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Trends in Geographic Disproportionality and Concentration in Selected Northeast US Fisheries

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ABSTRACT

Geographic concentration and disproportionality indices for 4 select fisheries in the Northeast region are constructed and examined with generalized Theil indices of geographic disproportionality. Fishing activity is alternatively measured by using monetary value and weight quantities. We use weighted relative indices to describe changes in the landing locations of individual fisheries relative to the broader fishing industry. We use weighted absolute indices to describe changes in the landing locations of individual fisheries relative to the uniform distribution across ports. These methods can be straightforwardly applied to other fisheries to describe geographic disproportionality and concentration.

INTRODUCTION

Geographic concentration of economic activity is a frequently studied phenomenon in regional science and economics¹. Explanations for concentration of economic activity tend to focus on economies of scale in combination with transport costs (Krugman 1991), technical spillovers within (Marshall 1890; Arrow 1962; Romer 1986) or between industries (Jacobs 1969; 1984), spatial variation in government policies and regulations (Holmes 1998), and geographical interpretations of comparative/natural advantages adapted from trade theory (Ohlin 1967; Fujita and Mori 1996). Not unexpectedly, some of the most geographically concentrated industrial sectors are the extractive natural resource industries, which are located in and near areas that have large endowments of natural capital (Guillain and Le Gallo 2010; de Dominicis et al. 2013).

Some of the forces driving geographic concentration of economic activity are likely to be present in marine fisheries. Fisheries regulations that close parts of the ocean off the coast of the Northeast region of the United States to fishing have been a commonly used management tool since the mid 1990s, when large areas on Georges Bank (Closed Area I and Closed Area II) were closed to bottom-tending gear to protect groundfish (59FR26²). Fisheries managers understand that spatially explicit fisheries regulations, like permanent closures of fishing grounds, will impact fishing vessels that utilize affected fishing grounds and can therefore result in shifts in the location and concentration of that fishery in the region. Spatially explicit regulations continue to be popular³. The local availability of certain fish stocks, the most important input in production, can vary highly from year-to-year because of movement of fish or natural variation in recruitment, growth, or survival. In addition to changing regulations and natural variability in abundances, there are also large-scale shifts in stock distributions in response to climate change (Lucey and Nye 2010; Pinsky and Fogarty 2012). The changing spatial distribution of the natural resource may alter the relative cost of access and therefore change the natural advantages of ports relative to each other.

¹ See Holmes and Stevens (2004), Combes and Overman (2004), and Fujita et al. (2004) for an overviews of concentration and specialization in North America, Europe, and East Asia, respectively.

² <https://federalregister.gov/a/93-32010>

³ The Greater Atlantic Regional Fisheries Office (GARFO) currently provides 215 files through its Geographic Information System (GIS) portal that delineate parts of the ocean, most of which are associated with a fisheries management measure. http://www.greateratlantic.fisheries.noaa.gov/educational_resources/gis/data/index.html. Accessed on December, 22, 2015.

Perhaps less obviously, changes in nonspatial fisheries policy may increase or decrease geographic concentration as well. For example, if scale economies and thick input markets are important, decreases in total allowable catch could result in fewer “full-service” ports and encourage consolidation of activity into a small set of core ports as mobile fishing firms (or fishing rights) migrate away from the periphery. Implementation of a catch share program, particularly one that dramatically shifts the individual incentives of fishing firms, could also cause changes in the geography of fishing. Describing and understanding the geographic dynamics of the Northeast fisheries can begin to provide insight into the relative importance of these economic forces. In this analysis, we characterize and examine changes in geographic concentration in 4 fisheries in the Northeast U.S. region, all of which currently have a catch-share component (Table 1). We take advantage of the freedom to independently select an appropriate weighting, reference benchmark, and projection function described by Bickenbach and Bode (2008). The methods employed are general and can be applied to any fishery or subset of a fishery. The concentration indices presented are descriptive and exploratory in nature. Changes in concentration that occur after a particular policy event cannot and should not be interpreted as being caused by that particular policy event

Biological and Regulatory Background

We provide a very brief background about the 4 selected fisheries; the interested reader is referred to Brinson and Thunberg (2013) and Brinson et al. (2015) for more detailed descriptions of the regulatory history and goals of management for these fisheries.

The Atlantic Surfclam and Ocean Quahog Fisheries

The Atlantic surfclam (*Spisula solidissima*) and ocean quahog (*Arctica islandica*) (jointly SCOQ) fishery is managed by the Mid-Atlantic Fishery Management Council (MAFMC). In 1990, this was the nation’s first fishery to adopt an Individual Transferable Quota (ITQ) management system. Prior to implementation of the ITQ, surfclams had been more intensively exploited than were ocean quahogs and were subject to limited access. Ocean quahog was an open access fishery that was found farther offshore and prosecuted by only larger vessels. Both species are caught with a hydraulic dredge that uses water pressure to separate shellfish from the substrate. There are currently few buyers of surfclam and quahog, some of these buyers are vertically integrated with fishing vessels (Mitchell et al. 2011; Walden et al. 2011). All federal catch of surfclam is managed under the ITQ system. The Maine mahogany clam fishery also targets the ocean quahog, but it is not managed under the ITQ system. Neither species is the target of a recreational fishery.

The Atlantic surfclam is found in sandy substrate along the continental shelf across the entire Northeast region in water less than 240 feet in depth (Cargnelli et al. 1999a). Major fishing grounds include the New Jersey, southern New England, and Georges Bank regions. The fishery has moved slightly north, to lesser used areas, over the past 30 years (NEFSC 2013). The ocean quahog is usually found in colder and deeper waters; it grows and matures slowly relative to surfclam (Cargnelli et al. 1999b)⁴. Over the past 30 years, fishing grounds for Ocean quahog

⁴ See NEFSC (2009) and Cargnelli et al. (1999a) for the most recent stock assessment and essential fish habitat (EFH) for Atlantic surfclam. See NEFSC (2014a) and Cargnelli et al. (1999b) for the most recent stock assessment and EFH for ocean quahog.

have slowly shifted north from the Delmarva and New Jersey regions to the Long Island and New England regions (NEFSC 2009). Large portions of fishing grounds for quahog on Georges Bank were closed in 2005 because of risk of paralytic shellfish poisoning; a portion of Georges Bank was reopened, subject to additional food safety monitoring in 2013.

The Golden Tilefish Fishery

The golden tilefish (*Lopholatilus chamaeleonticeps*) fishery is managed by the Mid-Atlantic Fishery Management Council (MAFMC). The fishery management plan for tilefish, along with mandatory federal reporting, began in 2001. On May 15, 2003, the US District Court for the District of Rhode Island set aside permit related regulations in the tilefish fishery, essentially converting the fishery back into an open-access fishery until these rules were reinstated on May 31, 2004 (69FR22454). The fishery converted from limited access to an Individual Fishing Quota (IFQ) program in 2009. There is some incidental catch of tilefish that occurs outside of the IFQ program, and golden tilefish are recreationally targeted.

Tilefish are found along the continental shelf in the entire Northeast region at depths of 250-1,500 feet and at water temperatures between 46-59°F. Major fishing grounds include parts of the Southern New England and Long Island regions (NEFSC 2014a). Tilefish seek shelter among rocks and boulders, and form complex burrows in the substrate (Steimle et al. 1999). The vast majority of tilefish are caught with longline gear, although there is some incidental catch by trawl gear as well.⁵

The LAGC-IFQ Sea Scallop Fishery

The Atlantic sea scallop (*Placopecten magellanicus*) fishery is managed by the New England Fishery Management Council (NEFMC). The fishery implemented limited access for the majority of the fishing fleet in 1994 but allowed for a small amount of open access (General Category or GC) participation. The Limited Access (LA) fleet is currently managed with vessel-level effort limits (Days-at-Sea), crew- and gear-limits, and rotational area closures. Under the rotational system, areas of the ocean with an abundance of juvenile scallops are closed to allow those scallops to grow larger. The LA fleet is also affected by spatial closures designed to protect scallop habitat, groundfish habitat, and groundfish.

In 2008, the GC fishery was converted into the Limited Access General Category (LAGC) program with 3 components: the IFQ, Northern Gulf of Maine fishery, and Incidental Catch components. IFQ fishing began with the 2010 fishing year; 2008 and 2009 were transition years. The IFQ component is allocated 5.5% of the scallop Annual Catch Limit (ACL). The geographic concentration and disproportionality indices are only constructed for GC fishery (1996-2009) and the LAGC-IFQ fishery (2010-2014). A vessel may hold a Limited Access (LA) and a LAGC permit simultaneously; it may also switch once during the fishing year between LAGC permit categories. Like the LA fleet, the LAGC-IFQ fleet is affected by spatial closures to designed protect scallop habitat, groundfish habitat, and groundfish. Regulations for the LAGC-IFQ fleet include a possession limit, currently 600 lbs, and a fleet-level aggregate limit on trips into scallop rotational access areas. Sea scallops are not targeted recreationally.

