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Profit and Price Effects of Multi-species Individual Transferable Quotas

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Regulators in many countries have adopted individual transferable quotas as a means of dealing with the open access problem inherent in fisheries. Using individual vessel data prior to and after the introduction of ITQs in Canada's multi-species Scotia-Fundy mobile gear fishery, the paper uses an index number profit decomposition to compare vessel performance over time and across individual vessels. The approach allows us to undertake both an ex post evaluation of short-term impacts of ITQs and an ex ante evaluation of longer term impacts. With respect to short-term impacts, the results suggest that larger vessels have benefited the most from the introduction of ITQs, but that all vessels have enjoyed increases in the prices received for those fish species that are included in the quota program. With respect to longer-term impacts, the transferability provisions of the ITQ program have encouraged exit and more efficient operations to prevail.

1. Introduction

The nature of regulation in the world's fisheries has been slowly changing. Early regulations operated largely by reducing the profitability and productivity of fishing enterprises in an effort to deal with the open access problem of too many fish harvesters (Dupont, 1996). Not only were these management regimes ineffective at reducing pressures on the biomass, they also encouraged capital-stuffing and other forms of unnecessary spending increases on the part of fishers (Homans and Wilen, 1997). Many lessons were learned from observing these inefficient outcomes. In particular, individual harvesting rights or individual transferable quota (ITQ) regimes came to be seen as a possible solution to fisheries problems (Grafton *et al.*, 1996).

ITQs are a form of property right or rights-based management. They can provide fishers with incentives to catch fish at the least cost and to choose levels of fixed and variable inputs that maximise returns per unit of quota (Scott and Neher, 1981). In addition, when ITQs (essentially output controls) replace input controls, fishers

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may gain from the incentive to improve the quality and increase the value of the landed product. Transferability of the harvesting rights allows fishers with higher returns per unit of fish to increase their share of the harvest and, thus, should increase the rents from fishing. Consequently, with the adoption of ITQs there is a potential for increased profitability of vessels and the fishing industry. The potential for increased profitability results from changes in the quantity of capital used by the fishing vessel, unrestricted market-driven responses to changes in variable input prices and output prices, and overall productivity improvements in line with unrestricted profit maximisation.

Fisheries regulators are often interested in undertaking both *ex ante* and *ex-post* evaluations of ITQ management schemes. From a management perspective, it would be useful to employ a technique of analysis that could decompose the separate effects of prices, vessel capital stock, productivity and fish biomass on the profits of individual vessels, both in anticipation of the introduction of ITQs, and several years after program operations. Such a tool would be capable of measuring the separate effects of the various input and output factors on changes in vessel-level profitability. In this way, both predicted and actual root causes of the changes in profitability associated with a regulatory shift to ITQs could be defined and evaluated. This is the issue we address in our paper. The starting point is an index number profit decomposition method developed in Fox *et al.* (2003) and applied in that paper solely to an *ex post* evaluation of a single-species fishery. The technique is an application of the Törnqvist (1936) index that takes advantage of its multiplicative property (Diewert and Morrison, 1986; Kohli, 1990) to allow for changes in profitability to be decomposed into the contributions from individual components of operations. Because of the single-species nature of the fishery studied in Fox *et al.* (2003), these components are only factor inputs (labour, fuel, capital, and fish stock).

In this paper we adapt the index number profit decomposition approach to the important and more common case of a multi-species fishery. In particular, we show how to apply the methodology to the important multiple output case in which some species are subject to ITQ regulation while others are not. We use our modified profit decomposition approach with data from Canada's multi-species Scotia-Fundy mobile gear fishery. In 1991 the Canadian Department of Fisheries and Oceans introduced ITQs for only three of the many species caught in this fishery, although two other species (Flounder and Redfish) were subsequently added to the ITQ list. Using these data with our modified approach, we first undertake an *ex post* evaluation of short-run changes in profitability for fishing vessels. Our modified approach has a very useful and important feature: it permits us to examine the differential impacts of ITQ *versus* non-ITQ species' prices upon profits, which other researchers have identified as an important short run effect of ITQs (Casey *et al.*, 1995; Hermann, 1996; Grafton *et al.*, 2000). Secondly, we illustrate how the modified profit decomposition approach can be used to make *ex ante* predictions about the subsequent evolution of an ITQ fishery and, in particular, longer term effects of such rights-based programs.

In the next section, the profit decomposition methodology and the Törnqvist index are described. Section 3 provides salient features of the fishery and summarises the data to which the methodology is applied. Section 4 discusses the application of the methodology to the Scotia-Fundy multi-species fishery. The *ex post* and *ex ante* analyses of the fishery are undertaken with output from the index number profit decomposition method and presented in Section 5. Section 6 concludes.

2. Profit Decomposition

The profit decomposition method applied here requires only observed data and relies upon intra-firm comparisons to measure performance. The methodology presented draws directly on that presented in Fox *et al.* (2003). To facilitate comparison a base case or numéraire vessel is defined as the firm with the largest profits in the data set. The most profitable firm is a natural choice for the numéraire, for ease of interpretation of the results and benchmarking across vessels. The decomposition starts by defining the ratio of profits ($\Gamma^{a,b}$) of any arbitrary firm *b* to the numéraire firm *a* written as:

$$\Gamma^{a,b} \equiv \frac{\pi^{b}}{\pi^{a}} \tag{1}$$

We then construct a relative input index $(K^{a,b})$ using the set of quasi-fixed inputs for the two vessels and a relative price index ($P^{a,b}$) using prices for both outputs and variable inputs for the two vessels. An output index is then generated by dividing the profit index ($\Gamma^{a,b}$) by the relative price index ($P^{a,b}$). The result is an implicit "netput" quantity index comparing the relative output of vessel *b* to vessel *a* (where outputs are positively signed and inputs are negatively signed).

With these indices defined, we can now calculate the total factor productivity index ($R^{a,b}$) between two firms as the (implicit) output index divided by the input index. The productivity index is written as:

$$R^{a,b} \equiv \frac{\left(\dfrac{\Gamma^{a,b}}{P^{a,b}}\right)}{K^{a,b}} \tag{2}$$

The productivity index ($R^{a,b}$) is interpreted as the difference in the two firms' netput quantity index that is not explained by their relative usage of quasi-fixed inputs. It is possible to rewrite Equation (2) in terms of intra-firm profitability because we are ultimately interested in how different factors affect relative profits:

$$\Gamma^{a,b} \equiv R^{a,b} \cdot P^{a,b} \cdot K^{a,b} \tag{3}$$

Equation (3) shows that the ratio of profits between the two firms can be decomposed into the relative differences between productivity, netput prices and quasi-fixed input utilisation.

