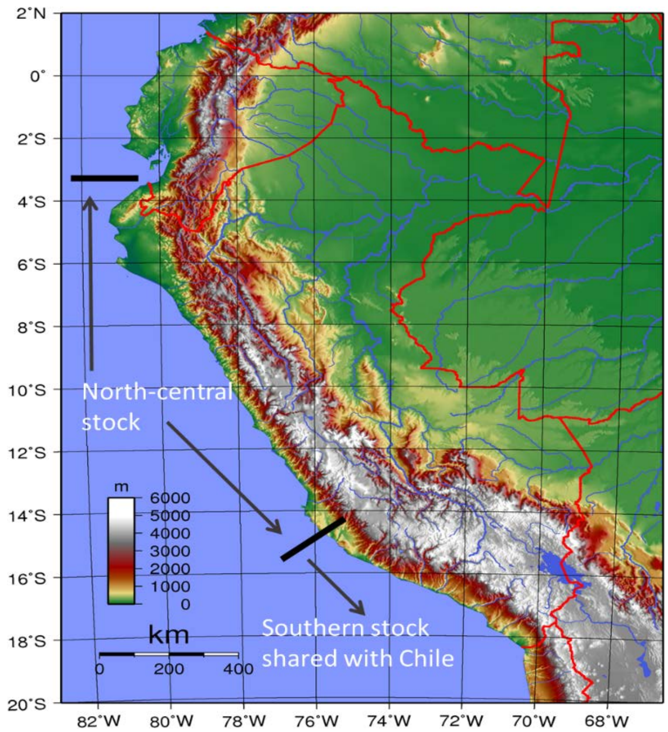
Appendix

1.1 Fishery Regulations

The anchovy fishery is comprised of two geographic regions with two separate total allowable catches (TACs): the North-Central and the South (Figure A1). The Southern stock is shared with Chile. A summary of important regulatory changes in each region is available in Table A1.

Figure A1: Anchovy Fish Stocks in Peru



Source: Arias Schreiber and Halliday (2013)

Note: The North-Central stock ranges from ~ -4^{o} To ~-15^{o} latitude and the Southern stock is south of ~-15^{o} latitude. The Southern stock is shared with Chile.

Table A1: Key Anchovy Fishing Regulations

	Fishing Year	Fishing Gear Regulations	Fishing Effort and Catch Regulations	Access Regulations	Source/Law
Pre-ITQ period	Before 1992	Minimum size instituted via mesh size in purse-seine nets. Landings with >10% juveniles will close fishery for a minimum of 3 days.	Total allowable catch set and enforced via season limit separately for North-Central and Southern stock.	Vessel permits were required in North-Central and Southern stock. Fishery was regulated open-access.	Arias Schreiber and Halliday (2013)
	1992		Limited-entry system in North-Central. Industrial vessels banned within 5 nm of North-Central coast.	Permits tied to vessel and hold capacity. Vessel could enter if it purchased and retired a vessel(s) of greater hold capacity.	General Fishing Law/ Arias Schreiber (2012)
	1998			Wooden vessels with hold capacities between 30 and 110 tons added to industrial fleet.	Arias Schreiber and Halliday (2013)
Post-ITQ period	2009-2012		Seasonal TACs for North-Central and Southern stocks. Vessels cannot make more than one trip per day.	Individual quotas for steel fleet tied to vessels catch history (2004-2007; 40%) and hold capacity (60%) and for wooden fleet tied to catch history. Duration of quota is 10 years. Quotas are transferable permanently (within a firm or purchasing a vessel with its quota) or leasing (renting) up to 3-years. Vessels must have a permit and must fish once every 3 years or lose their quota allocation. No carryover of quota permitted and no trading between steel and wooden fleet.	Legislative Decree 1086/ Arias Schreiber (2012); Young and Lankester (2013)
	2012			Artisanal fleet that operates outside the IVQ system with no controls given access rights to fishing ground out to 10nm from the coastline.	Legislative Decree 005
	2013			Artisanal fleet that operates outside the IVQ system with no controls given access rights to fishing ground out to 10nm from the coastline in the Center North region and 7 nm from the coastline in the Southern region.	Legislative Decree 011

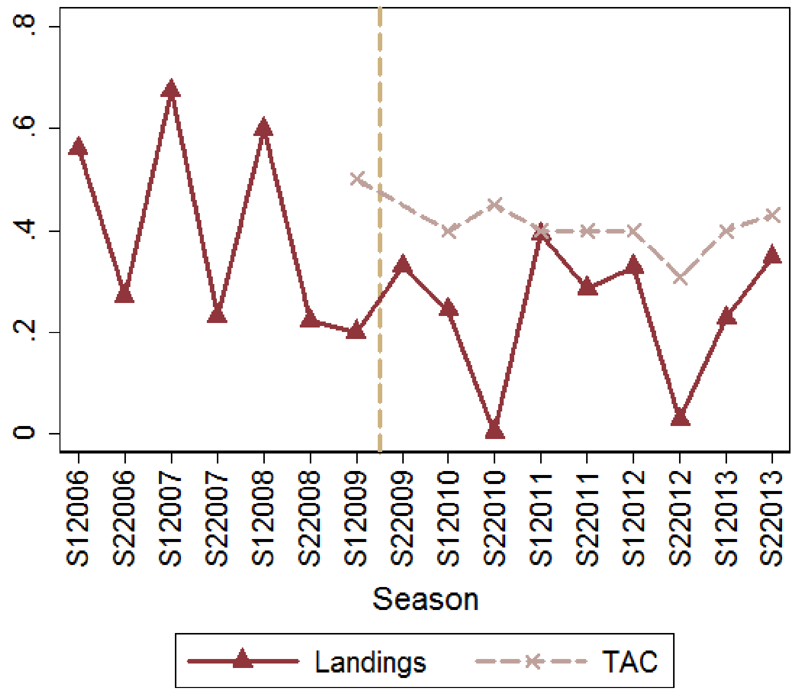
1.2 Southern Fishery

The Southern fishery is smaller than the North-Central fishery. From 2006-2013 the percentage of total fishery catch from the South fluctuated between 7-18%. Southern fishery summary statistics are presented in Figure A2, Table A2, and Table A3.

In the South the TAC is relatively constant and only binds in season 1 of 2011 (Figure A2). Additionally, the biomass in the Southern region is not as well studied and to our knowledge there is not a consistent time series of Southern stock estimates.

A TAC and formal seasons were only introduced at the advent of the IVQ system in 2009. For comparison purposes, for summary statistics, we assign each record during the pre-IVQ period to the equivalent "season" it would have occurred in post-IVQ. For further discussion of season assignment, see "Fishing Years, Seasons, and TACs" section below.

Figure A2: Landings and TAC (Million Metric Tons) for the Southern Stock.



Source: PRODUCE landings and TAC data.

Note: The dashed vertical line corresponds to the start of the IVQ system in the Southern region.

Table A2: Summary Statistics – Southern Steel Fleet

Fishing Season	Number of Active Vessels	Total Landings (MT)	Trips	Ave. Capacity (MT)	Ave. Landings per Vessel (MT)	Ave. Landings per Trip (MT)
S12006	327	517,833	5,594	273	1,584	93
S22006	268	229,078	2,936	261	855	78
S12007	332	596,816	6,307	286	1,798	95
S22007	272	182,497	2,690	279	671	68
S12008	333	492,328	5,900	289	1,478	83
S22008	231	163,392	2,042	280	707	80
S12009	207	156,421	1,641	265	756	95
S22009	223	289,258	2,911	302	1,297	99
S12010	213	205,872	3,665	295	967	56
S22010	1	124	1	423	124	124
S12011	186	347,644	2,553	306	1,869	136
S22011	147	271,064	1,888	305	1,844	144
S12012	155	307,994	2,469	320	1,987	125
S22012	106	27,685	347	324	261	80
S12013	158	215,726	2,474	330	1,365	87
S22013	158	332,072	2,579	314	2,102	129

Source: PRODUCE landings data.

Note: the IVQ system began in the second season of 2009 in the Southern region.

Table A3: Summary Statistics – Southern Wood Fleet.

Fishing Season	Number of Active Vessels	Total Landings (MT)	Trips	Ave. Capacity (MT)	Ave. Landings per Vessel (MT)	Ave. Landings per Trip (MT)
S12006	75	41,949	931	89	559	45
S22006	71	41,959	688	89	539	56
S12007	84	76,917	1,424	87	813	48
S22007	108	48,338	1,012	91	408	44
S12008	139	106,240	2,107	83	655	43
S22008	123	58,592	1,219	83	476	48
S12009	110	43,374	1,364	82	394	32
S22009	59	40,508	983	77	687	41
S12010	65	37,009	1,048	78	569	35
S22010	17	2,657	126	38	156	21
S12011	63	45,167	977	77	717	46
S22011	32	14,160	239	65	442	59
S12012	24	19,704	302	101	821	65
S22012	3	211	5	95	70	42
S12013	19	11,170	212	102	588	53
S22013	17	15,829	221	99	931	72

Source: PRODUCE landings data.

Note: the IVQ system began in the second season of 2009 in the Southern region.

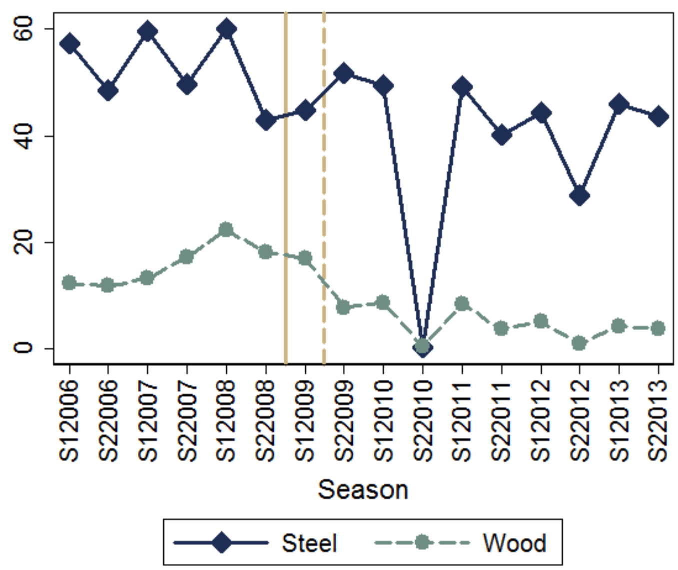
1.2.1 North-Central and South Fishery Overlap

In the fishery there is overlap in vessel participation between regions. Overlap primarily occurs in the steel fleet, where, in most seasons both pre- and post-IVQ, greater than 30% of the total active steel vessels fish in both regions (Figure A3).

Prior to the IVQ system, most steel vessels active in the South also fished in the North-Central. The main change with the IVQ system is that after implementation, an increasing number of vessels active in the South only fish in the South. Some vessels, about 10-15 in most seasons, which had fished exclusively in the North-Central prior to the IVQ, began fishing in the South (Figures A4-A7). The rule that a vessel must fish its North-Central quota before fishing Southern quota may, in part, explain this phenomenon. It may also help explain the relatively high percentage of vessels fishing only in the North-Central in the poor fishing seasons (season 2 of 2010 and season 2 of 2012), lower catch, and fewer active vessels in the South. Another important consideration is the placement of fishmeal production plants. There are fewer plants in the Southern region.

In the wood fleet, the number of vessels that are active in the North-Central that also fish in the South decreases with the IVQ implementation. Pre-IVQ and in the early post-IVQ years, there are some wood vessels that only fish in the South. However, in the last four seasons we have data for, there are no wood vessels only fishing in the South.