The Atlantic sea scallop is found off the coast of the Northeast United States, from North Carolina through Maine. Major fishing grounds include the waters of Georges Bank, Southern New England, and Mid-Atlantic Bight, and secondarily in the Gulf of Maine, at depths of up to

⁵ See for Steimle et al. (1999) for further details about habitat and NEFSC (2014b) for stock assessment.

approximately 350 feet (Hart and Chute 2004; Hart and Rago 2006). Scallops reproduce by producing large amounts of eggs; larvae subsequently drift with water currents before settling to the bottom of the ocean (Hart and Chute 2004). When ocean conditions are favorable, this method of reproduction can result in high abundances of juvenile scallops in spatially distinct areas of the ocean. The biological characteristics of sea scallops make them particularly well suited to spatial management: scallops grow relatively quickly, adults have low natural mortality, and scallops are relatively immobile after settling on the ocean floor (Hart and Rago 2006).⁶

The Northeast US Multispecies Fishery

The Northeast US Multispecies (“groundfish”) Fishery currently includes 22 stocks of 13 species⁷ that live near the bottom of the ocean and are often caught together with trawl and fixed gear. Groundfish are caught primarily in the waters of the Gulf of Maine and Georges Bank and, secondarily, in southern New England and the Mid-Atlantic Bight (Murphy et al. 2015). The life history characteristics and biology of the fish managed in the Northeast Multispecies Fishery Management Plan (FMP) management plan vary greatly⁸. Many of the species are targeted by the recreational sector.

Since 1994, groundfish have been managed with an effort control system that placed limits on Days-at-Sea (DAS) coupled with permanent and seasonal spatial closures, gear restrictions, and minimum sizes designed to achieve annual catch targets. Amendment 13 to the Northeast Multispecies FMP set up a “sector allocation” system in 2004, although only one sector (Georges Bank Cod Hook) was formed. Under the sector system, members agreed to be bound by a catch quota that applied to the sector as a whole. In return, sectors were able to request exemptions from certain regulations such as trip limits, closed areas, and fishing gear restrictions. In 2006 another group, the Fixed Gear sector, was authorized; this group also was only allocated Georges Bank cod.

With the transition to an output-based management system, Amendment 16 to the Northeast Multispecies FMP was implemented in 2010. The Amendment expanded the sector allocation program and divided the fishery into “sectors” and a “common pool” fishery. All fishing vessels are assigned potential shares for each allocated stock based on historical landings. Vessels decide to either join a sector or operate as part of the common pool. If a vessel operates in the common pool, it is subject to DAS limits, possession limits, and other regulations designed to limit aggregate catch. If a vessel joins a sector, its potential share is converted into a catch entitlement that is owned and managed by the sector. During the first year of the catch share program, approximately 98% of the catch was allocated to vessels that were in a sector. Many input-based regulations, such as the DAS system, that were made superfluous by the output caps were waived for sector members. In addition to switching from the input-based DAS to the output based system, large reductions in many of the ACLs were made in 2010 to meet the legal

⁶ See Hart and Chute (2004) for a more detailed description of scallop Essential Fish Habitat (EFH) and NEFSC (2014b) for the most recent stock assessment.

⁷ American plaice (*Hippoglossoides platessoides*), Atlantic cod (*Gadus morhua*), Atlantic halibut (*Hippoglossus hippoglossus*), haddock (*Melanogrammus aeglefinus*), ocean pout (*Zoarces americanus*), pollock (*Pollachius virens*), redfish (*Sebastes fasciatus*), white hake (*Urophycis tenuis*), winter flounder (*Pseudopleuronectes americanus*), windowpane (*Scophthalmus aquosus*), witch flounder (*Glyptocephalus cynoglossus*), Atlantic wolffish (*Anarhichas lupus*), and yellowtail flounder (*Limanda ferruginea*).

⁸ EFH documents can be found at <http://www.nefsc.noaa.gov/nefsc/habitat/efh> and details of the most recent operational stock assessment can be found at <http://www.nefsc.noaa.gov/groundfish/operational-assessments-2015>.

requirements of the Magnuson-Stevens Fishery Conservation and Management Act to end overfishing and rebuild overfished stocks. In contrast to the other 3 fisheries, the groundfish fishery includes stocks that are currently overfished and stocks that are experiencing overfishing (NMFS 2015).

METHODS

Many indices can and have been used to study disproportionality in spatial and nonspatial contexts including the Gini, Krugman, and Generalized Entropy (GE) indices (Bickenbach and Bode 2008 provide a concise review). A concentration index measures “the disproportionality of the distribution of the population across a set of mutually exclusive characteristics and a predetermined reference distribution” (Bickenbach and Bode 2008; p362). Bickenbach and Bode (2008) note that reference benchmark, the weighting system, and the projection function of the concentration indices frequently used in the literature can all be selected independently. The reference distribution serves as the benchmark with a null hypothesis of “no concentration.” The weighting system explicitly defines the population studied. The projection function aggregates the vector of regional proportionality factors into a scalar. The *population* in this research is fishing activity (denominated in either dollars or pounds) in a particular industry, and the *characteristics* of that population are the spatial units in which that activity occurs.

We use the generalized version of the Theil, or GE(1), index described in Bickenbach and Bode (2008) to examine geographic concentration and disproportionality. As a member of the class of GE indices, the Theil index (unlike the Gini index) is additively decomposable. If regions are partitioned into mutually exclusive subgroups, the total disproportionality can be decomposed into disproportionality *within* the subgroups and disproportionality *between* subgroups. This decomposition would allow for exploration of how overall geographic disproportionality of fishing between ports corresponds to disproportionality within and between larger spatial units (for example counties or states). Although we leave the exploration of the decompositions for future research, this feature was sufficiently important to warrant use of a Theil index.

The general form of the Theil index of concentration (T) for industry i in time period t is written as:

$$T_{it} = \sum_{r=1}^R w_{rt} \frac{\frac{X_{irt}}{\Pi_{irt}}}{\sum_r w_{rt} \frac{X_{irt}}{\Pi_{irt}}} \ln \left(\frac{\frac{X_{irt}}{\Pi_{irt}}}{\sum_r w_{rt} \frac{X_{irt}}{\Pi_{irt}}} \right) \quad (1)$$

where X_{irt} is the measure of economic activity of industry i in region r and time t and Π_{irt} is a reference distribution of activity that formalizes the null hypothesis of “no concentration” for industry i . The regional weights, w_{rt} , reflect the importance of each spatial unit and are selected so that $\sum_r w_{rt} = 1$. The $\frac{X_{irt}}{\Pi_{irt}}$ term is referred to as a region-specific proportionality factor (RSPF).

The generalized Theil index is insensitive to rescaling: it is homogenous of degree 0 in X_{irt} , Π_{irt} , and (X_{irt}, Π_{irt}) jointly. Therefore, construction of Theil indices based on value can be performed by using nominal (instead of real) dollars.

In theory, the reference distribution, Π_{irt} , can be almost anything (Bickenbach and Bode 2008). Most studies of concentration, specialization, or localization that construct a “relative” measure use a higher-level aggregate, such as sectoral or total employment, in region r as the reference (Brühlhart and Traeger 2005; Cutrini 2010; Bickenbach et al. 2010). We use “total

fishing” ($\Pi_{rt} = \sum_i X_{irt}$) as our relative reference. The relative concentration index, therefore, embeds the null hypothesis that fishery i is geographically distributed in proportion to total fishing activity. This removes the effects of broader sector-level forces (such as changes in the location of final consumers or prices of fuel) that can affect geographic concentration. High values of this index indicate that the geographic distribution of fishery i is dissimilar to the broader fishing industry, while low values indicate a similar geographic distribution. Increases in this relative Theil index can be interpreted as evidence that the geographic distribution of a fishery i is becoming less similar to the broader fishing industry, while decreases demonstrate a more similar distribution.⁹

We also construct an absolute concentration index by using the uniform distribution ($\Pi_r = 1$) as our absolute reference. The absolute Theil index embeds the null hypothesis that a particular fishery is distributed uniformly across ports in the Northeast United States region. While somewhat unrealistic, the uniform reference has an appealingly intuitive interpretation. Increases in the absolute Theil index are evidence of: (a) fish being landed in fewer ports or (b) fish being landed in the same number of ports, but that the larger ports are growing faster than the smaller ports. Decreases in the absolute Theil index are evidence of: (a) fish being landed in more ports or (b) fish being landed in the same number of ports, but with the smaller ports growing faster than the larger ports.