In order to make this identity operational we employ the Törnqvist index (1936). It is a widely used index in economics because it has a number of desirable properties. For the problem at hand, we assume that the i^{th} firm is characterised by an N netput vector, $\mathbf{y}^i_N$. Thus, if $\mathbf{y}^i_N$, n=1,…,N is greater than zero, it is an output and if $\mathbf{y}^i_N$, n=1,…,N is less than zero it is a variable input. Corresponding to the netput vector is a non-negative vector of prices, $\mathbf{p}^i_N$. In addition, we assume that the i^{th} firm has an M fixed-factor vector of inputs, $\mathbf{k}^i_M$, with corresponding strictly positive fixed input prices, $\mathbf{r}^i_M$.

Using this notation, the Törnqvist price index $(P^{a,b})$ between the numéraire firm, *a,* and any other arbitrary firm, *b,* can be defined as:

$$P^{a,b} \equiv \exp\left[\sum_{n=1}^{N} \frac{1}{2}\left(s_n^b + s_n^a\right)\ln\left(\frac{P_n^b}{P_n^a}\right)\right] \tag{4}$$

In this equation, s_n^b is the profit share of netput n for firm b and is defined as:

$$s_n^b \equiv \frac{p_n^b y_n^b}{\sum_{n=1}^{N} p_n^b y_n^b} \tag{5}$$

while s_n^a is defined for firm a using Equation (5) but substituting a for b. In a similar fashion, the Törnqvist fixed input quantity index is defined as:

$$K^{a,b} \equiv \exp\left[\sum_{m=1}^{M} \frac{1}{2}\left(s_m^b + s_m^a\right)\ln\left(\frac{k_m^b}{k_m^a}\right)\right] \tag{6}$$

In Equation (6), the profit share of fixed input m for firm b is defined as:

$$s_m^b \equiv \frac{r_m^b k_m^b}{\sum_{n=1}^{N} p_n^b y_n^b} \tag{7}$$

while s_m^a is defined for firm a using Equation (7) but substituting a for b.

The Törnqvist index has one particularly desirable property for the case of multiple species fisheries. Namely, it is additive in logs across indices provided that each index is itself a Törnqvist index. Thus, the aggregate price index between the two vessels (a and b) can be decomposed into the product of contributions from individual price differences, written as:

$$P^{a,b} = \prod_{n=1}^{N} P_n^{a,b} \tag{8}$$

where $P_n^{a,b}$ is the Törnqvist index for the n^{th} netput, as in (4).

Looking back at Equation (3) reveals that this feature implies we can separately identify the impacts of different prices upon relative profitability. In particular, we can highlight the presence of differential price impacts of ITQ *versus* non-ITQ species. In a similar way, the fixed input index can be decomposed into the product of individual fixed quantity differences, written as[2] :

$$K^{a,b} = \prod_{m=1}^{M} K_m^{a,b} \tag{9}$$

Equations (3), (8) and (9) constitute a decomposition of a profit ratio between vessels *a* and *b* into the relative contributions of productivity, prices (output and variable inputs) and fixed inputs. This measurement approach can be applied in many different contexts and does not require assumptions over the technology or market structure of vessels.

3. Profit Decompositions and the Scotia-Fundy Mobile Gear Groundfishery

3.1 The ITQ Program

The Scotia-Fundy mobile ground fishery is an Atlantic Canada inshore fishery, geographically located between the north-eastern tip of Cape Breton to the New Brunswick-Maine border, encompassing the Scotian Shelf and the Bay of Fundy. Fishers have caught predominantly Cod, Haddock, and Pollock (Department of Fisheries and Oceans Web Statistics, various years). However, during the latter part of the 1990s and early 2000s, other groundfish and non-groundfish species have been sought. The fleet consists of vessels ranging from 25 to 65 feet in length that use otter trawls.

As with many other Canadian fisheries during the 1970s and 1980s, productivity and capacity increased despite limited entry regulations and various input restrictions (Dupont, 1996). After many years of overshooting the total allowable catch and continuous declines in the catchable biomass of the major species, the (Federal) Department of Fisheries and Oceans introduced individual transferable vessel quotas for the 1991 fishing season for the three main species: Cod, Haddock and Pollock. These species represented the most important species targeted by the fishers in this area. This introduction of individual harvesting rights coincided with a subsequent reduction in the size of the principal fish stocks and harvests.

Under the quota program, vessel owners were given an initial, individual quota allocation based on the average of the best two years harvest during the 1986-1989

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[2] While we use only a single quasi-fixed input in our analysis, this approach could be used to examine the differential impacts of multiple input restrictions upon the relative profitability of vessels.

fishing seasons (Barbara *et al.* 1995). In 1991, 325 vessels were granted allocations of individual transferable quotas (ITQs). Of these vessels, 268 fished actively. Table 1 shows total landings for the fishery from 1990-1994, along with total fleet quotas over the same period for the three ITQ species: Cod, Haddock and Pollock. Both quota levels and landing declined precipitously over the period. However, the consequences of these very substantial declines in the quota and landings due to declines in fish stocks, have been mitigated because quota trading has allowed some fishers to exit and allowed others to maintain their catches by purchasing quota from those who no longer wish to remain active in the fishery.