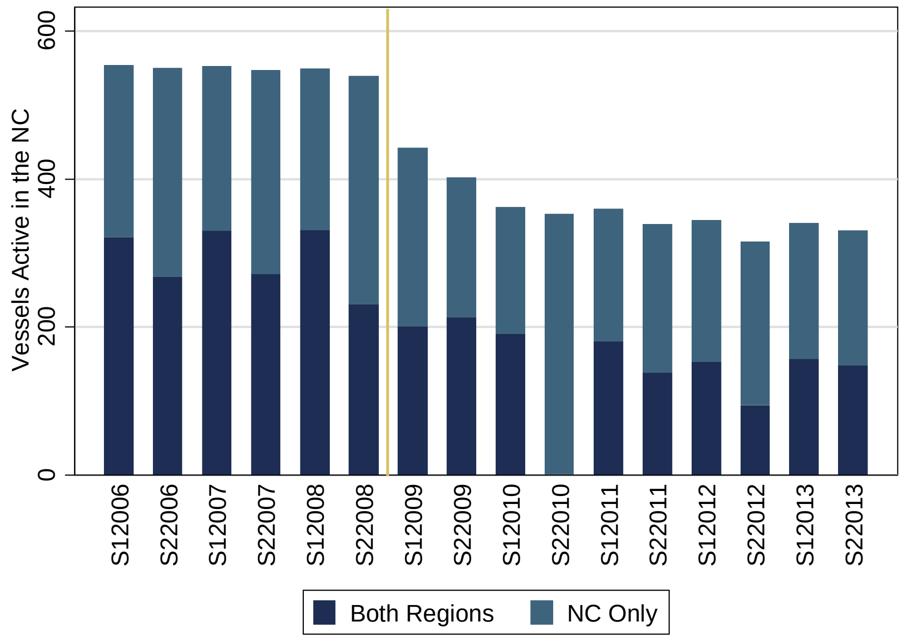
Figure A3: Percentage of Active Vessels with Catch in Both Regions.



Source: PRODUCE Landings Data.

Note: The solid vertical line corresponds to the start of the IVQ system in the Central-North region; the dashed line corresponds to the start of the IVQ system in the South.

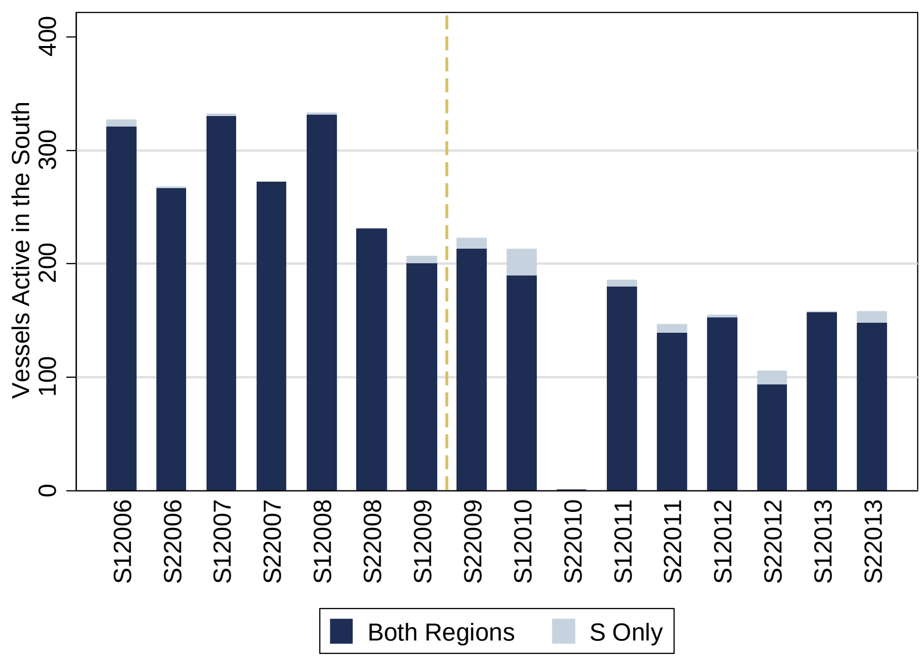
Figure A4: Participation of Active North-Central Steel Vessels in the Southern Region.



Source: PRODUCE landings data.

Note: The solid vertical line corresponds to the start of the IVQ system in the North-Central region.

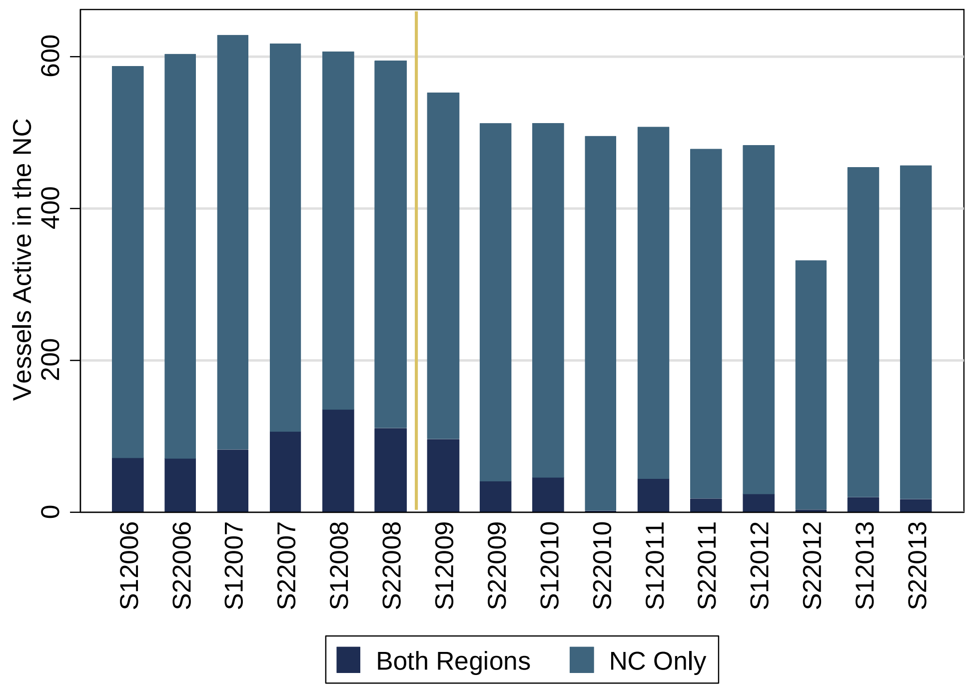
Figure A5: Participation of Active Southern Steel Vessels in the North-Central Region.



Source: PRODUCE landings data.

Note: The dashed vertical line corresponds to the start of the IVQ system in the Southern region.

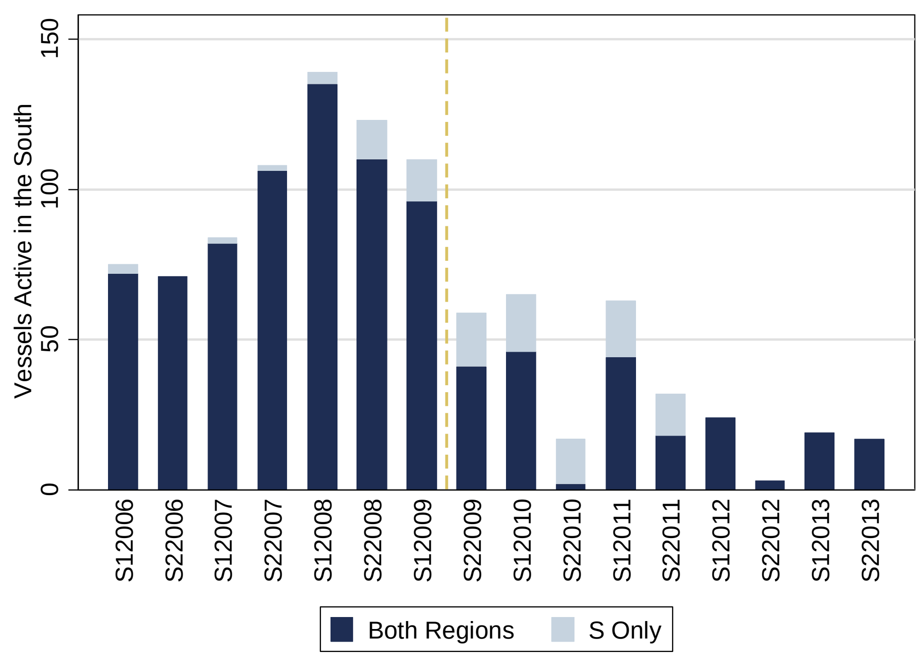
Figure A6: Participation of Active North-Central Wood Vessels in the Southern Region.



Source: PRODUCE landings data.

Note: The solid vertical line corresponds to the start of the IVQ system in the North-Central region.

Figure A7: Participation of Active Southern Wood Vessels in the North-Central Region.



Source: PRODUCE landings data.

Note: The dashed vertical line corresponds to the start of the IVQ system in the Southern region.

1.3 Landings Data

We have access to the confidential landings database from the Ministry of Production (Ministerio de la Producción, Dirección General de Extracción y Procesamiento Pesquero), also known as PRODUCE, that includes records of all anchovy landings between January 2006 and September 2014. We use landings data for 2006 through 2013, the years for which we have the entire fishing year (both seasons) of data. For each record in the database, we have information on: the name of the fishing vessel (along with boat attributes such as registration number, capacity, and hull type); landings (in metric tons); the port of delivery; processing plant; date and time of delivery; investigator; and a landing specific ID number. There are 406,732 records in this dataset. The yearly total landings in our database match within three percent of the total landings statistics reported for anchovy used for indirect consumption in the official PRODUCE Fishery and Aquaculture Statistics Report (Servicio Nacional de Pesca y Acuicultura, 1960-2013). Tables A4 and A5 present summary statistics by season and hull for the entire fishery. Tables A6-A11 present summary statistics by year, hull, and region.

Vessel capacity limits are measured in metric tons in the landings dataset. For the 1,325 vessels making at least one landing, there were 36 vessels that had missing or inconsistent capacity values over the database sample. In these cases the value of capacity was replaced with the median capacity per vessel. This resulted in the change of the value of capacity for 1,135 landing entries, or less than 1%, of total landings entries.

In the landings dataset there are 22 vessels that do not have an associated hull type because they are not in the quota database. We assign the hull type as wood if the capacity is less than 110 m^3 and steel if greater (see the Quota Ownership and Associations section for discussion).

The database also contains records where the vessel ID and all other attributes are missing. These records represent less than 1% of the records in the database. They all correspond to wood vessel landings, and 85% of the records correspond to the Southern region. Furthermore, they all occur in the pre-IVQ years. Within the Southern wood fleet the landings records with missing IDs comprise less than 2% of the total records for each season with the exception of season 2 of 2008. In this season, 14% of the records are missing an ID value. When we count total fishery landings and days with landings (e.g. to calculate season length) we include all records. When we count vessels, trips, vessel attributes, and other fleet statistics we exclude these records.

For this report, trips are defined as follows. Each landing record has an associated start and stop time and date associated with processing activity start and stop. Legislative Decree 1084 limits vessels to one landing every 24 (Paredes 2012) and so we assume that a vessel makes a maximum of one trip per calendar day. This amounts to grouping records for the same vessels on the same day, and treating the group as one trip with the trip landings equaling the sum of the landings in each of the associated records. Of the ~393,000 records for fishing years 2006-2013, ~16,000 have a recorded landing higher than the vessel capacity. About 90% of the overages are associated with wood-hulled vessels. After aggregating reported landings from a day and vessel, we end up with ~348,000 records (which we call unique trips), of which ~28,000 have reported landings over the hold capacity. Pre-IVQ years have about twice as many of these records as post-IVQ years.

We assume that a vessel fishes in the same region as the landing (the Southern region or the North-Central region). This assumption is based on personal communication with PRODUCE staff.

Table A4: Summary Statistics - Steel Fleet.