The appropriate choice of weights (w_{rt} in equation 1) is derived directly from the population studied (Brühlhart and Traeger 2005; Bickenbach and Bode 2008). Because we define the *population* as fishing activity in a particular industry, we weight each observation based on each port’s share of fishing activity in industry i : $w_{rt} = \frac{X_{irt}}{\sum_r X_{irt}}$. This weighting system maintains that each pound of landed fish (or dollar of value derived from that fish) is equally important. This choice of weights is somewhat atypical; weighting by “total value” ($w_{rt} = \frac{\sum_i X_{irt}}{\sum_r \sum_i X_{irt}}$) in a region is somewhat more common in economic geography literature (Cutrini 2010; Bickenbach et al. 2010). In our opinion, this would be a more reasonable choice for examining either port-level industrial specialization or localization of fishing activity in the region, but less appropriate for examining concentration of a particular industry.

Some additional details of the mechanics of equation 1 may provide more intuition about the interpretation of the disproportionality index. Equation 1 is of the form $T = \sum w A \ln(A)$ where:

$$A = \frac{\frac{X_{irt}}{\Pi_{irt}}}{\sum_r w_{rt} \frac{X_{irt}}{\Pi_{irt}}} \quad (2)$$

For the relative Theil index, each RSPF, $\frac{X_{irt}}{\Pi_{irt}}$, is industry i ’s share of total fishing activity in region r . The RSPF is divided by the weighted ($w_{rt} = \frac{X_{irt}}{\sum_r X_{irt}}$) average RSPF. For regions that have higher than average shares of industry i , A in equation (2) will be greater than unity and $\ln(A)$ will be positive. These regions will therefore make positive contributions to the relative Theil index, indicating dissimilarity with the reference distribution of all fishing. For regions that

⁹ The converse is also possible: changes in the relative Theil index can be interpreted that the broader fishing industry is becoming more or less similar to fishery i .

have lower than average shares of industry i , A in equation (2) will be less than unity and $\ln(A)$ will be negative. These regions will therefore make negative contributions to the Theil index, indicating similarity with the reference distribution of all fishing. By l'Hopital's rule, Theil contributions for regions in which $X_{irt} = 0$ are set to zero. Finally, if activity in industry i was directly proportional to aggregate fishing activity, then the RSPFs in all regions would be identical, A would be equal unity, $\ln(A)$ would equal zero, and the Theil index would be zero, indicating perfect similarity.

For the absolute Theil index with arbitrary weights w_{rt} , equation (2) becomes $A = \frac{X_{irt}}{\sum_r w_{rt} X_{irt}}$. For regions that have higher than the weighted average activity of industry i , A in equation (2) will be greater than unity, and $\ln(A)$ will be positive for those regions. These regions will therefore make positive contributions to the relative Theil index, indicating dissimilarity with the reference distribution of all fishing. For regions that have lower than average activity of industry i , A in equation (2) will be less than unity, and $\ln(A)$ will be negative for those regions. By l'Hopital's rule, Theil contributions for regions in which $X_{irt} = 0$ are set to zero. Finally, if activity in industry i in all regions is equal to the weighted average, A would be equal unity, $\ln(A)$ would equal zero, and the Theil index would be zero, indicating perfect similarity.

A change in the distribution of fishing activity will not necessarily change the relative and absolute Theil index in the same direction. A thought experiment may be useful as an illustration. Assume that aggregate fishing activity is quite geographically concentrated, with 80% of aggregate fishery value split equally between 4 major ports, and the remaining 20% split equally between 10 minor ports. This aggregate will be the reference distribution for the relative Theil index, and the uniform distribution will be the reference for the absolute Theil index. Assume that fishery A initially has 40% of the value split equally across the 4 major ports and the remaining 60% split equally between the 10 minor ports. Consider a change in fishery A such that the new distribution exactly matches the 80/20% split of the aggregate fishing industry. The absolute Theil index would indicate an increase in geographic concentration of fishery A; the new geographic distribution of fishery A is less similar (increasingly disproportional) to the uniform distribution. However, the relative Theil index would decrease to zero; the new geographic distribution of fishery A is exactly proportional to the aggregate fishery.

The population and characteristics are defined differently here than in the income inequality literature (for examples, see Theil 1967 or Sala-i-Martin 2006). Studies of income inequality typically define the population as individuals, the characteristics as “income,” and the reference distribution as “equal income.”¹⁰ We could analogously define our population as “ports” and characteristics as “fishing activity,” which would lead to equal weights for each port in our sample. This particular weighting system would examine inequality in the distribution of “fishing activity in ports” as opposed to examining inequality in the distribution of fishing activity across all ports in the Northeast Region.

Data

Three sets of commercial fishing data collected by NMFS in the Northeast region form the backbone of the data used for this research: mandatory Vessel Trip Reports (VTR), clam logbooks, and dealer reporting systems. The VTR data are used as the source for commercial

¹⁰ This is equivalent to defining the population as individuals, characteristics as “income shares,” and the reference distribution as “uniform shares.”

landings (pounds) and port. There are 2 reasons for using VTR data instead of dealer data to construct landings. First, VTR is the primary source for the port of landings. Vessel captains report the name of the port of landing (“Jonesboro, ME,” “City Island, NY,” or “Onancock, VA,”) which is encoded into a numeric code by NMFS. The majority of the VTR data are generated by vessel operators who fill out a paper logbook form by hand. These forms are archived electronically. For many earlier years in the VTR database, smaller, less-frequented ports were aggregated at the data entry step. For example, prior to April 7, 2007, landings in Jonesboro, ME were classified as “Other Washington County, ME.” We have corrected these aggregation problems by examining original images.

While dealer reported data contain a port code as well, this is a secondary source for the landing port; dealers may not always know or take care to accurately report this. Dealer data cannot be corrected in this (time consuming) manner because no original images exist. The dealer data have a major advantage over the VTR data; VTR quantities are hail (estimated) weights, while dealer data should be more accurately measured. As estimates, using VTR data obviously introduces some measurement error. The dealer data are used to construct the prices needed to compute value.

The clam logbook dataset is a separate dataset that is similar to the VTR dataset. Like the VTR data, the clam logbook data are generated by vessel operators who fill out a paper logbook form by hand. Similar to the VTR data, the clam data have data aggregation problems for the landing port. These forms are archived electronically, and we have corrected these aggregation problems by examining original images. There are 2 notable differences between clam logbook data and VTR data: for clam logbooks, quantities are reported in bushels and the reports include the price received. For construction of the quantity based Theil indices, we convert in-shell bushels to meat weights in pounds¹¹.

The mandatory VTR and dealer data collection processes began in 1994; mandatory trip-level reporting for surfclam and ocean quahog vessels began at the end of 1977. Because the first 2 years of the VTR data collection are regarded as low-quality, we begin our analysis in 1996. We aggregate to the US Census county subdivisions to construct annual port-level landings and value by fishery. The census county subdivisions correspond roughly to a “town”: they are minor civil divisions (MCDs) for states that have governmental or administrative units that are smaller than a county and Census County Divisions (CCDs) for states that do not. Figure 1 illustrates the US census 2013 definitions of the county subdivisions in the Northeast United States and shades the subdivisions that had landings after 1996. Aggregation to this spatial unit is likely to reduce or eliminate the effects of any remaining coding errors and combines nearby ports into a single unit.

For 3 of the 4 fisheries (SCOQ, groundfish, and tilefish), we include all landings and value attributed to the managed species in the construction of the disproportionality indices. Because the IFQ scallop fishery is allocated just 5.5% of the total catch, we classify landings and value as either in or out of the IFQ fishery. We use the permit data to determine category (or categories) of scallop permit held by a vessel on the landing date. Trips taken by vessels holding a single category of permit are easily classified. Trips taken by vessels holding both LA and LAGC-IFQ scallop permit categories are classified into or out of the IFQ fishery based on reported landings. The scallop IFQ fishery allows for increased possession when an observer is

¹¹ We also computed the Theil indices using in-shell weights (pounds); differences were minimal.

onboard, therefore, we apply a weight cutoff of 700 lbs before August 1, 2011 and 900 lbs after that date for these trips.