Table 1: Total Quotas and Landings by Species and Year (metric tonnes)

Year /Species	Cod Quota	Cod Landings	Haddock Quota	Haddock Landings	Pollock Quota	Pollock Landings
1990	na	19,117	na	4,624	na	7,468
1991	17,128	15,406	By-catch allowed	4,489	9,839	9,399
1992	17,960	14,954	By-catch allowed	3,535	9,840	8,215
1993	7,063	6,440	3,150	2,400	4,599	5,436
1994	6,103	5,943	3,516	3,306	5,491	4,098

Sources: Department of Fisheries and Oceans, Quota Reports, various years and data adapted from Barbara, Brander, and Liew (1995); na – not applicable

From the outset, the managers of the ITQ program recognised the potential problems associated with regulating a multi-species fishery. A crucial factor for encouraging efficiency of vessel operations is to allow for transferability of quota and the program was devised to allow for unlimited trading in quota. In practice, even small fractions of quota could be traded in order to cover accidental by-catches. Post-trip trading was permitted for up to 30 days after the catch had been landed. Moreover, fishers could even donate accidental catch in excess of their quota to the Crown (Barbara *et al.*, 1995).[3] These policies allowed efficient harvesters to cover excess landings by buying quota from vessels that had not filled their quota allocation

Only temporary transfers of quota were officially permitted in 1991 and 1992, but quota holders may have made private arrangements to allow for what was in effect a permanent transfer of quota. Beginning in 1993, however, the government removed the restriction on permanent transfers. Information from the first year of the program (1991) reveals an active market with only about 20% of the fleet choosing not to participate - 68 licencees out of 325 had no net trade activity. By

[3] At the outset of the program the government permitted fishers to exchange excess catches of one species for another species at pre-determined terms of exchange. However, this provision was quickly dropped since managers felt it was being abused. By 1992 and 1993, for example, quota traded for between $1.00 and $1.50 per pound, Barbara *et al.*, 1995).

contrast, 118 licencees were net buyers and a further 132 were net sellers. Of these net sellers, 41 sold more than 90% of their quota. By the third year of the program (1993) only 58 licencees exhibited no net trading activity while 112 were net buyers and 138 were net sellers, including 67 sellers of more than 90% of their quota. Of these 67, 14 licencees sold out of the fishery completely by selling 100% of their quota permanently.

In 1996 the Department of Fisheries and Oceans introduced changes to the management schemes in order to encourage further rationalisation in the fishery. Firstly, each vessel was required to have a minimum quota of 7 tonnes in total, divided up across the four species, under ITQ management (2 tonnes each of Cod, Haddock, and Pollock and 1 tonne of Flounder).[4] In addition, licence fees had to be paid in full before the government would approve any quota transfers. Secondly, the structure of the licence fees themselves was also changed so as to make the fee based on quota holdings. Each licence holder's fee was based on his individual quota allocation, weighted by the landed prices of the species (Burke and Brander, 1999). This was ultimately set to 3% of the average value of landings up to $50,000 and 5% of value of landings over $50,000.

In recent years the fleet has more or less stabilised at a level that is less than one half the active vessels that participated in the first year of the quota program. The number of active vessels fell to 137 by 1998 (Dupont and Grafton, 2001) and to 131 by 2001 (DFO, Maritimes Region, 2003). It is clear that the ITQ program with active trading allowed less efficient vessels to sell their quota share and leave the fishery in a more orderly fashion than would have been the case in the absence of the ITQ program. Moreover, given the low and declining abundance measures for the principal species during the early 1990s, which necessitated the setting of successively lower total allowable catches for major species, quota trading helped some fishers to maintain their catches while providing a financial incentive for others to sell their quota and exit the fishery. Thus, quota trading allowed for an adjustment process that "…required no government intervention to determine which licences (if any) could continue to fish" (Burke and Brander, 1999, p.6) and has helped the groundfishery fleet converge to a more efficient size of vessel and fleet size.

The reduction in fleet capacity, especially in the early years (Dupont *et al.,* 2002), was accompanied by a general improvement in handling and landing procedures both on board and at the dockside because there was less need to land fish in a short period of time. Barbara *et al*. (1995) report the pattern of monthly landings changed with the introduction of the ITQ system. Although a large percentage of landings still took place in the traditional month of June, more were landed later in the fishing year. Thus, overall fishing effort was spread more evenly throughout the year. As a result, even as early as the first year of ITQ operations, the average

[4] This requirement was subsequently changed so as not to disadvantage smaller quota holders. The minimums became 1 tonne each of Cod and Haddock and 0.5 tonnes for Flounder and either 0, 0.5 or 1 tonne of Pollock according to particular fishing areas (Annand and Hansen, 1997).

dockside price of ITQ species increased relative to previous years' prices and grew to be equal to that of longline caught fish — traditionally seen as being of higher quality (Barbara *et al.*, 1995).

In addition to increasing prices of ITQ fish, another interesting development occurred in the fishery that may have not been anticipated at the outset of the ITQ program. As TAC levels (and, thus individual quota allocations) fell for the three original species, fishers increasingly targeted other species. In response to this, the regulator introduced ITQs on two additional species, Flounder (1994) and Redfish (1996). In addition to focusing upon these alternative groundfish species, ITQ vessel holders directed effort at non-traditional, shellfish species (Scallops and Shrimp, especially). For the entire fleet, the total value of non-groundfish landings started to increase and by 1994 grew as large as the total value of groundfish landings.

3.2 Data Needs and Availability

In order to apply the profit decomposition approach we need data on a per vessel basis. While it would be preferable to have data for a long period prior to the adoption of ITQs, as well as data for a long period after ITQs have been put into place, this is not the case for this fishery. We have vessel-level data on prices, landings and vessel size for two years prior to the introduction of ITQs (1988 and 1990), as well as for the first year of the program (1991). Previous literature has suggested that revenue changes are fairly rapid in ITQ fisheries, but that structural adjustments occur over a longer period (Casey *et al.*, 1995; Hermann, 1996; Grafton *et al.*, 2000).

With our vessel level data we can conduct an *ex post* analysis of the immediate, or short- term impacts of ITQs, specifically, an increase in prices of ITQ species. The profit decomposition is particularly well suited to looking at these types of effects because we can examine separately the impacts of individual species' prices upon profitability and productivity. The decomposition approach not only allows managers to identify those vessels that have improved their profits and productivity relative to others, but it also enables them to examine which factors are responsible for these differences. In this way, the manager can undertake a comparison of profits, prices and productivity prior to and after the introduction of ITQ regulations and look for patterns leading to increased profitability.

In order to look at longer term or structural impacts of ITQs, we employ industry level information post-ITQ, along with observations from fishery regulators. We also illustrate how the profit decomposition method can be employed to perform *ex ante* predictions of these longer term impacts such as changing fleet composition associated with trading of quota and rationalisation of the fishery, greater specialisation of gear and effort by fishers leading to a more homogeneous fleet, increased capacity utilisation in both harvesting and processing, and adjustments in targeting effort within a multi-species fishery context.