Fishing Season	Number of Active Vessels	Total Landings (MT)	Trips	Ave. Capacity (MT)	Ave. Landings per Vessel (MT)	Ave. Landings per Trip (MT)
S12006	560	2,060,393	12,856	304	3,679	160
S22006	551	1,867,212	10,199	308	3,389	183
S12007	554	2,932,300	16,841	308	5,293	174
S22007	547	1,780,461	11,006	311	3,255	162
S12008	551	2,992,021	18,212	312	5,430	164
S22008	539	1,883,899	9,305	315	3,495	202
S12009	448	2,877,951	14,028	324	6,424	205
S22009	412	1,855,092	11,664	332	4,503	159
S12010	385	2,174,199	11,321	337	5,647	192
S22010	353	629,472	4,813	348	1,783	131
S12011	366	3,267,774	15,196	346	8,928	215
S22011	347	2,260,841	9,491	353	6,515	238
S12012	346	2,412,530	14,050	355	6,973	172
S22012	327	641,606	6,040	356	1,962	106
S12013	341	1,819,114	9,429	353	5,335	193
S22013	340	2,151,686	11,224	351	6,328	192

Source: PRODUCE landings data.

Note: the IVQ system began in the first season of 2009 in the North-Central region and the second season of 2009 for in Southern region.

Table A5: Summary Statistics - Wood Fleet.

Fishing Year	Number of Active Vessels	Total Landings (MT)	Trips	Ave. Capacity (MT)	Ave. Landings per Vessel (MT)	Ave. Landings per Trip (MT)
S12006	590	401,544	8,625	64	681	47
S22006	603	409,895	8,311	65	674	49
S12007	630	721,913	13,993	66	1,121	50
S22007	619	589,259	11,826	66	936	49
S12008	610	740,994	15,163	66	1,173	47
S22008	607	474,295	9,629	66	781	49
S12009	566	741,223	16,261	67	1,310	46
S22009	530	436,124	11,334	68	823	38
S12010	531	534,918	9,736	68	1,007	55
S22010	510	152,675	4,010	69	299	38
S12011	526	771,040	15,424	69	1,466	50
S22011	492	501,932	8,532	69	1,020	59
S12012	483	521,941	12,241	70	1,081	43
S22012	331	128,986	3,372	78	390	38
S12013	454	393,762	6,741	71	867	58
S22013	456	445,600	7,227	70	977	62

Source: PRODUCE landings data.

Note: the IVQ system began in the first season of 2009 in the North-Central region and the second season of 2009 for in Southern region.

Table A6: Summary Statistics - Steel Fleet.

Fishing Year	Number of Active Vessels	Total Landings (MT)	Trips	Ave. Capacity (MT)	Ave. Landings per Vessel (MT)	Ave. Landings per Trip (MT)
2006	566	3,927,605	23,055	305	6,939	170
2007	558	4,712,761	27,847	309	8446	169
2008	555	4,875,920	27,517	312	8785	177
2009	461	4,733,043	25,692	327	10267	184
2010	402	2,803,670	16,134	333	6974	174
2011	376	5,528,614	24,687	346	14704	224
2012	351	3,054,135	20,090	354	8701	152
2013	346	3,970,799	20,653	352	11476	192

Source: PRODUCE landings data.

Note: the IVQ system began in the first season of 2009 in the North-Central region and the second season of 2009 in the Southern region.

Table A7: Summary Statistics – North-Central Steel Fleet.

Fishing Year	Number of Active Vessels	Total Landings (MT)	Trips	Ave. Capacity (MT)	Ave. Landings per Vessel (MT)	Ave. Landings per Trip (MT)
2006	565	3,180,694	14,525	305	5,630	219
2007	558	3,933,449	18,850	309	7,049	209
2008	553	4,220,199	19,576	312	7,631	216
2009	458	4,287,364	21,140	327	9,361	203
2010	389	2,597,674	12,468	339	6,678	208
2011	372	4,909,906	20,246	348	13,199	243
2012	349	2,718,457	17,274	354	7,789	157
2013	344	3,423,001	15,600	351	9,951	219

Source: PRODUCE landings data.

Note: the IVQ system began in the first season of 2009 in the North-Central region.

Table A8: Summary Statistics – Southern Steel Fleet.

Fishing Year	Number of Active Vessels	Total Landings (MT)	Trips	Ave. Capacity (MT)	Ave. Landings per Vessel (MT)	Ave. Landings per Trip (MT)
2006	359	746,911	8,530	273	2,081	88
2007	374	779,312	8,997	291	2,084	87
2008	357	655,721	7,942	290	1,837	83
2009	269	445,679	4,552	294	1,657	98
2010	214	205,997	3,666	296	963	56
2011	228	618,708	4,441	314	2,714	139
2012	182	335,679	2,816	328	1,844	119
2013	194	547,798	5,053	333	2,824	108

Source: PRODUCE landings data.

Note: the IVQ system began in the second season of 2009 in the Southern region.

Table A9: Summary Statistics – Wood Fleet.

Fishing Year	Number of Active Vessels	Total Landings (MT)	Trips	Ave. Capacity (MT)	Ave. Landings per Vessel (MT)	Ave. Landings per Trip (MT)
2006	612	811,439	16,936	65	1,320	48
2007	639	1,311,172	25,819	66	2,012	50
2008	632	1,215,289	24,792	65	1,882	48
2009	580	1,177,347	27,595	67	2,030	43
2010	548	687,594	13,746	68	1,255	50
2011	542	1,272,973	23,956	68	2,349	53
2012	489	650,927	15,613	71	1,331	42
2013	475	839,361	13,968	71	1,767	60

Source: PRODUCE landings data.

Note: the IVQ system began in the first season of 2009 in the North-Central region and the second season of 2009 for in Southern region.

Table A10: Summary Statistics – North-Central Wood Fleet.

Fishing Year	Number of Active Vessels	Total Landings (MT)	Trips	Ave. Capacity (MT)	Ave. Landings per Vessel (MT)	Ave. Landings per Trip (MT)
2006	609	727,532	15,317	65	1,195	47
2007	636	1,185,917	23,383	66	1,845	50
2008	619	1,050,457	21,471	66	1,680	48
2009	562	1,093,464	25,248	68	1,946	43
2010	529	647,929	12,572	69	1,225	52
2011	523	1,213,646	22,740	70	2,321	53
2012	489	631,012	15,306	71	1,290	41
2013	475	812,362	13,535	71	1,710	60

Source: PRODUCE landings data.

Note: the IVQ system began in the first season of 2009 in the North-Central region.

Table A11: Summary Statistics – Southern Wood Fleet.

Fishing Year	Number of Active Vessels	Total Landings (MT)	Trips	Ave. Capacity (MT)	Ave. Landings per Vessel (MT)	Ave. Landings per Trip (MT)
2006	106	83,908	1,619	88	756	50
2007	134	125,256	2,436	90	839	46
2008	184	164,832	3,326	80	813	45
2009	122	83,882	2,347	81	688	36
2010	65	39,665	1,174	78	610	34
2011	66	59,327	1,216	78	899	49
2012	24	19,916	307	101	830	65
2013	26	26,999	433	101	1,038	62

Source: PRODUCE landings data.

Note: the IVQ system began in the second season of 2009 for in Southern region.

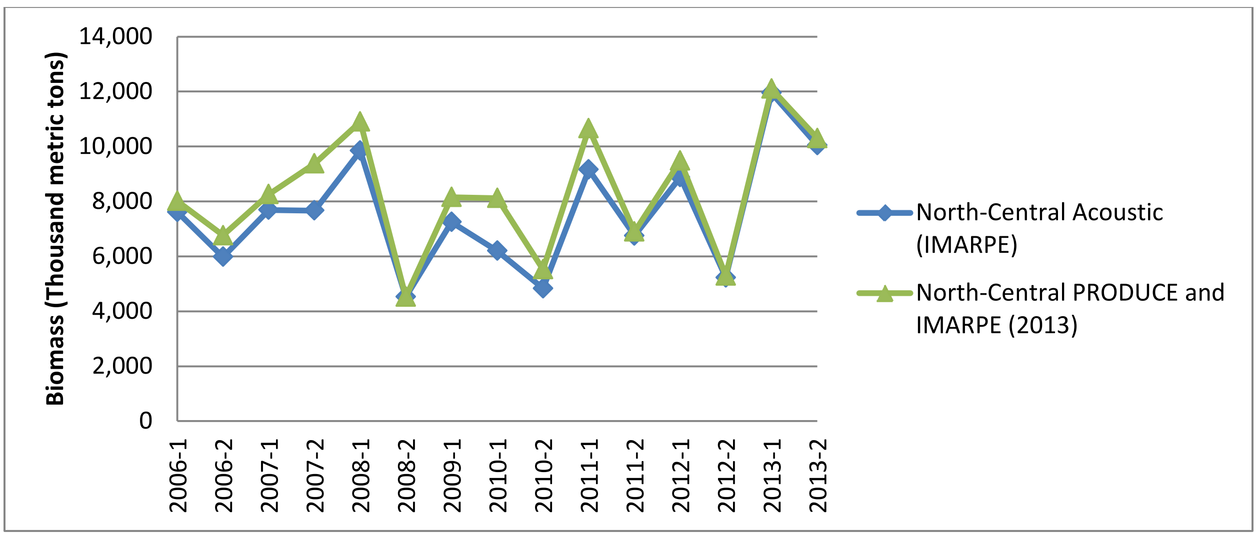
1.4 <u>Biomass</u>

We use two sources of biomass information to track biomass in the North-Central fishery over time. First, we use estimates from acoustic research surveys done by IMARPE. Second, we use data on the North-Central biomass from PRODUCE official reports (IMARPE 2015). We graph the estimates from the two sources in Figure A8. The trend over time is similar for both series, although there is slight variation season-to-season.

Typically there is a separate estimate for the first and second fishing seasons. One exception is that in 2008 there are three recorded acoustic survey estimates. We use values from the first and second, because these correspond to the IMARPE (2015) estimates. Additionally, there is only one acoustic survey estimate in 2009. In the main report, where we graph by season, we apply the same value to both seasons.

Although raw survey data from research cruises is available, we are unaware of any seasonal biomass estimates of the Southern stock.

Figure A8: North-Central Biomass.



1.5 <u>Fishing Years, Seasons, and TACs</u>

Fishing seasons and the official total allowable catch (TAC) for each season are presented in Tables A12 and A13. The season start and end dates do not take into account closures due to juveniles and other management measures. Fishing seasons do not align perfectly with the calendar year. In some years the second fishing season extends past December 31 into the following calendar year. For example, the second fishing season in the North-Central region in 2009 ended on January 31, 2010. For this analysis, all statistics are reported by fishing year. Following along with the example, landings recorded in the North-Central between January 1, 2010 and January 31, 2010, are assigned to fishing year 2009.

The North-Central region was regulated using two seasons per year for the entire period of analysis (2006-2014). We list the official fishery dates in Table A12.

The Southern fishery did not have regulated fishing seasons until the start of the IVQ system in 2009. For purposes of comparison statistics and analysis, for the period predating the start of the IVQ system (season 2 of 2009), we construct two seasons per year that match the start and end dates of post-2009 seasons. We use a start date of February 1 for the first season of each year and an end date of July 31. For the second season, we use a start date of August 1 and end date of July 31. See Table A13 for a summary of the 2009 seasons we use for the analysis.

We attribute landings that occur between seasons (after the end date of one season but before the start date of the next season) to the prior season.

The landings database includes all landings starting on January 1, 2006. The 4,438 landings from January 1, 2006-January 31, 2006 are considered part of season 2 of 2005, and therefore we drop them for the analysis.

To calculate the number of days with at least one recorded landing we included recorded landings not attributed to a specific vessel but exclude records if they did not contain a landings date. Figure A9 presents the number of days with at least one landing in the South. In the Southern region there is not a clear pattern post-IVQ. If anything, the number of active days actually decreases. In Figures A10 – A13 we present results broken down by region and hull.