We construct 2 measures of “total fishing” activity. This allows us to understand the robustness of our findings to changes in the way the “total fishing” benchmark is constructed. The first reference uses only species of fish with federal mandatory reporting requirements in 1996¹². Fishing vessels that held permits to catch those species were required to report catch of all species, including catch of species without reporting requirements. This benchmark omits species for which federal reporting was adopted after 1996 (such as goosefish [*Lophius americanus*], Atlantic herring [*Clupea harengus*], and scup [*Stenotomus chrysops*]) and species for which there are currently no federal reporting requirements (such as American lobster [*Homarus americanus*], Atlantic croaker [*Micropogonias undulates*], and weakfish [*Cynoscion regalis*]). Some of these species are frequently caught in state-waters (less than 3 miles from shore) by fishing vessels with no federal fishing permits¹³. The major advantage of this benchmark is that reporting requirements did not change over time, and these should be a census of landings of those regulated species. A major drawback is that some species that have grown to be important are not included, so this method may not truly be representative of “total fishing.”

The second measure of total fishing activity uses all non-lobster landings and value in the VTR databases. Landings for species that did not have a federal reporting requirement would have been reported through the VTR system if a vessel held another federal permit. While the difference between the 2 value-based references is moderate, the difference between the 2 quantity-based references is relatively large (Figure 2). This difference is primarily driven by the Atlantic herring fishery, which is a high-volume, low-price fishery that did not have a federal reporting requirement in 1996. Because the fisheries have different start dates for a fishing year, we construct separate versions of each of the references to match (See Table 1). The advantage of this method of defining total fishing is that it will include species that have become more prevalent. However, the disadvantage is that landings of these species may not have been consistently reported over time.

Some shorthand will be useful. We use RV1 and RV2 to refer to the *relative* Theil indices of concentration constructed by using *value* with the first and second methods of measuring aggregate fishing activity respectively. Similarly, we use RQ1 and RQ2 to refer to the *relative* Theil indices of concentration constructed by using *quantities* with the first and second methods of measuring aggregate fishing activity respectively. Finally, we use AV and AQ to refer to the *absolute* Theil indices of concentration constructed using *value* and *quantity* respectively.

¹²These species are American plaice, Atlantic cod, Atlantic halibut, haddock, ocean pout, pollock, redfish, white hake, winter flounder, windowpane, witch flounder, Atlantic wolffish, yellowtail flounder, Atlantic sea scallop, surf clam, ocean quahog, summer flounder (*Paralichthys dentatus*), Atlantic mackerel (*Scomber scombus*), *Loligo* and *Illex* squid, and butterfish (*Peprilus triacanthus*).

¹³ The reason for omitting these species is to ensure a consistently defined benchmark; while catch data exists for these species, these cannot be treated as a census and including them may not be representative of the geographic distribution of “marine fishing.”

RESULTS

Before examining concentration in each of the fisheries, we illustrate the absolute concentration measure for all fisheries with the 2 methods of measuring fishing activity by using a calendar year time step (Figure 3). The AV indices computed using both aggregates indicate that fishery value has grown moderately less concentrated over time. AV for aggregate 1 is always a bit larger than AV for aggregate 2. However, the AQ indices show that quantities have grown moderately more concentrated since approximately 1999. In contrast to the AV indices, the AQ1 and AQ2 indices do not have a consistent relationship: in some years AV for aggregate 1 is larger than AV for aggregate 2, in other years the opposite is true. The inconsistent relationship between the AQ1 and AQ2 indices is likely due to variability in the herring fishery. Over the entire time-series, the AV index indicates a bit more concentration than the comparable AQ index.

The Surfclam and Ocean Quahog Fisheries

Since 1996, nominal surfclam value remained relatively constant near \$20M per year, while ocean quahog value has varied between \$18 and \$34M per year (Figure 4a). Quantities of surfclam have moderately declined over this time period, while quantities of ocean quahog have varied between 38 and 57 million pounds (Figure 4b).

The RV1 index indicates that the value of the SCOQ fishery was geographically distributed similarly to the broader fishing industry from 1996-2003. From 2004-2014, the SCOQ fishery has become less similar to the broader fishing industry (Figure 5a). The RV2 Theil index illustrates an identical pattern. The RQ1 Theil index indicates that landings in the SCOQ fishery became less similar to the broader fishing industry from 1996-2009. However, from 2010-2014, the SCOQ fishery has become slightly more similar to the broader fishing industry. The RQ2 index is similar to the RQ1 index from 1996-2009; however the RQ2 index indicates increasing dissimilarity compared to the broader fishing industry from 2010-2014 in the SCOQ fishery. The disagreement between the RQ1 and RQ2 index is due solely to the differences in the reference distribution. In absolute terms, the SCOQ fishery has grown moderately less geographically concentrated over the entire time period when measured by using either value or quantity (Figures 5a and 5b).

Examination of the relative geographic disproportionality of surfclam and ocean quahog separately indicates that these industries evolved quite differently over the 2004-2012 time period (Figure 6a). During this section of the time series, the surfclam fishery first grew more similar to the broader fishing industry, and then grew less similar to the broader fishing industry. During the same time period, the ocean quahog fishery first grew less similar to the broader industry, and then grew more similar to the broader industry. This particular pattern is not evident in the absolute measures of concentration (Figure 6b).

The Golden Tilefish Fishery

The tilefish fishery management plan (FMP) mandated federal reporting in 2001; prior to this time, the VTR records may not have been a census, and many of the VTR records do not distinguish between golden tilefish and blueline tilefish (*Caulolatilus microps*), simply reporting them as “tilefish.” Therefore, we only examine geographic concentration from 2001 to 2014. Because it seems a bit strange to benchmark the geographic distribution of tilefish to an

aggregate of fishing that does not contain tilefish, we define an alternative reference (1A) that incorporates tilefish activity into reference 1; reference 2 already includes tilefish and does not need modification. With the exception of a spike in landings in 2003 from open access condition as a result of an order by the US District Court for the District of Rhode Island, landings have been near 1.5M pounds for most of the time series¹⁴. Nominal fishery value has increased substantially over the time series as well, with prices increasing fairly dramatically beginning in 2009 (Figure 7).

The RV1a and RV2 Theil indices indicate that the geographic distribution of tilefish value grew less similar to the broader fishing industry in 2003 when the fishery was functioning as an open-access fishery (Figure 8a). RQ1a and RQ2 Theil indices illustrate a similar effect. (Figure 8b). With the exception of 2003, the Tilefish fishery has become more similar to the broader industry. In absolute terms, the tilefish fishery has grown less concentrated over the time period when measured by using both value and quantity.

The LAGC-IFQ Sea Scallop Fishery

Nominal scallop value (LA and GC combined) increased substantially from 1996-2012, before decreasing moderately in 2013 and 2014 (Figure 9a). Landing quantities have followed the same general pattern (Figure 9b). The IFQ scallop fishery was implemented in 2010; vessels could qualify into this program based on their landings during the qualification period, which occurred from March 1, 2000 to November 1, 2004 (73FR20090). In addition to the landings and value for the IFQ fleet, we construct landings and value for the GC fleet over the 1996-2009 time period. Examining geographic concentration of the IFQ scallop fishery relative to the aggregate scallop fishery is also interesting. We refer to the relative Theil indices of concentration constructed by using the aggregate scallop fishery as a reference distribution as RVS and RQS.

The RV1 Theil index indicates that the GC scallop fishery grew less similar to the broader fishing industry from 1996-2002 (Figure 10a). From 2002-2009, the GC fishery grew more similar to the fishing industry, with the bulk of this change occurring by 2005. After the catch share program was implemented, the IFQ fishery has grown slightly less similar to the broader fishing industry. The RV2 Theil index illustrates almost identical patterns. The general pattern of the RQ1 and RQ2 indices are similar to the RV1 and RV2 indices, although the RQ2 index is quite high from 1998-2000, indicating that scallops were being landed in very different places than were other fish (Figure 10b). Like the value based indices, the RQ1 and RQ2 Theil indices are slightly lower after the catch share program was implemented and increase moderately from 2010-2014. We note that the RQ indices are always larger than the corresponding value indices. The RVS and RQS indices use the entire scallop fishery as the benchmark for the GC and IFQ fishery. The GC fishery became less similar to the aggregate scallop fishery from 1996 through 2004. From 2004-2005, the GC fishery grew more similar to the aggregate scallop fishery and remained at this level through 2009 (Figure 10c). The IFQ fishery in 2010 was moderately less similar to the GC fishery in 2009. Since 2010, the geographic distribution of the IFQ fishery has converged a bit towards the geographic distribution of the aggregate scallop fishery.

The AV and AQ indices are quite similar to each other (Figure 10d). Concentration in the GC fishery generally decreased (dispersion increased) from 1999 through 2009, although this

¹⁴ Data for the 2014 fishing year are still incomplete.

decrease was nonmonotone. Post-IFQ implementation, we see no dominant pattern in absolute geographic concentration of the IFQ component of the fishery.