4. Profit, Price and Productivity Comparisons

4.1 Data Description

Data collected by the Canadian Department of Fisheries and Oceans are used to derive the profit decompositions for the fishery. The data are obtained from costs and earnings surveys conducted on random samples of fishers in 1988, 1990 and 1991. These data are supplemented with annual sales slip data that include vessel level information on landings by species, value of landings by species, vessel characteristics (size), variable costs and usage (fuel and labour). From these data we construct annual ex vessel species' prices. Profits are defined as the residual of gross returns from fishing less variable costs of production.

Tables 2a-c present summary statistics on a number of variables of interest for the 35 observations in 1988, 35 observations in 1990 and 38 observations in 1991. The tables show that the largest average catches of Cod, Haddock and Pollock occurred in 1988 and that these are higher than the average catches observed in 1991, the year in which ITQs were introduced. On the other hand, the largest average revenues (in nominal dollars) for both Cod and Pollock are observed in 1991, the year in which the ITQs were introduced.[5]

Table 2a: Summary Statistics of Sample Vessels (1988)

Variable	Mean	Min.	Max.	Std. Dev.
Observations	35	0	0	0
Gross Registered Tons	55	15	110	27
Average Crew	2	1	5	1
Fuel Expenditures ($)	26,209	3,618	60,000	13,573
Qty Cod (kg)	139,305	0	546,600	130,609
Qty Haddock (kg)	74,656	0	237,736	60,936
Qty Pollock (kg)	57,364	0	184,950	49,833
Value Cod ($)	88,543	0	327,961	74,863
Value Haddock ($)	82,266	0	244,868	67,450
Value Pollock ($)	19,241	0	66,582	16,279

5 We analysed quantity and value for non-ITQ species landed by the mobile-gear fishery by vessel size for the three year period 88, 90, and 91. We found that, over the period, total landings declined but revenues increased. When separated by vessels size, vessels less than 45 feet suffered both declines in quantity and revenue. Interested readers may contact the authors for further information.

Table 2b: Summary Statistics of Sample Vessels (1988)

Variable	Mean	Min.	Max.	Std. Dev.
Observations	35	0	0	0
Gross Registered Tons	55	15	110	27
Average Crew	2	1	5	1
Fuel Expenditures ($)	26,209	3,618	60,000	13,573
Qty Cod (kg)	139,305	0	546,600	130,609
Qty Haddock (kg)	74,656	0	237,736	60,936
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Value Haddock ($)	82,266	0	244,868	67,450
Value Pollock ($)	19,241	0	66,582	16,279

Table 2c: Summary Statistics of Sample Vessels (1991)

Variable	Mean	Min.	Max.	Std. Dev.
Observations	38	0	0	0
Gross Registered Tons	52	13	110	27
Average Crew	2	1	6	1
Fuel Expenditures ($)	26,350	3,000	70,000	15,051
Qty Cod (kg)	98,431	8,245	819,753	128,609
Qty Haddock (kg)	36,475	0	89,284	25,563
Qty Pollock (kg)	45,302	0	189,276	45,389
Value Cod ($)	104,306	11,404	543,552	89,358
Value Haddock ($)	57,231	0	129,457	39,427
Value Pollock ($)	33,643	13	110	27,129

In order to focus upon the immediate impacts of ITQs, namely higher prices, Table 3 records average values for ten output prices in real terms - all prices are net of general inflation, measured by the consumer price index (1991=100). The prices are for three ITQ species: Cod (COD), Haddock (HAD) and Pollock (POL) and seven non-ITQ species including: Silver Hake (HAK), Redfish (RED), Flounder (FLD), Halibut (HLT), Cusk (CUS), Catfish (CAT) and an unspecified or remainder group of species (USG). These prices are the average values for the actual ex-vessel prices observed in our data, so they are reflective of market conditions at the dockside in each year. Using these data we can look at real price changes over the period since it is often claimed that increased output price with private harvesting rights are due to better handling of the fish, timing of delivery and changing product form (frozen to fresh product). The last column in Table 3 reports the percentage change between 1988 and 1991. All species except Redfish experienced real price increases between the two years and most non-ITQ species experienced moderate price changes over the period, with Hake and Catfish prices increasing substantially (although the actual landings involved were moderate in terms of total fleet harvest). It is noteworthy, however, that the largest increases occurred for the two ITQ species: Pollock (94%) and Cod (60%). From the perspective of fisheries management, the interesting aspect of these price increases is the determination of the contribution of each to relative vessel profitability. We turn to this point later in the paper.

Table 3: Average Real Prices, by Species and Year (per kg)

Variable	1988	1990	1991	% change 88 to 91
Cod	0.745	0.836	1.198	0.61
Haddock	1.218	1.326	1.563	0.28
Pollock	0.380	0.603	0.738	0.94
Redfish	0.517	0.450	0.492	-0.05
Flounder	1.203	1.243	1.327	0.10
Halibut	4.402	3.934	4.740	0.08
Silver Hake	0.418	0.528	0.604	0.45
Cusk	0.536	0.496	0.544	0.01
Catfish	0.335	0.402	0.494	0.48
Remainder	0.630	0.655	0.685	0.09

Although the price effects observed for the fishery in 1991 are consistent with the predicted impacts associated with a shift to an ITQ regulatory scheme, it must be noted that output price increases can be a combination of both demand shocks and supply effects. Supplementary evidence available on price changes however, supports the hypothesis that the ITQ program brought about substantial change in prices for the ITQ species. For the Scotia-Fundy fishery the resulting adjustments in catching and landing meant both better handling of fish (leading to a higher quality output) and a greater dispersion in the pattern of deliveries, thereby reducing the landing gluts that might depress prices.[6] As a result, even as early as the first year of ITQ operations, the average dockside price of ITQ species increased relative to previous years' prices. They actually become equal to that of longline caught fish (traditionally seen as being of higher quality and commanding a higher price), Barbara *et al.* (1995).[7]

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[6] Barbara *et al.*, (1995) note that, after introduction of ITQs, landings continued to peak in June following the openings of the Georges and Browns Banks fishing areas. However, it is only since ITQs that relatively more landings have occurred in the later months of the year. For example, while the median number of days at sea was the same in 1988 as in 1991 (100 days), the maximum number of days increased from 215 to 235. With less of an incentive to race for the fish, the crew can be more careful in hauling the fish on board. Such general improvements in handling procedures on board has allowed for more of the catch to be delivered to the fresh market (Burke and Brander, 1999). And, with ITQs limiting quantity of catch (unless more quota is purchased), the only way to raise revenue for a given quota holding is to increase quality. As Burke and Brander (1999) state, "…IQs have created a fishing environment which rewards planning and organization (p.7). Such results are similar to those found in the B.C. single species halibut fishery (Grafton *et al*., 2000). Namely, in the early period of the ITQ program gains came originally on the revenue side (in the form of higher prices). Cost efficiencies did not occur until the later period, 1991-1994.