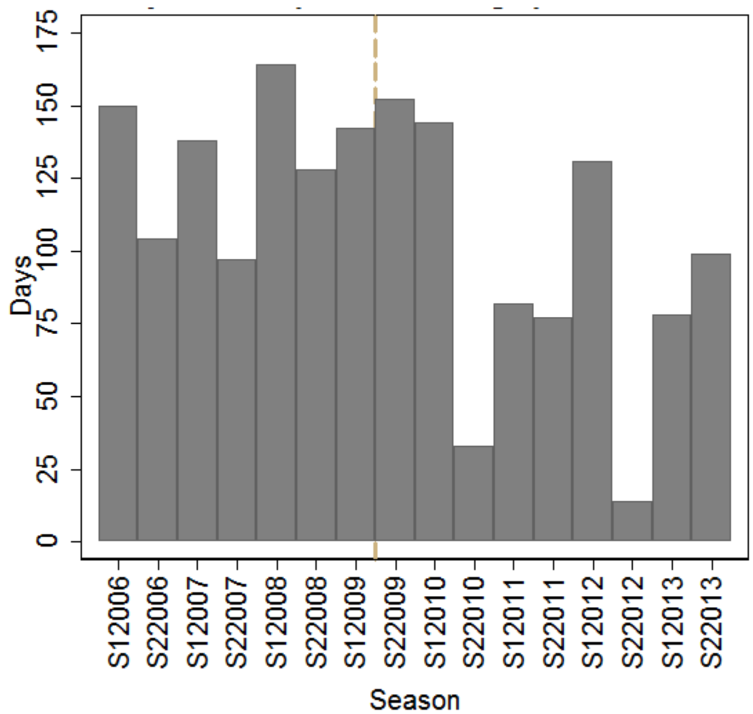
Table A12: Seasons and TAC for the North-Central Region.

Year	Season	Start Date	End Date	Quota
2006	S12006	5/2/2006	7/31/2006	2,250,000
2006	S22006	11/3/2006	4/8/2007	2,000,000
2007	S12007	4/10/2007	10/31/2007	3,000,000
2007	S22007	11/1/2007	4/20/2008	2,300,000
2008	S12008	4/21/2008	11/9/2008	3,000,000
2008	S22008	11/15/2008	4/19/2009	2,000,000
2009	S12009	4/20/2009	7/30/2009	3,500,000
2009	S22009	11/6/2009	1/31/2010	2,000,000
2010	S12010	5/13/2010	7/31/2010	2,500,000
2010	S22010	11/20/2010	1/31/2011	2,070,000
2011	S12011	4/1/2011	7/31/2011	3,675,000
2011	S22011	11/23/2011	1/31/2012	2,500,000
2012	S12012	5/2/2012	7/31/2012	2,700,000
2012	S22012	11/22/2012	2/1/2013	410,000
2013	S12013	5/17/2013	8/31/2013	2,050,000
2013	S22013	11/12/2013	1/31/2014	2,304,000
2014	S12014	4/23/2014	8/10/2014	2,530,000

Table A13: Seasons and TAC for the Southern Region.

Year	Season	Start Date	End Date	Quota
2006	S12006	2/1/2006	7/31/2006	
2006	S22006	8/1/2006	1/31/2007	
2007	S12007	2/1/2007	7/31/2007	
2007	S22007	8/1/2007	1/31/2008	
2008	S12008	2/1/2008	7/31/2008	
2008	S22008	8/1/2008	1/31/2009	
2009	S12009	2/1/2009	7/6/2009	
2009	S22009	7/7/2009	1/24/2010	500,000
2010	S12010	1/25/2010	7/31/2010	400,000
2010	S22010	8/1/2010	1/19/2011	450,000
2011	S12011	2/17/2011	6/30/2011	400,000
2011	S22011	7/1/2011	1/31/2012	400,000
2012	S12012	2/17/2012	8/1/2012	400,000
2012	S22012	8/7/2012	1/8/2013	307,000
2013	S12013	1/11/2013	9/1/2013	400,000
2013	S22013	10/31/2013	6/22/2014	430,000
2014	S12014	6/23/2014	9/30/2014	234,300

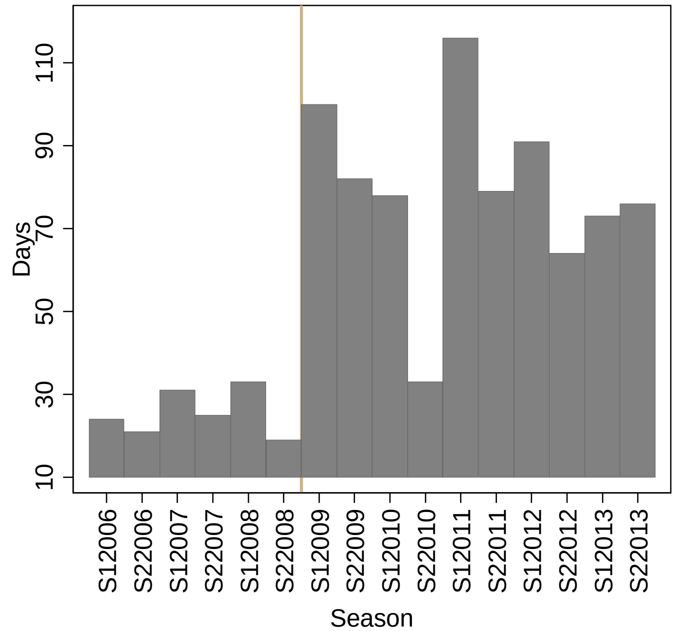
Figure A9: Number of Days per Fishing Season with at Least One Landing Record in the South.



Source: PRODUCE landings data.

Note: The dashed vertical line corresponds to the start of the IVQ system in the Southern region. Prior to this season, there were no official seasons; the calculation of pre-IVQ seasons is described in the Appendix.

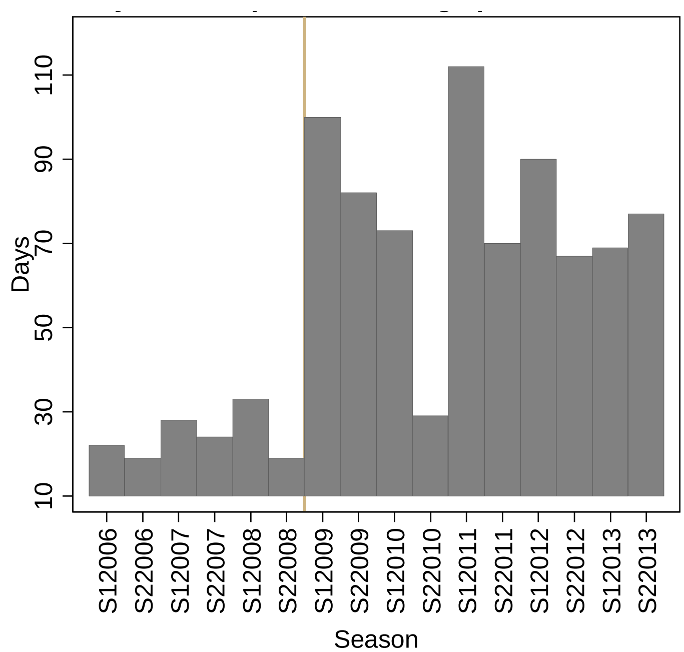
Figure A10: Number of Days per Fishing Season with at Least One Landing Record by the North-Central Steel Fleet.



Source: PRODUCE landings data.

Note: The solid vertical line corresponds to the start of the IVQ system in the North-Central region.

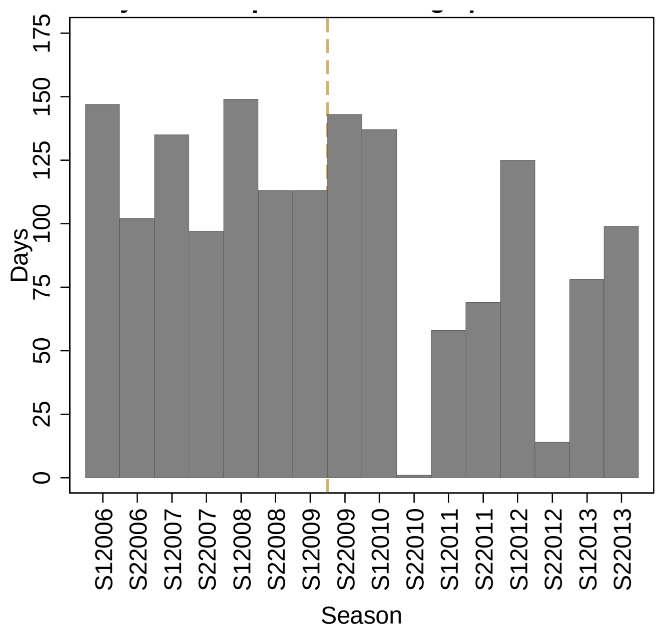
Figure A11: Number of Days per Fishing Season with at Least One Landing Record by the North-Central Wood Fleet.



Source: PRODUCE landings data.

Note: The solid vertical line corresponds to the start of the IVQ system in the North-Central region.

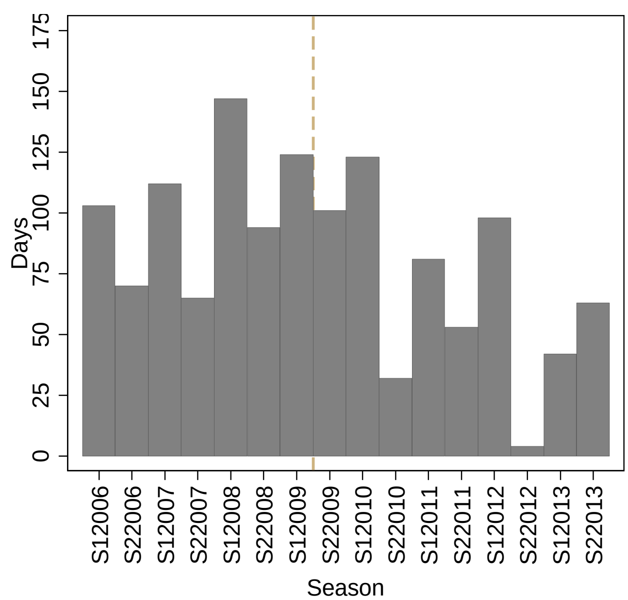
Figure A12: Number of Days per Fishing Season with at Least One Landing Record by the South Steel Fleet.



Source: PRODUCE landings data.

Note: The dashed vertical line corresponds to the start of the IVQ system in the Southern region. Prior to this season, there were no official seasons; the calculation of pre-IVQ seasons is described in the Appendix.

Figure A13: Number of Days per Fishing Season with at Least One Landing Record by the South Wood Fleet.



Source: PRODUCE landings data.

Note: The dashed vertical line corresponds to the start of the IVQ system in the Southern region. Prior to this season, there were no official seasons; the calculation of pre-IVQ seasons is described in the Appendix.

1.6 Quota Ownership and Hull Designation

We obtained a confidential database containing information on quota allocation per vessel from PRODUCE. The data covers 2009 through 2014 and is provided separately for each season in each region. Each dataset contains the name, registration number, hull type, owner, applicable law, authorized hull capacity, and allowed total landings for the season as a percentage of the total catch and in metric tons for each vessel granted quota for that season.

The hull types are listed as wood, steel, or fiberglass. There are three vessels in this dataset that have fiberglass hulls, responsible for 247 landings (0.06% of all landings in the period of analysis), all in the period from 2006-2009. We group these vessels with the wood vessels.

The quota dataset contains two indicators of hull type: the regime and a hull type variable. We calculate 2010 wood hull vessels associated with regime LEY Nº26920 to have a mean capacity (in m^3) of 55.46, with a 95% CI (33.18, 109). In 2010 steel hull vessels associated with DECRETO LEY Nº25977 have a mean capacity (in m^3) of 295.87, with a 95% CI of (110.84, 547.08). As we describe in the landings data section, we use the cutoff of $110m^3$ to assign a wood or steel hull for the observations where we are missing a hull type.

For all but ~200 of ~170,000 quota records, wood hull vessels are associated with LEY Nº26920 and steel hull vessels are associated with DECRETO LEY Nº25977. The 191 records correspond to 15 vessels with wood hulls listed with regime DECRETO LEY Nº25977. All but one vessel has a capacity less than or equal to that of the “wood”/LEY Nº26920 vessel with the highest capacity listed in 2010. Therefore, we do not make any adjustments.