The Northeast US Multispecies Fishery

Since 1996, nominal groundfish value and quantities have oscillated, but generally declined (Figure 11). We group the species into flatfish (all flounders plus halibut) and roundfish (everything else). Landings and nominal value peaked in 2001 and reached lows in 2013 and 2014. In addition, the importance of flatfish relative to round fish has decreased over that time period.

The RV1 and RV2 indices have similar trends for groundfish (Figure 12a). From 2001-2006, the groundfish fishery grew less similar to the broader fishing industry. From 2006-2009, the groundfish fishery grew more similar to the broader fishing industry before growing less similar again from 2010 to present. The RQ1 and RQ2 indices have the same general trends (Figure 12b), although there is far more year-to-year variability, particularly in the RQ2 index.

The AV and AQ indices are very similar and indicate that groundfish has become less geographically concentrated (more dispersed) over time (Figure 12). From 1996-2014, groundfish value declined, and absolute concentration decreased. This indicates that larger ports contracted more than smaller ports during the time that the overall groundfish industry contracted in size.

We compute RV1 for flatfish and roundfish separately; both components have grown less similar to the broader fishing industry over time. Flatfish and roundfish have similar trends from 1996 until approximately 2001 (Figure 13a). Beginning in 2002, the flatfish segment has grown less similar to the broader fishing industry than the roundfish segment. The increase in relative concentration in the flatfish segment was responsible for most of the increase in the disproportionality of the overall groundfish fishery from 2002 to 2006. The AQ index for flatfish and roundfish also illustrates the contrasting trends in these segments (Figure 13b). Absolute geographic concentration in roundfish increased moderately from 1996-2009, indicating that more roundfish were landed in fewer ports. From 2009-2014, absolute concentration decreased sharply, indicating that this segment of the fishery dispersed or grew more uniform. The flatfish segment has almost the exact opposite trend: decreases in absolute concentration from 1996-2010 were followed by a moderate increase from 2010-2014.

DISCUSSION AND CONCLUSIONS

This research has characterized and described geographic concentration in 4 select Northeast US fisheries. For all fisheries, we construct relative and absolute indices of geographic concentration. We alternatively use value and quantities to examine the robustness of our findings to alternative methods of measuring fishing activity. For the absolute concentration indices, trends are robust to the choice of measuring fishing activity in output or value. This is true for the single species fisheries (scallop and tilefish) and for some fisheries with multiple species (surfclam and ocean quahog jointly and Northeast Multispecies). For the relative concentration indices, our results are sensitive to the definitions of both fishing activity (landings or value) and the reference distribution. These different findings are not particularly surprising: varying these attributes is equivalent to forming and examining alternative research questions (Bickenbach and Bode 2008).

Distributional issues at the individual or business level have been examined fairly extensively. In the Northeast United States., performance reports for the Northeast multispecies fishery have documented increased concentration at the vessel and business level through the use of a Gini index (Murphy et al. 2012, 2014, 2015). Mitchell et al. (2011) use the Herfindahl-Hirshman Index (HHI) to examine issues associated with “excessive share” in the surfclam and ocean quahog fishery. Further afield, Pálsson and Helgason (1995), Perrez-Labajos et al. (2006), Abayomi and Yandle (2012), and Chan and Pan (2014) examine vessel level concentration in various fisheries.

Understanding inequality and variability in the distribution of fishing activity across a region can provide insight into the way that fisheries regulations affect ports and fishing communities. To the best of our knowledge, Agnarsson et al.’s (2016) study of concentration of quota shares is the only examination of port-level concentration in fisheries. We hope that illustrating changes in geographic disproportionality and concentration in a few of the Northeast US fisheries begins to address this gap in the literature. In particular, exploiting the decomposability of the Theil Index by counties, states, or other meaningful spatial units could provide insight into the geographic scale at which agglomerative forces are at work. The methods used in this analysis are quite general and could be easily applied to other fisheries or subsets of fishery. Similarly, alternative weights (populations) or reference distributions could be used to examine and describe closely related geographic concentration and disproportionality phenomena. Similar methods could be brought to bear to examine trends in specialization by spatial units to further understand agglomeration in the Northeast Region.

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Table 1. Catch Share fisheries examined in this manuscript.

Fishery	Fishing Year Start Date	Catch Share Implementation	Federal Register	Council Action
Northeast Multispecies Catch Share	May 1	5/1/2010	75FR18262	Amendment 16
Limited Access General Category IFQ Scallop	March 1	3/1/2010	73FR20090	Amendment 11
Surfclam and Ocean Quahog	May 1	9/30/1990	55FR24184	Amendment 8
Tilefish	November 1	11/1/2009	74FR42581	Amendment 1

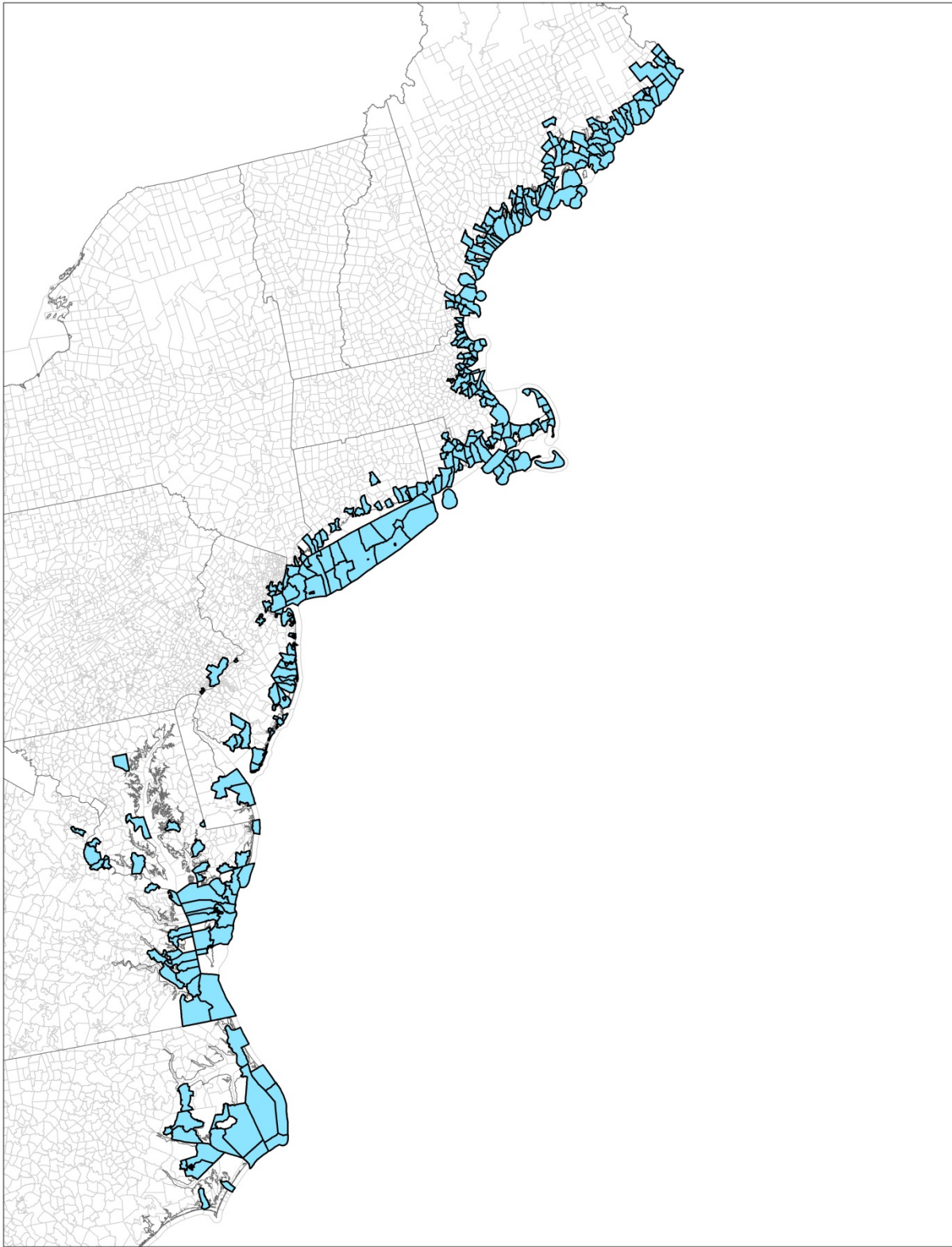
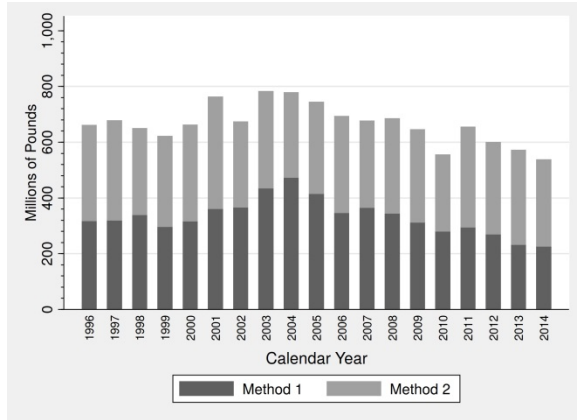
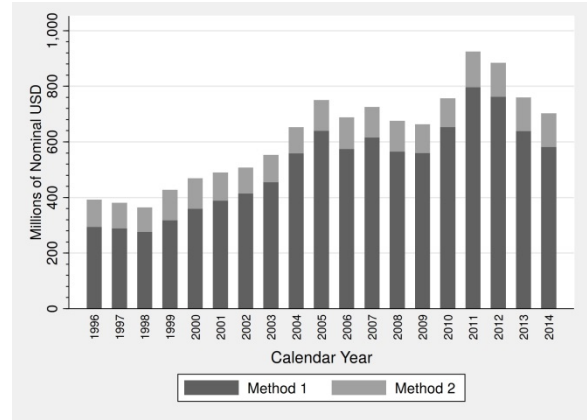