[7] Barbara *et al.*, (1995) estimate prices for Cod and Haddock had the ITQ program not been in place. They argue that Cod prices would have been 12% lower and Haddock prices would have been 15% lower in 1992.

Further evidence that the ITQ program brought about price increases is presented in Dupont and Grafton (2001). They examined price series for two different vessel types that operate in the Scotia-Fundy groundfishery; fixed-gear vessels not subject to any ITQs and the ITQ regulated mobile-gear vessels that we analyse in this paper. Fixed-gear vessels tend to be more selective in their catches and tend to land high-quality fish. Over the 1980s this resulted in consistently higher prices for Cod, Haddock and Pollock received by fixed-gear vessels compared to mobile-gear vessels.[8] However, since the introduction of ITQs, and particularly since 1993, average real prices for these same species caught by mobile gear rose to be equal to or even greater than those paid for fish caught by fixed gear.

4.2 Profit Decompositions

While the raw data on price changes are suggestive of the beneficial impacts of ITQs upon prices, we can go further and examine each price's impact upon profitability by formulating the profit decompositions discussed earlier. The first step in applying this approach is to choose a numéraire vessel. In order to facilitate the analysis we choose the vessel with the highest profits of any vessel over the three-year period: 1988, 1990 and 1991. Using the defined indices from Equations (2), (4), and (6) and following Equation (3), the specific profit decomposition equation for the Scotia groundfish fishery is represented by:

$$\Gamma^{a,b} = R^{a,b} \cdot PO^{a,b} \cdot PF^{a,b} \cdot PL^{a,b} \cdot K^{a,b} \tag{10}$$

where,

$$\begin{aligned} PO^{a,b} = {} & COD^{a,b} HAD^{a,b} POL^{a,b} HAK^{a,b} RED^{a,b} FLD^{a,b} \\ & HLT^{a,b} CUS^{a,b} CAT^{a,b} USG^{a,b} \end{aligned} \tag{11}$$

Thus, we construct Törnqvist indices for the ten output prices identified above and discussed earlier, two variable input prices (*PF* for fuel and *PL* for labour),[9] one fixed input (*K* for Gross Registered Tonnage), and productivity as defined in Equation (2).

The interpretation of each variable on the right hand side of Equation (10) is that it represents the relative contribution of that variable to profits of vessel *b* relative to the numéraire (vessel 27 in 1988). Specifically, if $PO^{a,b}$ exceeds unity, this implies that aggregate output prices make a larger contribution to profits for vessel *b* than for the numéraire. If $R^{a,b}$ exceeds unity, then this implies that productivity makes a greater contribution to the profits of vessel *b* than it does to the profits of the numéraire vessel *a*. A value for $PF^{a,b}$ or $PL^{a,b}$ that is greater than unity provides

8 It should be noted that both fixed and mobile gear vessels are subject to the same reductions in biomass that occurred in the late 1980s and 1990s. Thus, increases in output prices for mobile gear (ITQ) vessels relative to fixed gear (non-ITQ) vessels from 1993 onwards cannot be attributed to lower stock levels.

9 The former is the fuel price in the vessel's homeport. The latter is obtained by dividing total labour costs by the crewsize, including skipper.

evidence that the contribution of the price of these inputs to the profit ratio is greater than it is for the numéraire vessel. From Equation (4), this implies that vessel *b* faces lower per unit prices for these inputs than the numéraire vessel.[10] Finally, a value of $K^{a,b}$ that is greater than one, provides evidence that the contribution of the quasi-fixed input to profit is greater for vessel *b* relative to that for the numéraire vessel, *a*. We define profits as the gross return on capital (Lawrence *et al.*, 2004), so the share of the single capital input is equal to one, and $K^{a,b}$ is then simply the ratio of gross registered tonnage between *a* and *b*. Another way of putting this is that due to there being only one capital input, there is no aggregation of capital inputs as per Equation (6).

It should be noted that all comparisons are made relative to the numéraire vessel to ensure that the transitivity (circularity) property is satisfied. This means that we cannot use these indices to compare some vessel *b* with some other vessel *c* and directly draw inferences about the relative prices of the two vessels. This is because each vessel is compared with vessel *a* first and so the comparisons involve the shares of vessel *a*. These shares would not be involved in a direct comparison of *b* and *c*. That is, the comparisons are consistent by being made relative to the same vessel, rather than by comparisons to various different vessels.

Tables A1-A3 in the Appendix present the individual components of the profit decompositions for each vessel in our sample for 1988, 1990 and 1991, where observations have been ordered according to increasing vessel size.[11]

The data in these tables provide important micro-information to fisheries managers on the contribution of each index category to profits relative to the numéraire vessel (vessel 27 in 1988 as shown in Table A1). By construction, the values for all components of the profit decomposition for this numéraire vessel are set to one.

Consider, for example, vessel number 1 in 1988 (whose data are presented in the first row in Table A1). For this vessel, capital's contribution to profit (0.1875 < 1.0000) is substantially less than that for the numéraire. We note that vessel 1 pays a substantially lower price for labour (reflected in a large contribution to profits from labour as 5.8578 > 1.0000) but the price of fuel has an identical impact upon profits for both vessels (1.0000 = 1.0000). Finally, the contribution of output price (1.3752 > 1.0000) to profits is larger for vessel 1 but both productivity (0.0297 <

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[10] Recall that the price ratio that we are dealing with is the Törnqvist price index ($P^{a,b}$) defined in Equation (4). If vessel *b* pays a higher price for an input than the numéraire (vessel *a*), the price ratio of *b* to *a* is greater than one. The Törnqvist index requires that this value be raised to the power of the arithmetic average of the share values of the input in profit for the two vessels. For inputs the shares are negative by construction, and consequently, the index is less than one in this case. On the other hand, if vessel *b* pays a lower price for an input than the numéraire, the Törnqvist index is then greater than one.