For each season, less than 100% of the TAC is distributed to vessels, reflecting the reserved contingency stock held by fishery managers, which can be up to 2.2% but is often less than that amount. See Tables A14-A15 for details.

Table A14: Percent of the TAC Allocated to Vessels.

Season	CN Region	S Region
S12009	97.96175	
S22009	98.52327	98.62728
S12010	98.57764	98.07246
S22010	99.22331	99.49057
S12011	99.47563	99.55391
S22011	98.11655	98.975
S12012	98.6639	99.09983
S22012	97.01013	99.09983
S12013	96.86756	98.52145
S22013	98.54986	99.09821
S12014	97.91598	98.81806

Table A15: TAC and Quota Allocations.

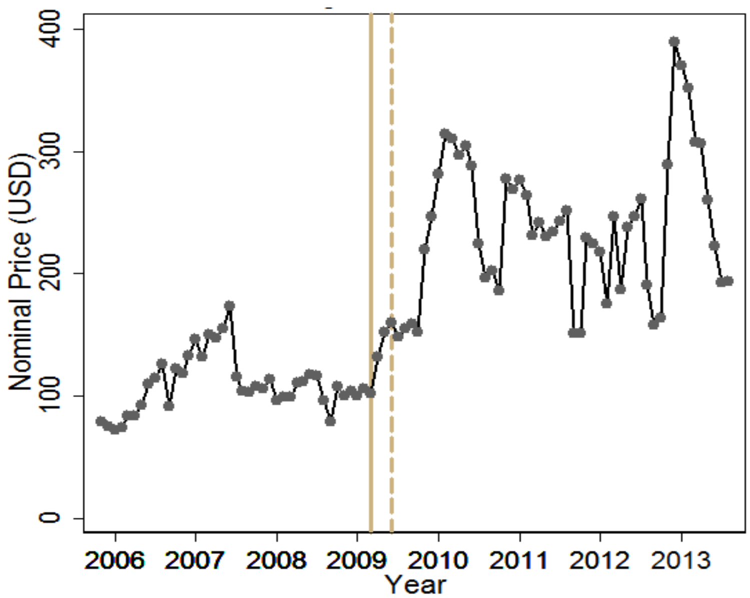
Season	Total NC Quota	NC TAC	Total S Quota	S TAC
S12009	3,428,660.55	3,500,000		
S22009	1,970,273.04	2,000,000	493,136.39	500,000
S12010	2,464,331.65	2,500,000	392,289.82	400,000
S22010	2,053,453.60	2,070,000	447,614.39	450,000
S12011	3,655,724.88	3,675,000	398,044.94	400,000
S22011	2,452,696.78	2,500,000	395,899.98	400,000
S12012	2,663,493.50	2,700,000	395,552.41	400,000
S22012	785,719.44	810,000	303,807.55	307,000
S12013	1,985,767.28	2,050,000	393,889.71	400,000
S22013	2,270,448.46	2,304,000	426,113.19	430,000
S12014	2,476,790.60	2,530,000	231,215.90	234,300

1.7 Ex-Vessel Price

For 2006 through August 2013 we obtained confidential monthly ex-vessel price data from PRODUCE. The prices are for raw, unprocessed anchovy, and are in nominal Peruvian Nuevo Sols. Prices were converted into U.S. dollars using United Nations Treasury Operational

Rates of Exchange for the Nuevo Sol and U.S. dollar. For the 17 months with no listed exchange rate, the conversion rate was obtained by taking the average of the two adjacent months. If two months were missing, the first month was given the average of the two provided months preceding and following the missing values and the second rate was calculated by averaging the rates of the months immediately preceding and following. Prices are indexed to 2013 values using the Peruvian Wholesale Price Index from the World Bank Development Indicators. For landings after August 2013 we use the average ex-vessel price for 2013, reported by PRODUCE, of $724.42 Peruvian Nuevo Sols. Figure A14 is a graph of nominal monthly prices and Figure A15 is a graph of real prices.

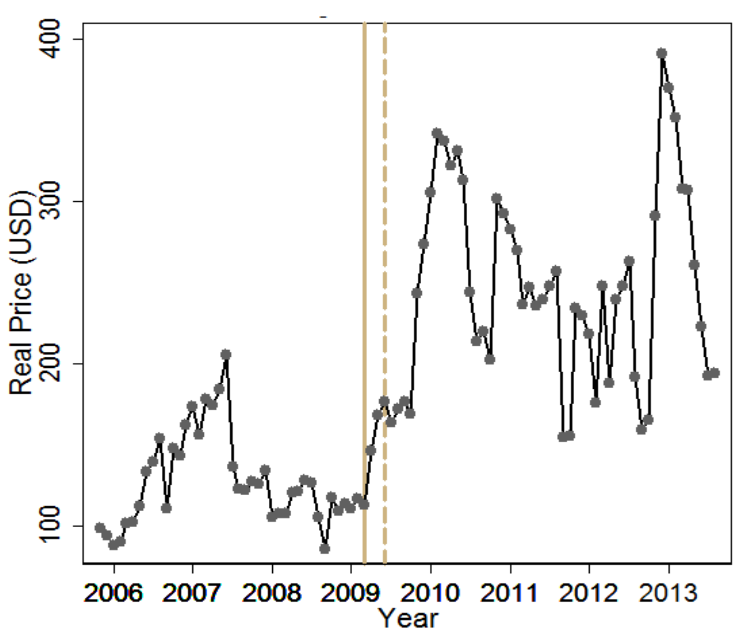
Figure A14: Nominal Monthly Ex-Vessel Price.



Source: PRODUCE ex-vessel price data.

Note: The solid vertical line corresponds to the start of the IVQ system in the North-Central region in April 2009; the dashed line corresponds to the start of the IVQ system in the Southern region in July 2009.

Figure A15: Real Monthly Ex-Vessel Price.



Sources: PRODUCE ex-vessel price data, World Bank (Peruvian Wholesale Price Index), and UN Treasury (operational rates of exchange).

Note: The solid vertical line corresponds to the start of the IVQ system in the central-north; the dashed line corresponds to the start of the IVQ system in the south.

1.8 Fishing Costs

Cost data was obtained from a large integrated fishing and processing company. Information on costs was provided for 2006, 2008, 2010 and 2013. Cost data was only provided for steel hulled vessels, which is consistent with our databases, which show that this firm only directly owns vessels in the steel fleet.

Cost estimates are broken down into classes by capacity (in m^3). The capacity classes used by the firm differ from the capacity units (metric tons) in the landings dataset. We compared the capacity estimates in the landings database to those in the quota dataset, which were provided in cubic meters. They are within 3% of one another. Therefore, for the purposes of the analysis, we apply the cost category groupings (in m^3) to the vessel landings (in metric tons).

The cost data for the steel fleet, broken down by vessel capacity and refrigeration status, is summarized in Tables A16-A19. For the main analysis we use the cost for non-refrigerated vessels, when both are available. We are unable to identify refrigerated vessels in our landings data for all years. Costs were broken down into variable costs that scale with catch (e.g. fuel), semi-variable costs (e.g. crew salaries), and maintenance.

Table A16: Costs per Metric Ton for Steel Vessels (Nominal $USD) Greater Than or Equal To 440 M^3 Capacity.

	With Refrigeration	*Without Refrigeration*

	2006	2008	2011	2013	2006	2008	2011	2013
Variable costs								
Fuel	20.87	21.87	19.46	28.20	15.25	16.72	16.04	25.64
Lubricants	0.53	1.00	0.69	0.96	0.36	0.79	0.59	0.67
Food	1.16	0.88	0.71	0.95	1.16	1.01	0.92	1.61
Crew	22.94	31.28	50.08	55.92	23.30	32.93	39.85	62.82
Total Variable	45.50	55.03	70.94	86.04	40.07	51.46	57.40	90.75
Semi-Variable costs								
Fishing Rights	0.01	2.33	3.47	4.20	0.02	3.48	3.54	4.29
Other	4.32	7.71	7.18	1.79	5.96	11.49	2.89	11.11
Total Semi-Variable	*4.34*	*13.02*	*14.96*	*18.10*	*6.06*	*16.50*	*7.73*	*22.74*
Maintenance costs								
Maintenance	23.27	23.04	20.17	22.43	23.14	16.11	9.29	20.01
Total Maintenance	*23.27*	*23.04*	*20.17*	*24.25*	*23.70*	*15.36*	*9.97*	*20.25*
TOTAL PER METRIC TON	73.11	88.10	101.76	114.46	69.19	82.53	73.11	126.17

Table A17: Costs per Metric Ton for Steel Vessels (nominal $USD) 300-440 m^3 Capacity, No Refrigeration.

	2006	2008	2011	2013

Variable costs				
Fuel	17.47	22.55	21.55	26.82
Lubricants	0.64	0.88	0.63	0.68
Food	1.16	1.62	1.17	1.83
Crew	25.15	32.47	41.06	59.38
Total Variable	*45.26*	*56.48*	*65.12*	*81.32*
Semi-Variable costs				
Fishing Rights	0.02	3.33	3.59	4.31
Other	6.76	11.00	6.37	11.71
Total Semi-Variable	6.78	14.33	9.96	16.02
Maintenance costs				
Services and general mechanical	29.44	15.13	14.47	24.45
Total Maintenance	29.44	15.13	14.47	24.45
TOTAL PER METRIC TON	**82.84**	**89.36**	**101.50**	**139.66**

Table A18: Costs per Metric Ton for Steel Vessels (nominal $USD) Less than 300 m^3 Capacity, no Refrigeration.

	2006	**2008**

Variable costs		
Fuel	14.62	11.19
Lubricants	0.50	0.39
Food	1.16	1.09
Crew	26.13	32.74
Total Variable	42.29	56.44
Semi-Variable costs		
Fishing Rights	0.03	4.10
Other	8.35	13.56
Total Semi-Variable	***8.38***	***17.66***
Maintenance costs		
Maintenance	29.16	15.98
Total Maintenance	29.16	15.98
TOTAL PER METRIC TON	**79.83**	**90.09**

Table A19: Nominal Cost ($USD) Per Metric Ton for Steel Vessel Operation.

	2006	*2008*	*2011*	*2013*
Variable Costs				

Greater than or equal to 440 m^3 capacity (with refrigeration)	45.5	55.03	70.94	86.04
Greater than or equal to 440 m^3 capacity (no refrigeration)	40.07	51.46	57.4	90.75
300-440 m^3 capacity (no refrigeration)	44.42	57.53	64.4	88.72
Less than 300 m^3 capacity (no refrigeration)	42.29	56.44		
Semi-Variable Costs				
Greater than or equal to 440 m^3 capacity (with refrigeration)	4.34	10.04	10.65	5.99
Greater than or equal to 440 m^3 capacity (no refrigeration)	5.98	14.96	6.43	15.41
300-440 m^3 capacity (no refrigeration)	6.78	14.33	9.96	16.02
Less than 300 m^3 capacity (no refrigeration)	8.38	17.66		
Maintenance Costs				
Greater than or equal to 440 m^3 capacity (with refrigeration)	23.27	23.04	20.17	22.43
Greater than or equal to 440 m^3 capacity (no refrigeration)	23.14	16.11	9.29	20.01
300-440 m^3 capacity (no refrigeration)	29.44	15.13	14.47	24.45
Less than 300 m^3 capacity (no refrigeration)	29.16	15.98		
Total Cost per Metric Ton				
Greater than or equal to 440 m^3 capacity (with refrigeration)	**73.11**	**88.1**	**101.76**	**114.46**
Greater than or equal to 440 m^3 capacity (no refrigeration)	**69.19**	**82.53**	**73.11**	**126.17**
300-440 m^3 capacity (no refrigeration)	**80.64**	**86.99**	**88.83**	**129.19**
Less than 300 m^3 capacity (no refrigeration)	**79.83**	**90.09**	--	--