Figure 1 Study area illustrating US census county subdivisions. Regions with landings over the 1996-2014 time period are shaded blue.



(a) Value



(b) Quantity

Figure 2: Calendar year aggregate fishing activity constructed by using two methods based on (a) value and (b) quantity. Method 1 uses only species of fish with federal mandatory reporting requirements in 1996. Method 2 uses all non-lobster landings and value in the Vessel Trip Report (VTR) databases. Bars for Method 2 represent *additional* fishing activity that is not captured in the Method 1.

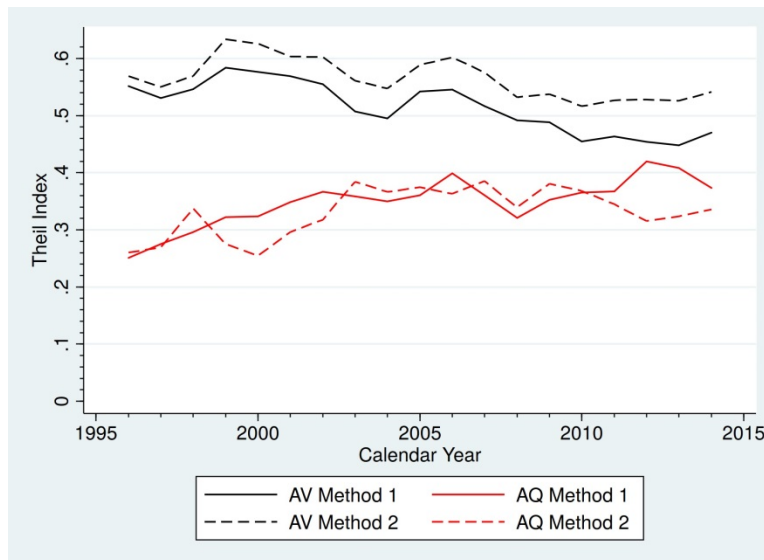
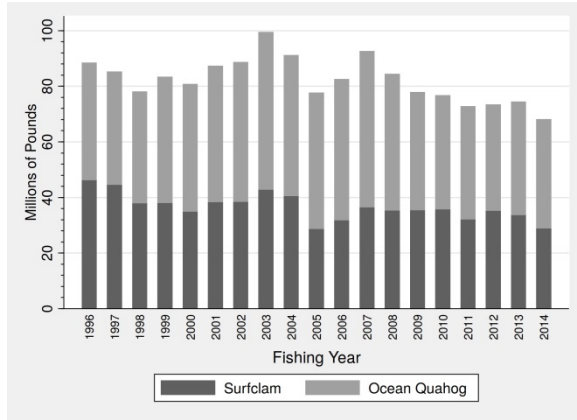
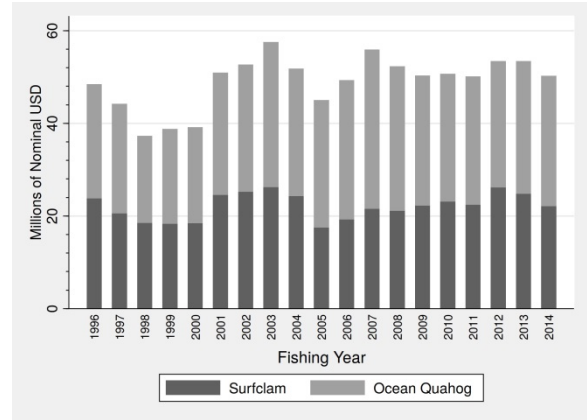


Figure 3: Absolute Value (AV1 and AV2) and Absolute Quantity (AQ1 and AQ2) Theil Indices of all fishing in the Northeast Region computed by using 2 methods. Method 1 uses only species of fish with federal mandatory reporting requirements in 1996. Method 2 uses all non-lobster landings and value in the Vessel Trip Report (VTR) databases.

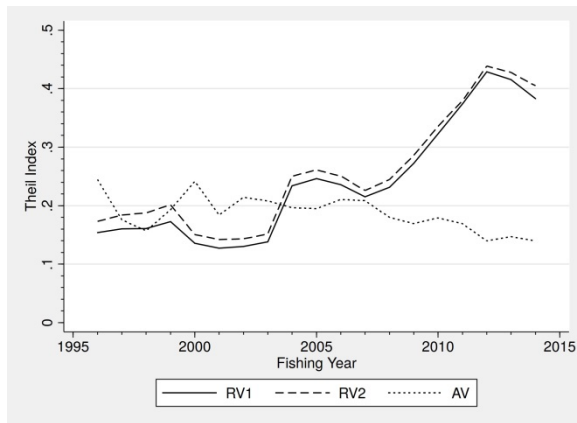


(a) Value

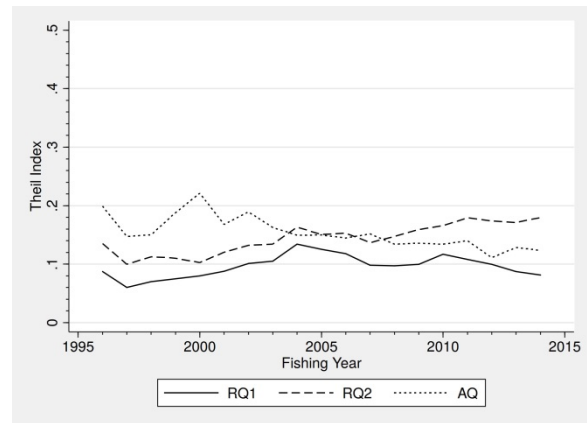


(b) Quantity

Figure 4: Aggregate value and quantities for Atlantic surfclam (*Spisula solidissima*) and ocean quahog (*Arctica islandica*).



(a) Value



(b) Quantity

Figure 5: Relative Value (RV1 and RV2), Relative Quantity (RQ1 and RQ2), and Absolute (AV and AQ) Theil Indices for the Atlantic surfclam (*Spisula solidissima*) and ocean quahog (*Arctica islandica*) fishery. Reference 1 is constructed using only species of fish with federal mandatory reporting requirements in 1996. Reference 2 uses all non-lobster landings and value in the Vessel Trip Report (VTR) databases. The reference distribution for the AV and AQ indices is the uniform distribution. Increases in a Theil index indicate that geographic distribution of the fishery is growing less similar to the corresponding reference distribution.