[11] Ideally the profit decompositions should be adjusted to reflect changes in fish stocks or abundance over time (Fox *et al.*, 2003), but abundant data by species is unavailable for the fishery for the sample periods 1988, 1990 and 1991.

1.0000) and overall profit (0.0449 < 1.0000) indices are much less compared to the numéraire vessel.

While this discussion highlights the usefulness of the data in the table for making comparisons between vessels in 1988, they can also be used to compare vessels across years and, in this way, serve as input into both *ex post* and *ex ante* analyses.

5. Using the Profit Decomposition Approach

5.1 An Ex Post Evaluation

We look first at the *ex post* analysis of short-term effects of the ITQ. Economic theory predicts price increases for ITQ species, but very few other immediate adjustments. In terms of our model we should expect to see higher prices for Cod, Haddock, and Pollock (which we have already illustrated). However, now we look at the impact of these price increases upon relative profitability and, to a lesser extent, productivity.

The most striking result of the decompositions is that aggregate output prices have been providing a greater (and increasing) contribution to profits over the time period of our data. While this can be seen in Tables A1-A3, it is more easily observed in annual summary statistics for the variables in Tables A1-A3. Table 4 reports these summary values, specifically geometric means and corresponding standard deviations, for each index for each year.

Table 4: Geometric Means of Main Index Variables For All Years

Year	Profit	Productivity	Output Price	Fuel Price	Labour Price	Capital
1988	0.351	0.258	1.113	1.000	1.993	0.612
	(0.245)	(0.416)	(0.243)	(0.001)	(1.238)	(0.348)
1990	0.302	0.153	1.340	0.987	2.175	0.687
	(0.217)	(0.202)	(0.519)	(0.006)	(1.620)	(0.347)
1991	0.306	0.144	1.986	0.967	1.993	0.555
	(0.262)	(0.161)	(0.506)	(0.015)	(1.626)	(0.352)

Geometric means. Standard deviations (from geometric means) are in parentheses.

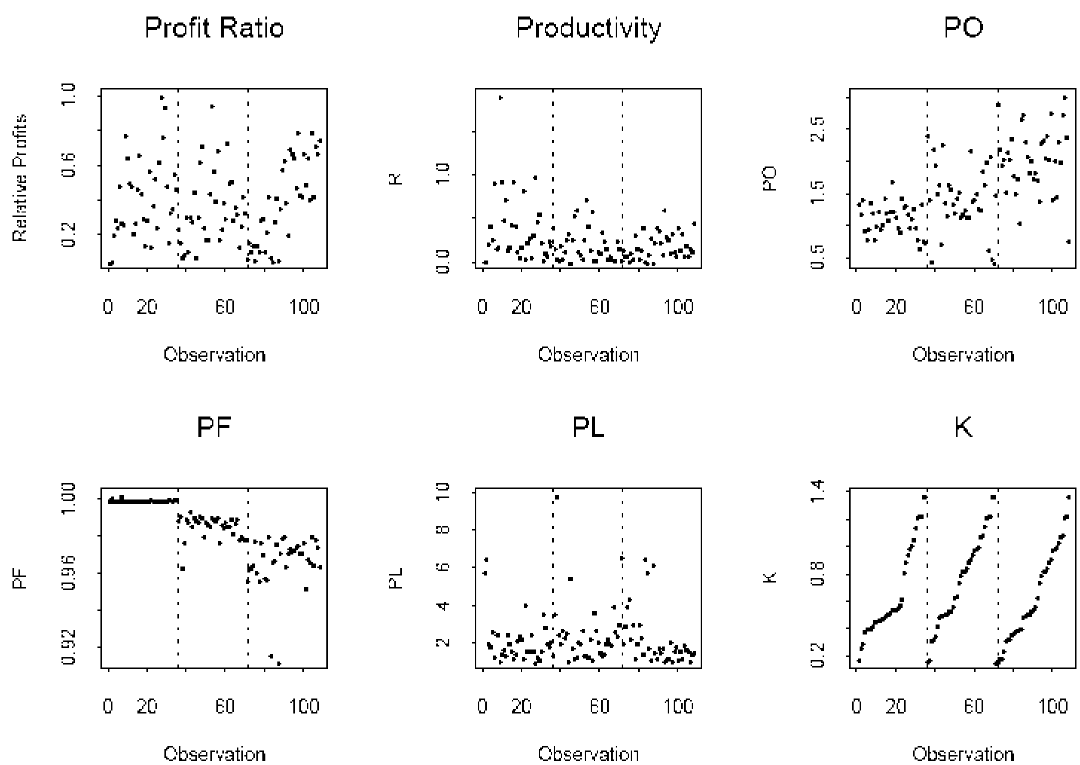
What the statistics in Table 4 clearly show is the substantial contribution to profits from increases in the aggregate output price over the period. We note further that, while we observe a 20% increase in the contribution of overall price to relative profitability between 1988 and 1990, there is an additional 48% increase in its contribution between 1990 and 1991. This provides support for the hypothesis that the major impact arising from the first year of ITQs in this fishery is the increased importance of output price contributing to overall profits. The reason for this is that ITQs remove the "race to fish" and empower fishers with property rights that provide the economic incentives for output price improvements (see footnote 6).

On the other hand, the summary values indicate little change for the two variable input indices (fuel and labour) and vessel tonnage, in either mean values or dispersion of individual values across vessels in each year. Apart from the change in the contribution to relative profits due to output prices, the biggest change over the period is in terms of productivity. The decline from 1988 to 1990, before the introduction of ITQs, is attributable to major declines in the biomass of key fish stocks (Dupont and Grafton 2001). It is worth emphasising, especially to lay the groundwork for our later *ex-ante* analysis, that the declines in catches from 1988 to 1991 were not uniform across vessel size. In particular, smaller vessels were affected much more than larger vessels by declines in biomass as larger vessels were able to travel greater distances and fish further offshore to maintain their catches. This differential impact is evident in the decline in the total catch of Cod, Haddock and Pollock over the period. For vessels less than 45 feet in length the total catch of these three species fell some 32% over the period 1988-1991, while for vessels of 45-65 feet in length the total catch declined by only 13% (Dupont and Grafton 2001).