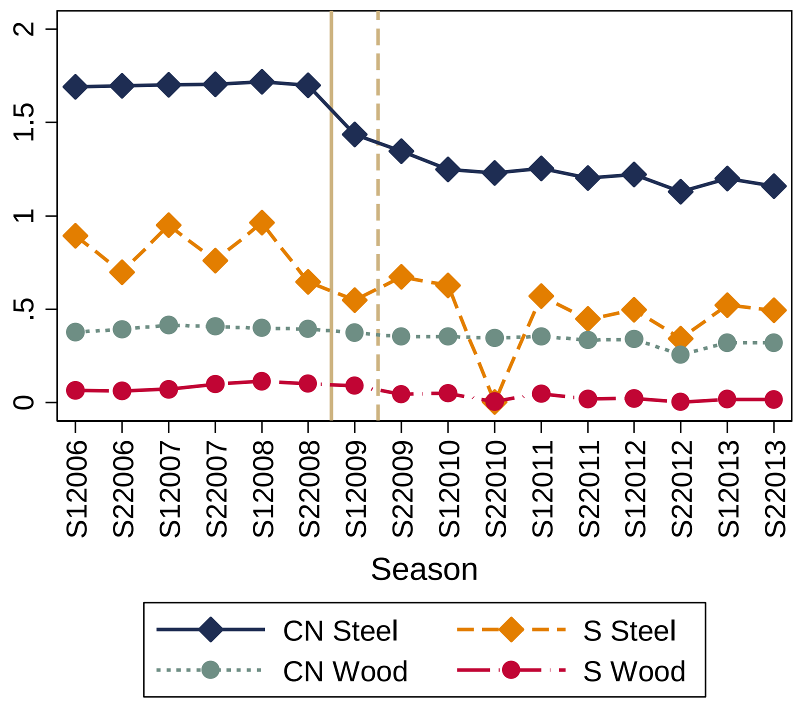
Note: The costs are broken down by vessel capacity groups defined by the firm.

1.9 <u>Margins of Change Figures</u>

In this section we present figures breaking down input margins over additional margins of change. We examine fleet capacity, in aggregate (Figure A17), the wood median capacity (Figure A18), and the average capacity when landings are used as weights (Figures A19 and A20). We also provide a more detailed breakdown of catch per vessel and days fished per vessel, the percentage of the hull filled, the catch per trip, and the percentage of total catch and total trips per vessel (Figures A21-A35).

1.9.1 Capacity

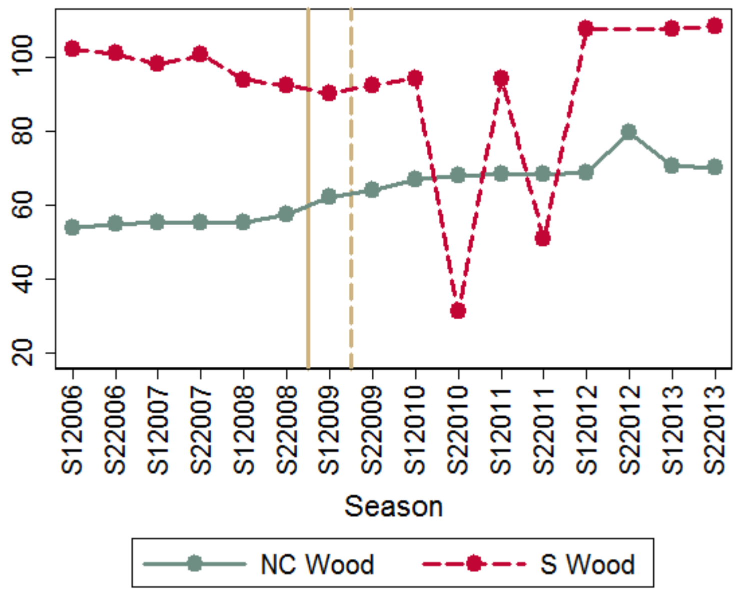
Figure A17: Total Fleet Capacity (100,000 m^3).



Source: PRODUCE landings data.

Note: Total capacity is calculated by summing the total hull capacity of all active vessels.

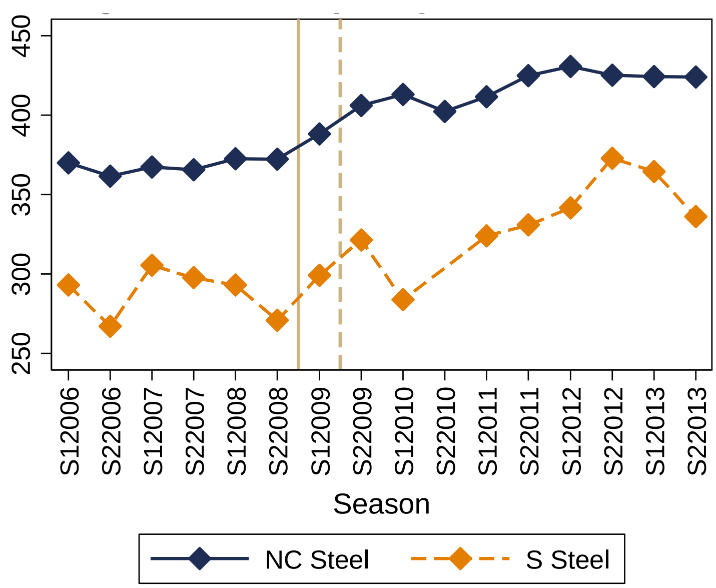
Figure A18: Median Hull Capacity of Active Wood Vessels.



Source: PRODUCE landings data.

Note: The solid vertical line corresponds to the start of the IVQ system in the North-Central region; the dashed vertical line corresponds to the start of the IVQ system in the Southern region. We do not present a summary statistic for the Southern S22012 season because only three vessels fish.

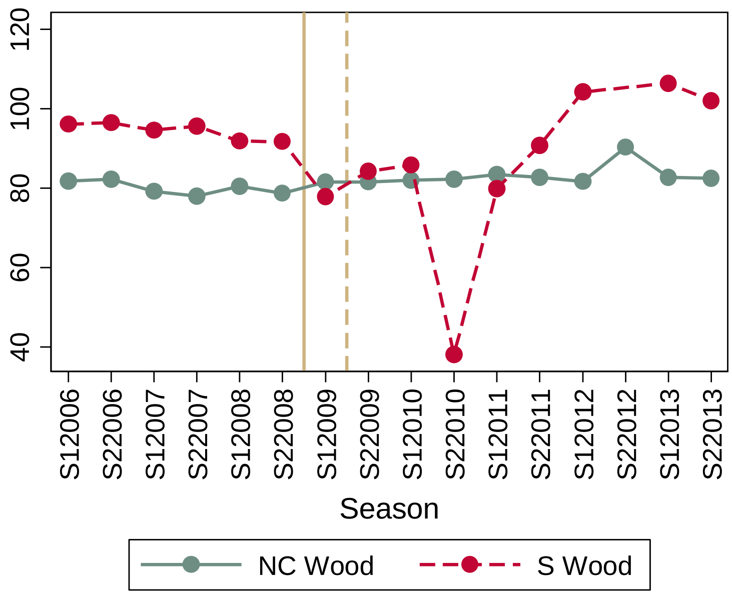
Figure A19: Steel Vessel Weighted Average Hull Capacity.



Source: PRODUCE Landings Data.

Note: The solid vertical line corresponds to the start of the IVQ system in the Central-North region; the dashed line corresponds to the start of the IVQ system in the South. We do not present a summary statistic for the Southern region for the second season of 2010 because only one vessel fishes. The landings made by a vessel are used as the weight when calculating the average capacity.

Figure A20: Wood Vessel Weighted Average Hull Capacity.

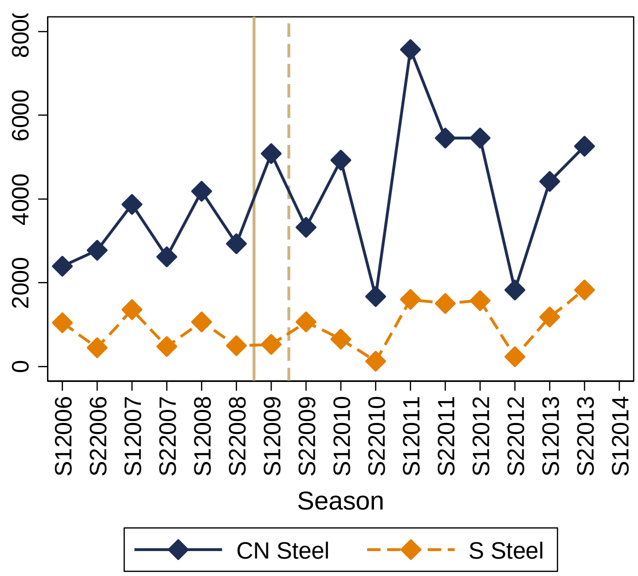


Source: PRODUCE Landings Data.

Note: The solid vertical line corresponds to the start of the IVQ system in the Central-North region; the dashed line corresponds to the start of the IVQ system in the South. We do not present a summary statistic for the Southern region for the second season of 2012 because only three vessels fish. The landings made by a vessel are used as the weight when calculating the average capacity.

1.9.2 Catch and Days Fished per Vessel

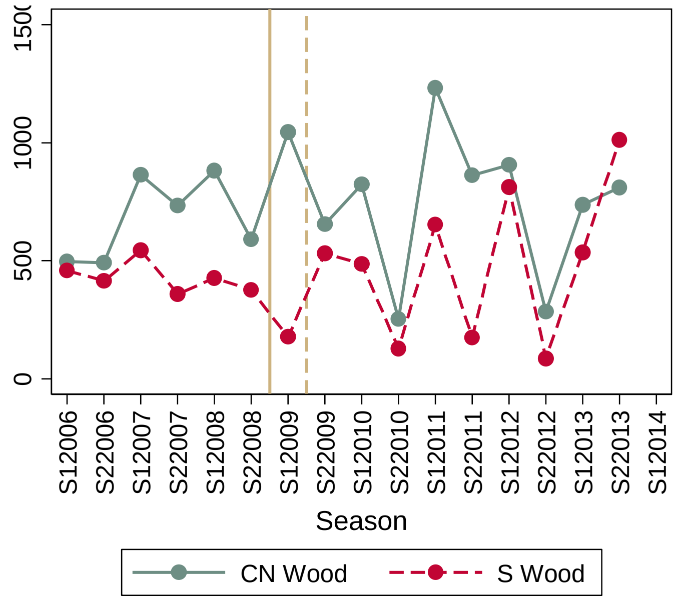
Figure A21: Median Metric Tons Caught per Steel Vessel.



Source: PRODUCE Landings Data.

Note: The solid vertical line corresponds to the start of the IVQ system in the Central-North region; the dashed line corresponds to the start of the IVQ system in the South.

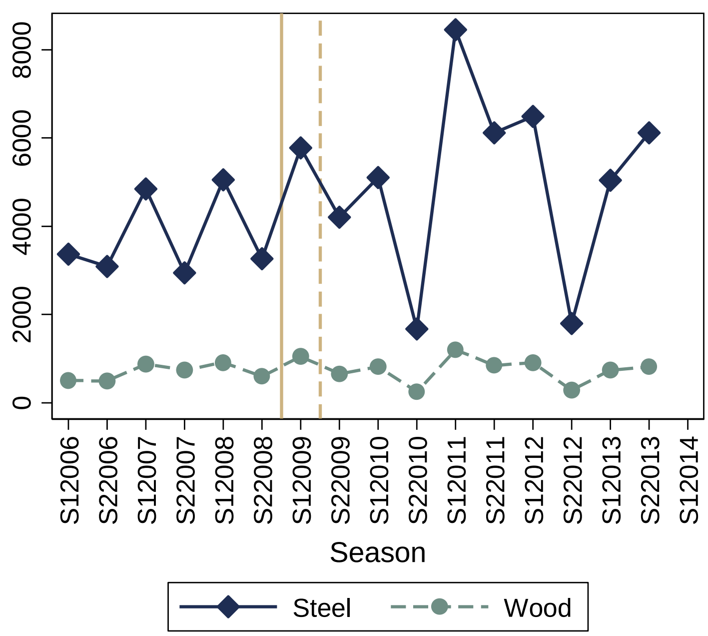
Figure A22: Median Metric Tons Caught per Wood Vessel.