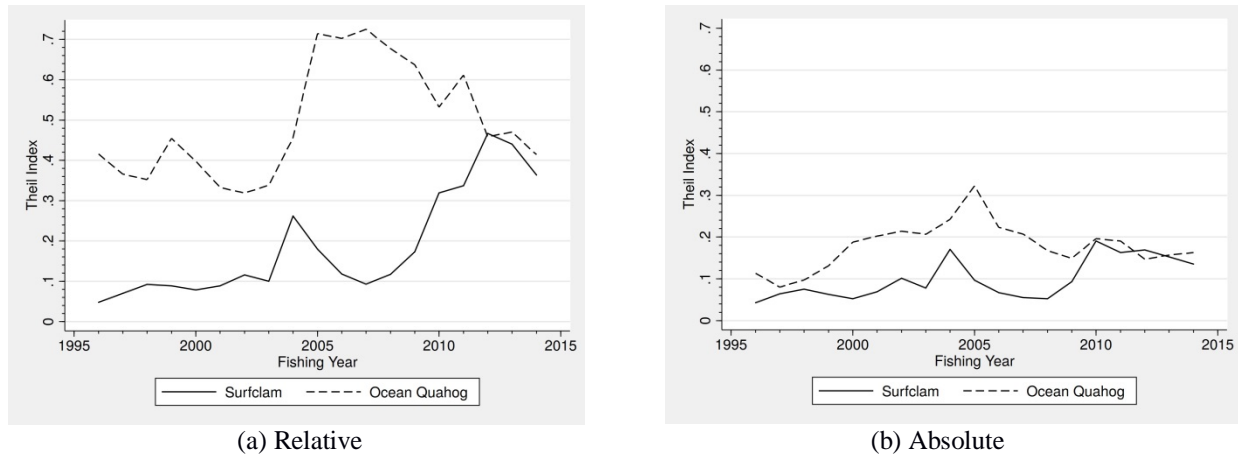


Figure 6: Relative Value (RV) and Absolute Value (AV) Theil Indices for Atlantic surfclam (*Spisula solidissima*) and ocean quahog (*Arctica islandica*) individually. The reference distribution for the RV index is constructed by using only species of fish with federal mandatory reporting requirements in 1996. The reference distribution for the AV index is the uniform distribution. Increases in a Theil index indicate that geographic distribution of a fishery is growing less similar to the corresponding reference distribution.

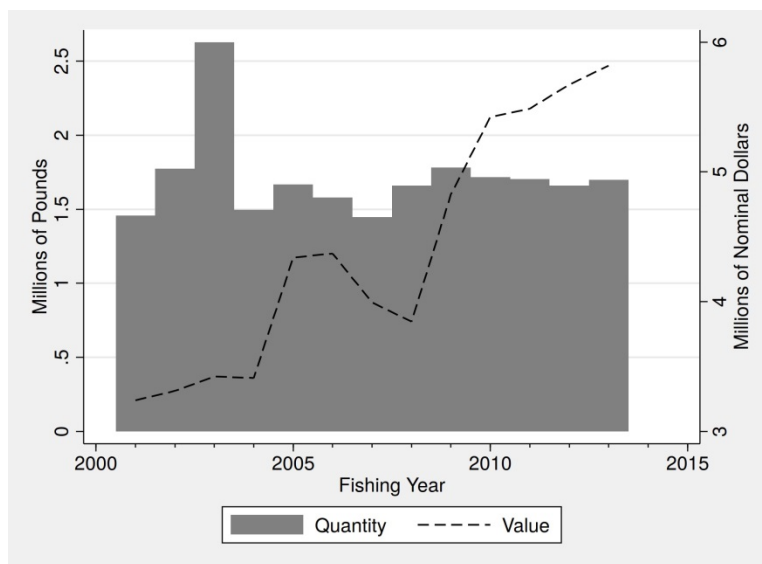
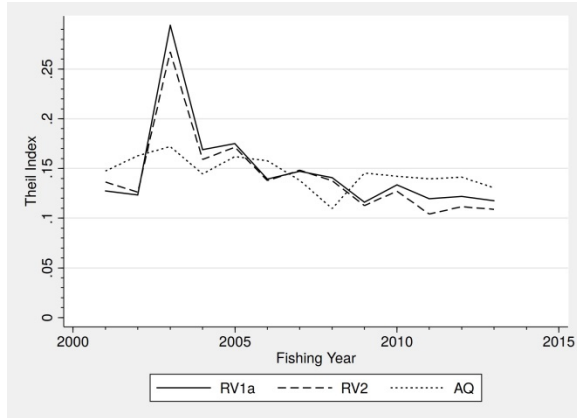
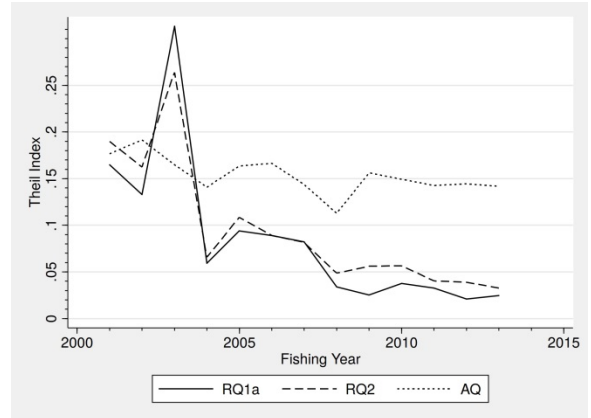


Figure 7: Aggregate value and quantities for tilefish. Data for the 2014 fishing year are incomplete and not included.

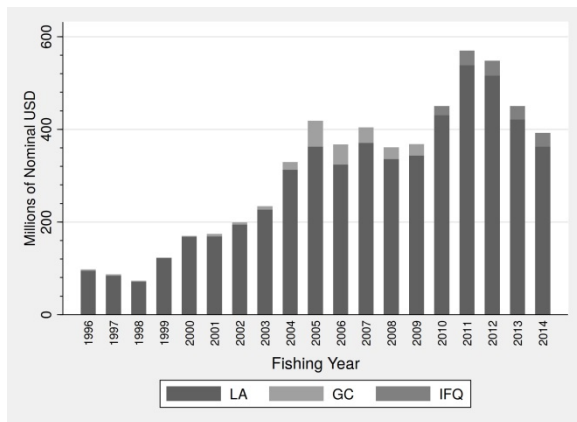


(a) Value

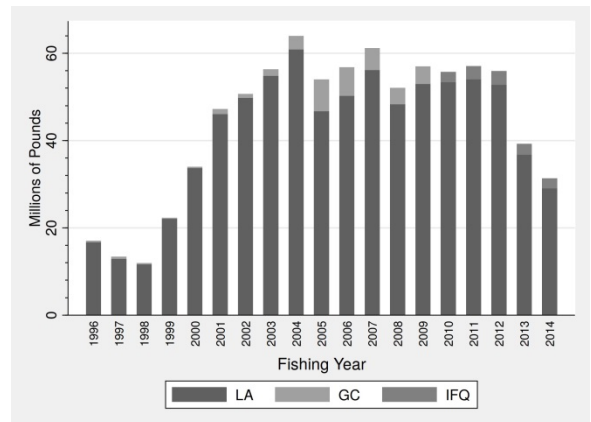


(b) Quantity

Figure 8: Relative Value (RV1a and RV2), Relative Quantity (RQ1a and RQ2), and Absolute (AV and AQ) Theil Indices for the golden tilefish fishery. Reference 1a is constructed using species of fish with federal mandatory reporting requirements in 1996 plus golden tilefish. Reference 2 is constructed from all non-lobster landings and value in the Vessel Trip Report (VTR) databases. The reference distribution for the AV and AQ indices is the uniform distribution. Data for the 2014 fishing year are incomplete and not included. Increases in a Theil index indicate that geographic distribution of the tilefish fishery is growing less similar to the corresponding reference distribution.

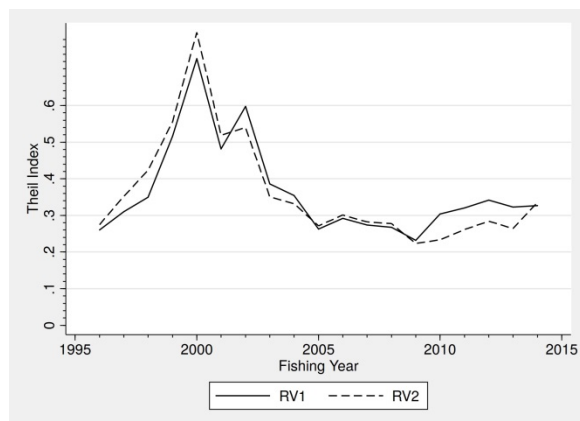


(a) Value

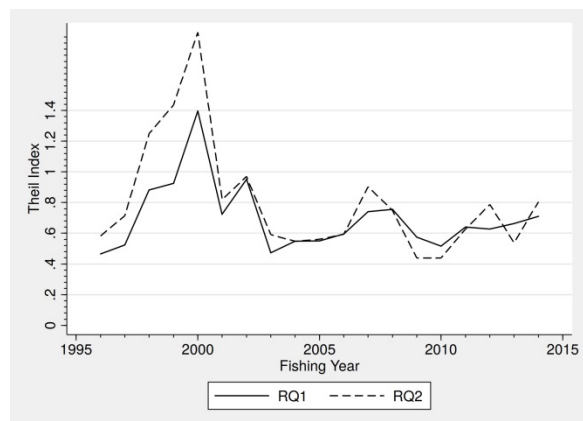


(b) Quantity

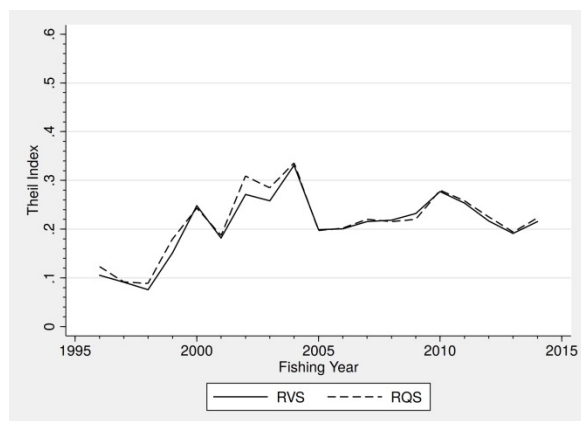
Figure 9: Aggregate value and quantities for Limited Access (LA), General Category (GC; 1996-2009), and Individual Fishing Quota (IFQ; 2010-2014) sea scallop (*Placopecten magellanicus*) fisheries.