We can look at the average summary effects in a different way by graphing out the individual indices for each period. Figure 1 presents graphs of the profit decompositions for all observations. The dotted vertical line in each graph denotes a demarcation between one observation period and another (from 1988 to 1990, then from 1990 to 1991). Within each period, vessels are ordered from left to right by increasing vessel size (also shown in the bottom right panel in Figure 1). The profit ratio in Figure 1 indicates a strong positive relationship between profits and vessel size only for 1991, the year in which ITQs were introduced. In a similar way, there is a noticeable downward relationship for the impact of fuel prices upon relative profitability for the same year (1991). A less strong, but noticeable, positive relationship also exists between vessel size and productivity for 1991. A possible explanation for this result is that fishers were able to trade and, thus, acquire quota to achieve a more optimal scale of production for a given vessel size in 1991 as compared to the pre-ITQ years of 1988 and 1990. A consequence of the trading of quota is that larger vessels became the principal beneficiaries in terms of productivity gains. Moreover, larger vessels were better placed to adjust their fuel usage in such a way as to lower their costs and increase their profits.

While it is not possible to apportion exactly the extent to which this outcome is attributable to the introduction of ITQs as opposed to exogenous market changes, we can illustrate the importance of ITQs having a positive impact upon the price received for harvest and, hence, profitability of individual vessels.

Figure 1: Profit-Ratio Decomposition



At this point we can exploit one particularly useful feature of the indices used in our profit decomposition approach. Recall that we originally constructed the overall output price index ($PO^{a,b}$) as the product of the ten separate output price indices, shown explicitly in Equation (11). This means that we can easily decompose this overall index into its component prices. Figure 2 presents a graphical breakdown of individual output price indices for each fish species over the three-year period. These give the contributions of each output price to relative profits. It is striking that the trend of increased price indices across vessels between 1988 (before ITQs) and 1991 (with ITQs) only occurs for the three species (Cod, Haddock and Pollock) included under the ITQ program and for Flounder, which was subsequently added to the ITQ species in 1994.

Price index impacts for all other fish types are moderate (Cusk, Redfish, Catfish, Hake, all other species) or not discernible (Halibut). Consequently, although all but Redfish experienced real price increases between 1988 and 1991 (Table 3) in terms of relative profits only the ITQ species (with the possible exception of Flounder) show substantial contribution to increased profits.

In order to reinforce this point, Table 5 presents the geometric mean values for ($PO^{a,b}$), as well as for each of the individual species' prices for the three years of data. Table 5 clearly illustrates two things. Firstly, ITQ species make larger contributions to profit than do non-ITQ species. Secondly, this differential beneficial impact intensified in the first year of the quota program.

We can be even more specific about identifying the revenue boost to fishing vessels from the ITQ program because, as Equation (11) shows, we can easily calculate an ITQ species price index and a non-ITQ species price index so as to identify the separate contributions of each species type to profit. Thus, in 1988 for example, if one wanted to calculate the contribution to the aggregate output price index (and hence profits) from Cod, Haddock and Pollock, one would simply multiply the individual price indices. This property carries over to the geometric means, so the average aggregate ITQ price contribution index for 1988 is 1.0876 1.0448 1.0094= 1.1470, from the geometric mean values reported in Table 5 for the respective species.