Source: PRODUCE Landings Data.

Note: The solid vertical line corresponds to the start of the IVQ system in the Central-North region; the dashed line corresponds to the start of the IVQ system in the South.

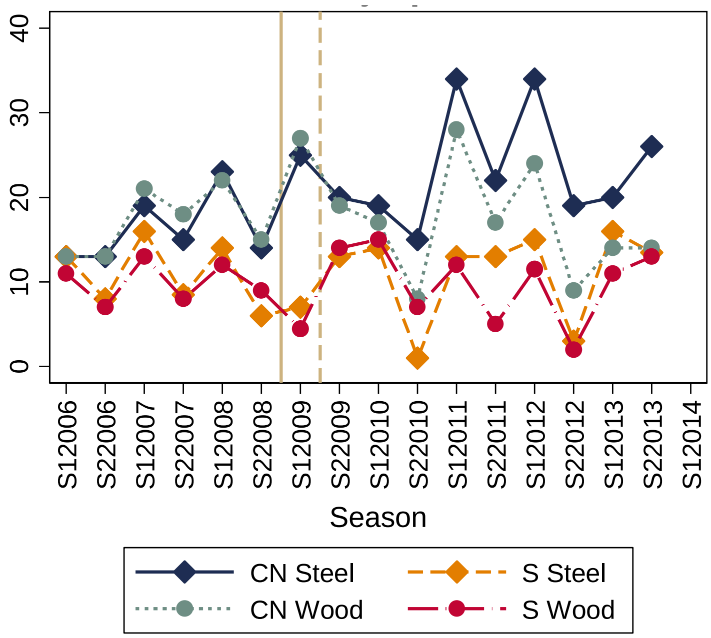
Figure A23: Median Metric Tons Caught per Vessel.



Source: PRODUCE Landings Data.

Note: The solid vertical line corresponds to the start of the IVQ system in the Central-North region; the dashed line corresponds to the start of the IVQ system in the South.

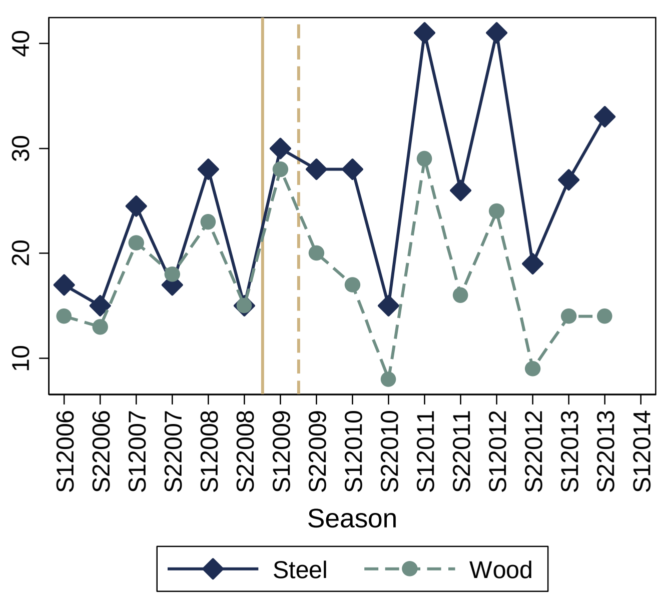
Figure A24: Median Days Fished per Vessel.



Source: PRODUCE Landings Data.

Note: The solid vertical line corresponds to the start of the IVQ system in the Central-North region; the dashed line corresponds to the start of the IVQ system in the South.

Figure A25: Median Days Fished per Vessel.

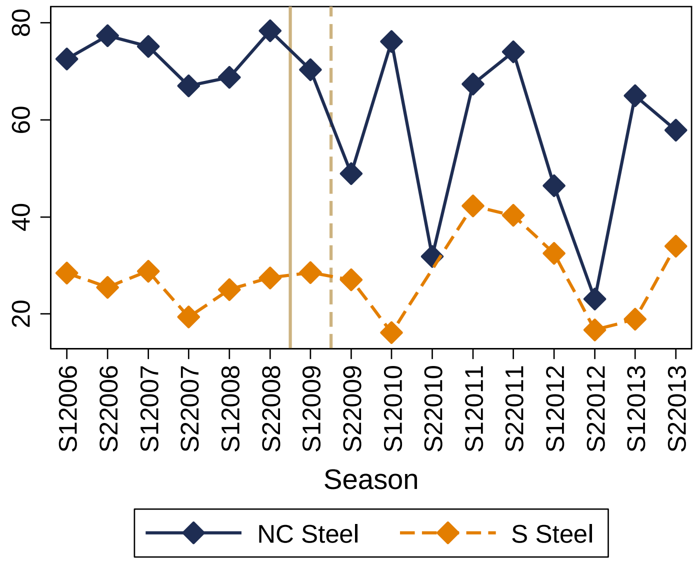


Source: PRODUCE Landings Data.

Note: The solid vertical line corresponds to the start of the IVQ system in the Central-North region; the dashed line corresponds to the start of the IVQ system in the South.

1.9.3 Hull Capacity Filled

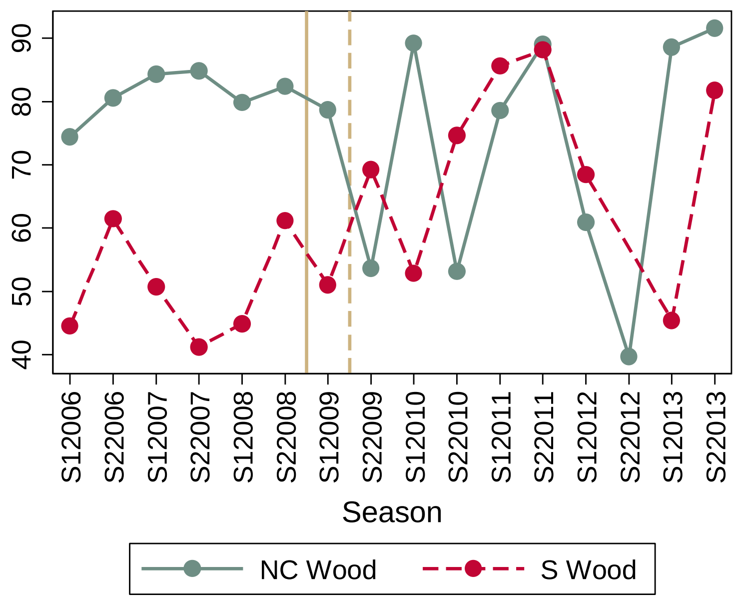
Figure A26: Median Percent Hull Filled per Steel Vessel Trip.



Source: PRODUCE Landings Data.

Note: The solid vertical line corresponds to the start of the IVQ system in the Central-North region; the dashed line corresponds to the start of the IVQ system in the South.

Figure A27: Median Percent Hull Filled per Wood Vessel Trip.

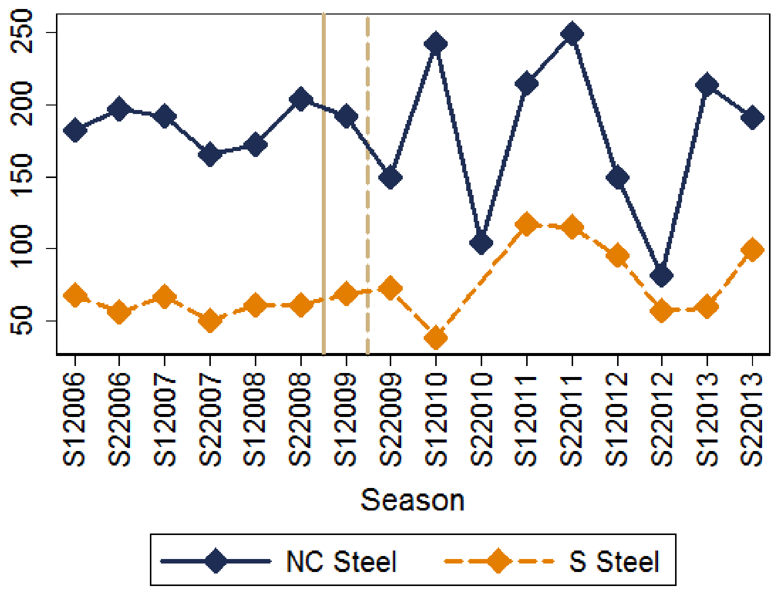


Source: PRODUCE Landings Data.

Note: The solid vertical line corresponds to the start of the IVQ system in the Central-North region; the dashed line corresponds to the start of the IVQ system in the South.

1.9.4 Catch per Trip

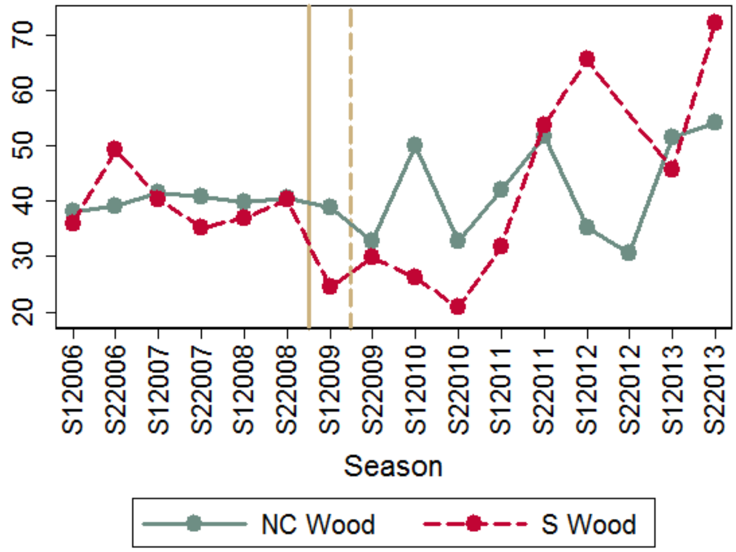
Figure A28: Median Catch per Trip (Metric Tons) for Steel Vessels.



Source: PRODUCE Landings Data.

Note: The solid vertical line corresponds to the start of the IVQ system in the Central-North region; the dashed line corresponds to the start of the IVQ system in the South.

Figure A29: Median Catch per Trip (Metric Tons) for Wood Vessels.

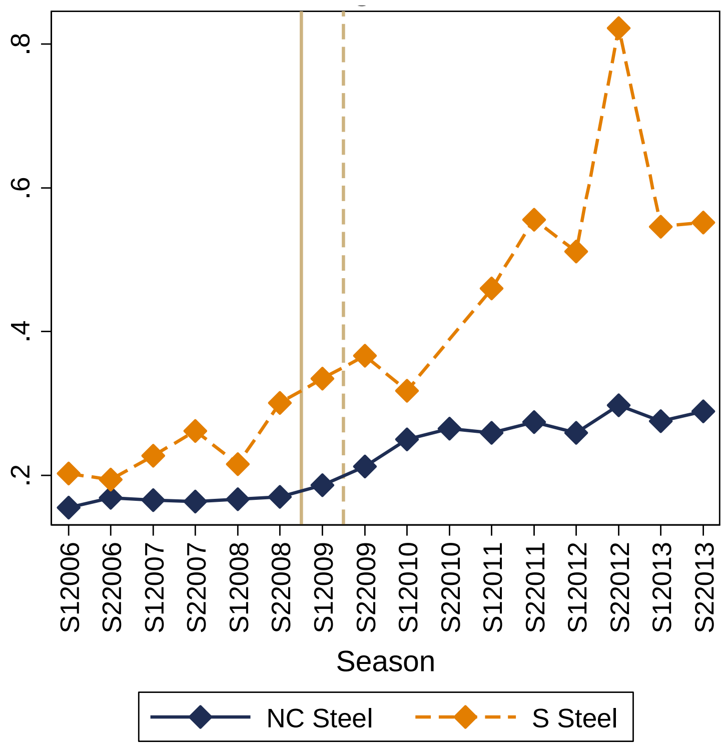


Source: PRODUCE Landings Data.