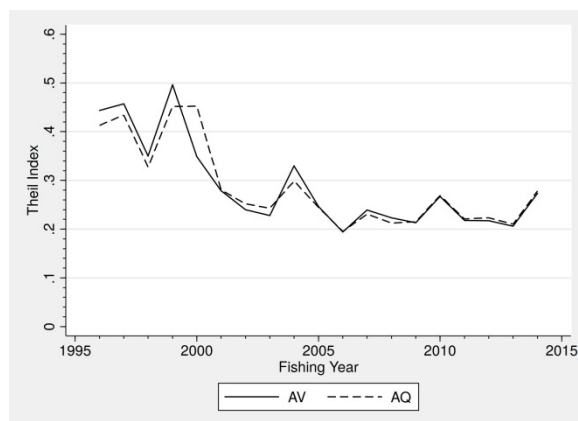
(a) Relative value



(b) Relative quantity

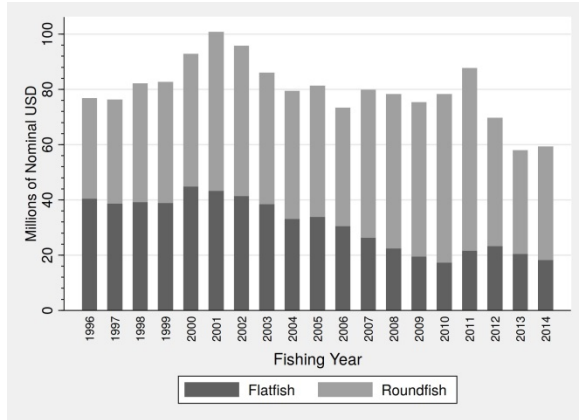


(c) Relative to all scalloping

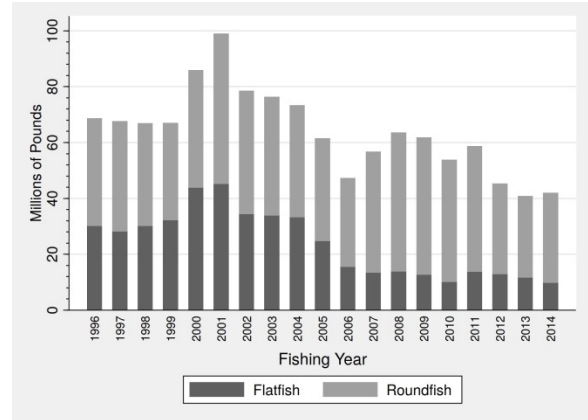


(d) Absolute

Figure 10: Relative (a,b,c) and Absolute (d) Theil indices for the General Category (GC) and Limited Access General Category -Individual Fishing Quota (LAGC-IFQ) sea scallop (*Placopecten magellanicus*) fishery. Reference 1 is constructed using species of fish with federal mandatory reporting requirements in 1996. Reference 2 is constructed from all non-lobster landings and value in the Vessel Trip Report (VTR) databases. Reference S is constructed from only scallop landings and value. The reference distribution for the AV and AQ indices is the uniform distribution. Increases in a Theil index indicate that geographic distribution of the fishery is growing less similar to the corresponding reference distribution.

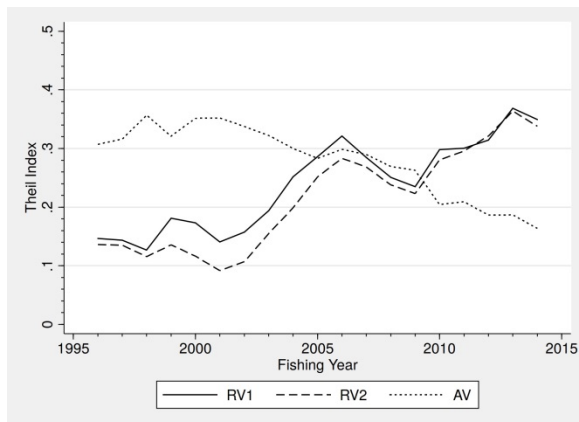


(a) Value

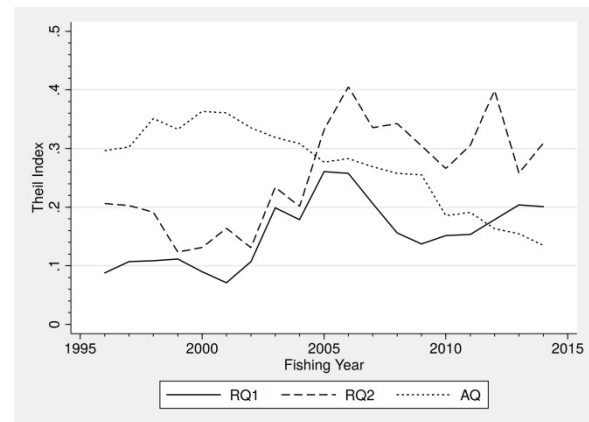


(b) Quantity

Figure 11: Groundfish (a) value and (b) quantity, disaggregated into flatfish and roundfish.

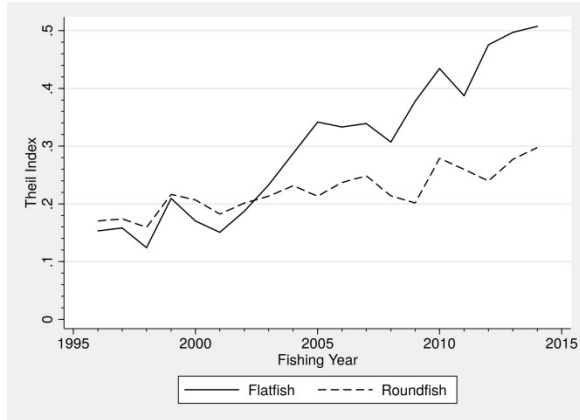


(a) Value

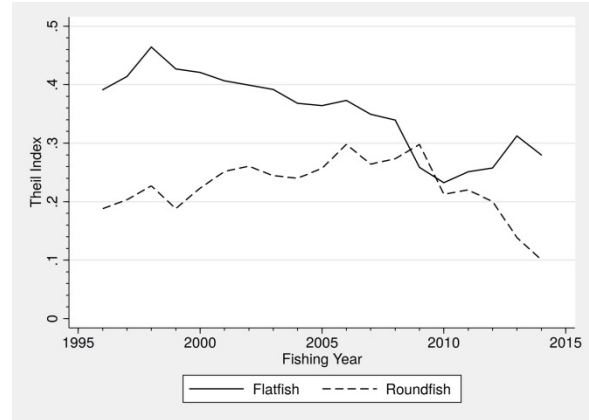


(b) Quantity

Figure 12: Relative Value (RV1 and RV2), Relative Quantity (RQ1 and RQ2), and Absolute (AV and AQ) Theil Indices for the Northeast Multispecies fishery. Reference 1 is constructed using only species of fish with federal mandatory reporting requirements in 1996. Reference 2 uses all non-lobster landings and value in the Vessel Trip Report (VTR) databases. The reference distribution for the AV and AQ indices is the uniform distribution. Increases in a Theil index indicate that geographic distribution of the groundfish fishery is growing less similar to the corresponding reference distribution.



(a) Value



(b) Quantity

Figure 13: Relative and absolute Theil indices based on value for flatfish and roundfish. The reference distribution for the relative index is constructed using only species of fish with federal mandatory reporting requirements in 1996. The reference distribution for the absolute indices is the uniform distribution. Increases in a Theil index indicate that geographic distribution of the fishery is growing less similar to the corresponding reference distribution.

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