Note: The solid vertical line corresponds to the start of the IVQ system in the Central-North region; the dashed line corresponds to the start of the IVQ system in the South.

1.9.5 Vessel Percentage of Total Catch and Total Trips

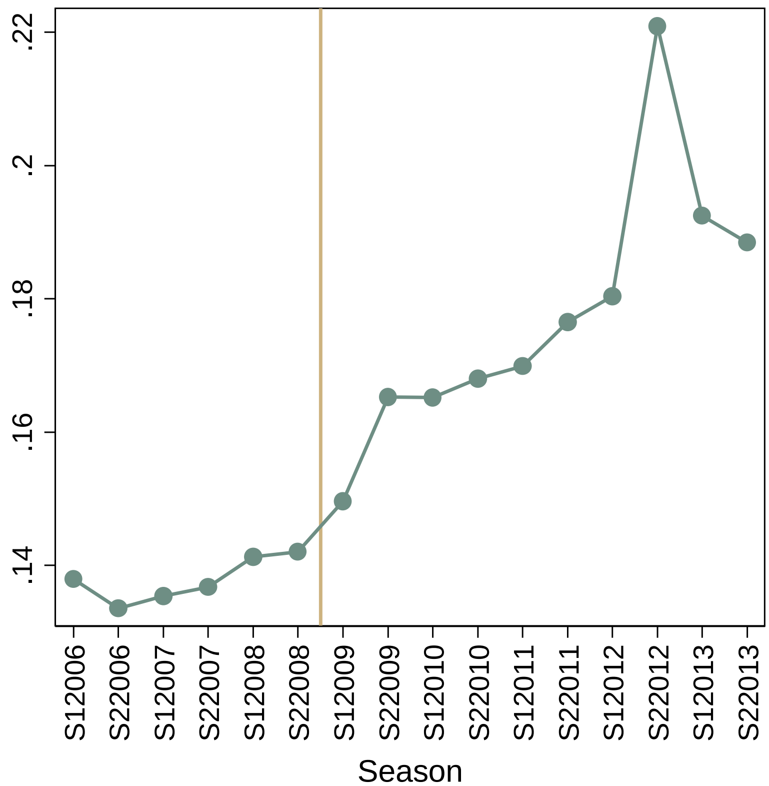
Figure A30: Median Steel Vessel Percentage of Catch.



Source: PRODUCE landings data.

Note: The solid vertical line corresponds to the start of the IVQ system in the North-Central region; the dashed vertical line corresponds to the start of the IVQ system in the Southern region. We do not present a summary statistic for the second Southern 2010 season because only one vessel fishes.

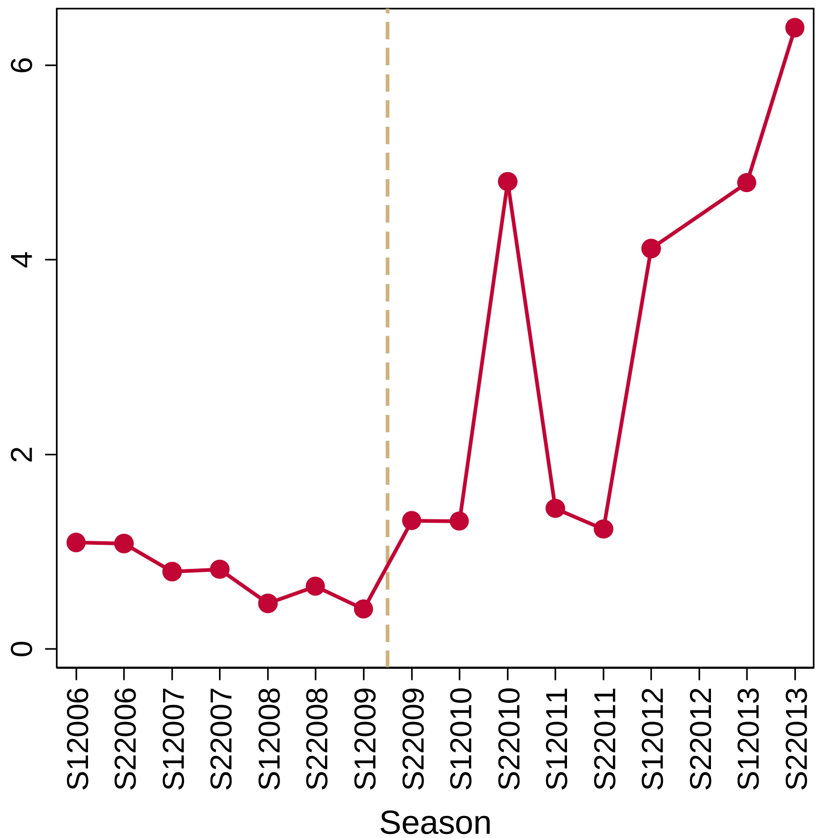
Figure A31: Median North-Central Wood Vessel Percentage of Catch.



Source: PRODUCE landings data.

Note: The solid vertical line corresponds to the start of the IVQ system in the North-Central region.

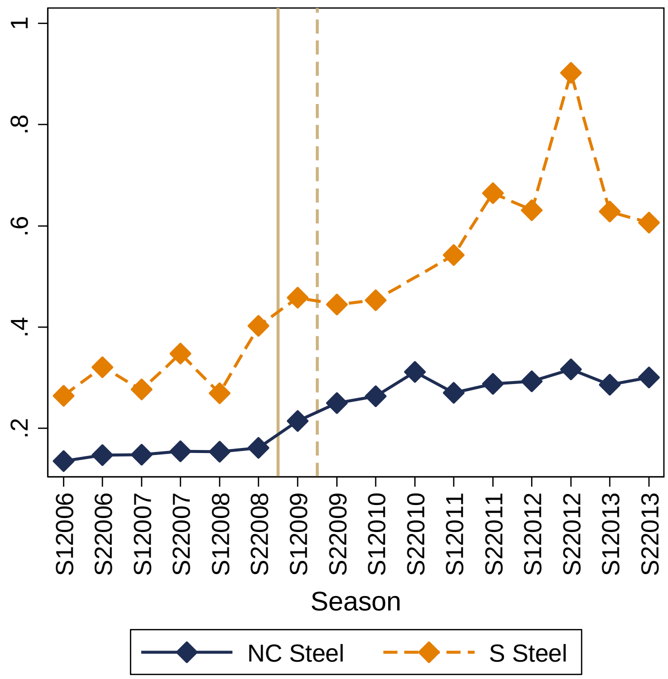
Figure A32: Median Southern Wood Vessel Percentage of Catch.



Source: PRODUCE landings data.

Note: The dashed vertical line corresponds to the start of the IVQ system in the Southern region. We do not present a summary statistic for the Southern S22012 season because only three vessels fish.

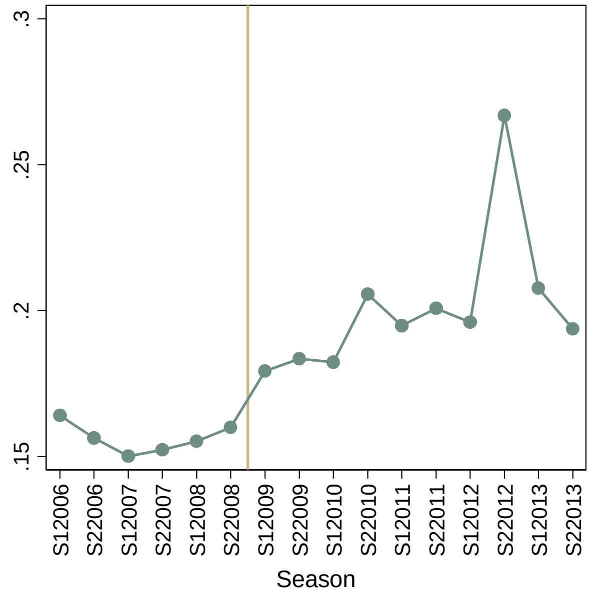
Figure A33: Median Steel Vessel Percentage of Trips.



Source: PRODUCE landings data.

Notes: The solid vertical line corresponds to the start of the IVQ system in the North-Central region; the dashed vertical line corresponds to the start of the IVQ system in the Southern region. We do not present a summary statistic for the second Southern 2010 season because only one vessel fishes. The North-Central statistic is calculated by summing the total trips by vessels with steel hulls in the North-Central, calculating the percent of these total trips fished by each active vessel, and then calculating the median of the percentages. The same process is followed to calculate the South statistic.

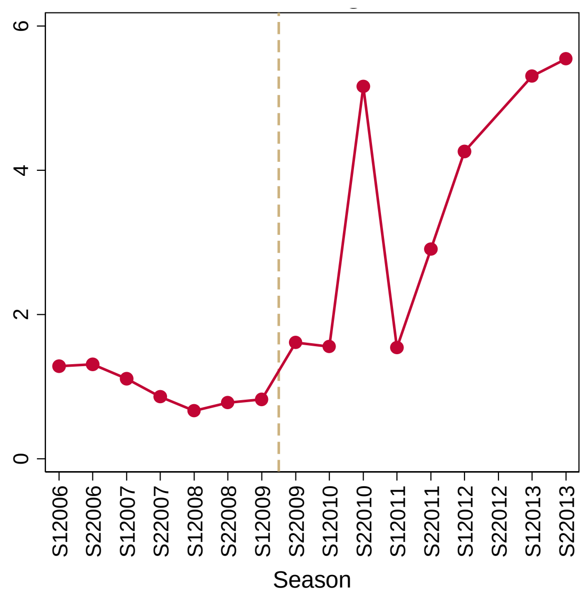
Figure A34: Median North-Central Wood Vessel Percentage of Trips.



Source: PRODUCE landings data.

Notes: The solid vertical line corresponds to the start of the IVQ system in the North-Central region. The statistic is calculated by summing the total trips by vessels with wood hulls in the North-Central, calculating the percent of these total trips fished by each active vessel, and then calculating the median of the percentages.

Figure A35: Median Southern Wood Vessel Percentage of Trips.



Source: PRODUCE landings data.

Notes: The dashed vertical line corresponds to the start of the IVQ system in the Southern region. We do not present a summary statistic for the Southern S22012 season because only three vessels fish. The statistic is calculated by summing the total trips by vessels with wood hulls in the South, calculating the percent of these total trips fished by each active vessel, and then calculating the median of the percentages.

1.10 Steel Vessel Yearly Profit

In addition to the seasonal calculations we present in the main report, we also aggregate to the yearly level (Table A23).

Table A23: North-Central Steel Variable Profit (2013 USD).

Fishing Year	2006	2008	2011	2013
Total Revenue (million USD)	440	500	1,164	847
Total Variable Cost (million USD)	298	398	416	413
Total Profit (million USD)	142	102	749	434
Revenue per metric ton	138	118	237	247
Cost per metric ton	93	94	85	120
Profit per metric ton	45	24	152	127
Per-Ton Profit as % of Ex-Vessel Revenue/Ton	33%	20%	64%	51%

Sources: firm cost data and PRODUCE landings data.

1.11 North-Central Steel Vessel Replacement Costs

We present the replacement costs for the vessels active in the North-Central of the fishery in Table A24. The replacement cost per ton is calculated as the total replacement costs divided by the total tons landed in the North-Central.

Table A24: North-Central Fixed Capital Costs (2013 USD).

	Steel				Wood			
Fishing Year	**2006**	**2008**	**2011**	**2013**	**2006**	**2008**	**2011**	**2013**
Active Vessels	565	553	372	344	609	619	523	475
Fleet Replacement Cost (Billion USD)	1.94	1.94	1.45	1.36	.254	.266	.243	.223
Replacement Cost per MT Landed	609	459	296	398	349	255	200	274

Sources: Paredes (2008) and PRODUCE landings data.

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