Figure 2: PO Decomposition

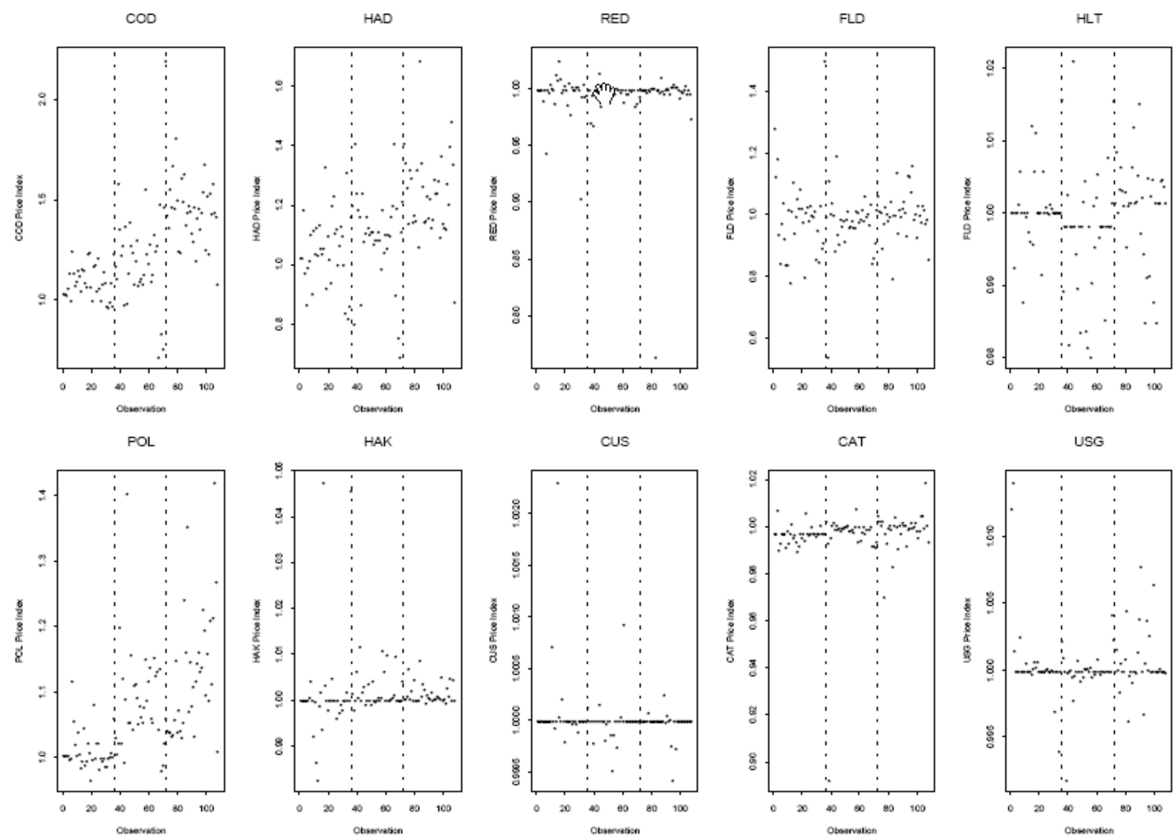


Table 5: Geometric Means of Output Price Indices By Species and Year

Variable	1988	1990	1991
Overall Output Price Index	1.113 (0.243)	1.340 (0.519)	1.986 (0.506)
Price Index for Cod	1.088 (0.078)	1.171 (0.192)	1.453 (0.190)
Price Index for Haddock	1.045 (0.121)	1.087 (0.152)	1.228 (0.138)
Price Index for Pollock	1.009 (0.029)	1.086 (0.077)	1.118 (0.094)
Price Index for Redfish	0.995 (0.020)	0.996 (0.009)	0.992 (0.039)
Price Index for Flounder	0.977 (0.107)	0.979 (0.134)	1.002 (0.072)
Price Index for Halibut	1.000 (0.005)	0.997 (0.009)	1.001 (0.007)
Price Index for Silver Hake	1.000 (0.009)	1.003 (0.008)	1.002 (0.002)
Price Index for Cusk	1.000 (0.0004)	1.000 (0.0002)	1.0000 (0.0001)
Price Index for Catfish	0.997 (0.004)	0.996 (0.018)	0.999 (0.007)
Price Index for Remainder	1.001 (0.003)	1.000 (0.002)	1.001 (0.002)

Geometric means. Standard deviations (from geometric means) are in parentheses.

The results from this aggregation are shown in Table 6 for all three years, along with aggregate non-ITQ species' price contribution indices. These numbers confirm the extent to which the ITQ species enjoyed price increases over their non-ITQ counterparts, even in the first year of the program, and, moreover, how these price increases translated into increased profitability.

Table 6: Geometric Means of ITQ and Non-ITQ Price Indices

Price Index	1988	1990	1991
ITQ Species (Cod, Haddock, and Pollock)	1.147 (0.371)	1.381 (0.412)	1.995 (0.714)
Non-ITQ Species (all others)	0.970 (0.116)	0.971 (0.149)	0.996 (0.097)

Geometric means. Standard deviations (from geometric means) are in parentheses)

5.2 An Ex Ante Evaluation

Even though we do not have vessel-specific data for a long period after the introduction of the ITQs, we can use the index decompositions already calculated to perform *ex ante* types of evaluations to predict how the fishery might change as the ITQ program matures.

One particular focus is fleet adjustment, in particular, whether larger vessels are more likely to benefit from the trading aspects of the program. We note from Tables A1-A3 that there are smaller ranges of differences, relative to the numéraire vessel, for the profitability and productivity variables in 1991 when compared to the values for the previous two years. This suggests a reduction in the dispersion in values from 1988 to 1991, thereby suggesting that the fleet became more homogeneous in 1991. We also note, however, that there appears to be more dispersion in the aggregate output price index, especially in the ITQ-species only aggregate price index for 1991 (Table 6). This suggests that the higher ITQ prices have differential impacts upon the profitability of individual vessels in the fleet. This may have arisen because, on the one hand, ITQ trading activity allows vessel owners to purchase quota and enjoy enhanced profitability from this freedom. On the other hand, the ITQ program allows less efficient vessel owners to sell quota that is unproductive to them but this may lower their profitability relative to the numéraire vessel.

In order to investigate potential impacts upon differently sized vessels in the fishery we present Table 7. This shows a breakdown of annual mean indices for the main variables according to vessel size regulations that were previously used for regulatory purposes in the fishery (Dupont and Grafton, 2001). For each of the three years results are presented for two vessel sizes: less than 45 feet and greater than 45 feet.[12] From our previous review of the literature we would expect larger vessels to be better placed to take advantage of quota available for purchasing in order to increase profitability.

The most interesting result from Table 7 is found by examining the contribution of output price to profit levels. We observe that, while both large and small vessels have benefited from the improved output prices on profit that occurred in the year ITQs were introduced, larger vessels have been the greatest beneficiaries since their mean output price index values increased from 1.07 to 1.28 to 2.00 by 1991. One hypothesis that is consistent with these results is that large vessels are able to respond more effectively to the introduction of ITQs as measured by an overall increase in profitability for these vessels observed in 1991 compared to the non-ITQ years.

Table 7 also allows us to examine the relative importance of the impacts of input prices and capital upon profitability according to vessel size. For example, the labour price ratio shows that small vessels have benefited from lower labour costs

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[12] While gross registered tonnage (GRT) is generally considered a better measure of vessel size (and hence is our measure of size for the profit decomposition), we present size results according to length as it is vessel length that has been used for regulatory purposes As with most fisheries, the correlation between length and GRT is very high and positive. For 1988 the correlation is 0.93, while it is 0.90 for 1990 and 0.92 for 1991.

relative to large vessels and that this has increased over the three year period: 2.18 to 1.80 for small to large vessels in 1988 compared to 2.56 to 1.46 in 1991. By contrast, little change in terms of fuel prices has occurred for either vessel classes. Interestingly, the role of capital's contribution to relative profitability has increased over the period for larger vessels (0.908 in 1988 to 0.960 in 1991) but fallen for smaller vessels (0.439 in 1988 to 0.357 in 1991). Again, this suggests that larger vessels are expected to benefit to a greater extent from the trading opportunities inherent in an ITQ program.

Table 7: Geometric Means of Index Variables by Vessel Length for All Years

Year	Profit	Productivity	Output Price	Fuel Price	Labour Price	Capital
1988						
< 45 feet	0.272	0.248	1.148	1.000	2.176	0.439
(19)[a]	(0.209)	(0.488)	(0.235)	(0.001)	(1.522)	(0.107)
≥45 feet	0.474	0.271	1.073	1.000	1.795	0.908
(16)	(0.244)	(0.328)	(0.254)	(0.001)	(0.720)	(0.318)
1990						
< 45 feet	0.226	0.167	1.441	0.987	2.368	0.401
(13)	(0.216)	(0.213)	(0.593)	(0.008)	(2.476)	(0.139)
≥45 feet	0.359	0.145	1.284	0.987	2.069	0.946
(22)	(0.208)	(0.198)	(0.471)	(0.005)	(0.777)	(0.238)
1991						
< 45 feet	0.187	0.107	1.975	0.963	2.565	0.357
(21)	(0.185)	(0.152)	(0.449)	(0.018)	(1.925)	(0.136)
≥45 feet	0.564	0.207	2.001	0.972	1.461	0.960
(17)	(0.169)	(0.160)	(0.582)	(0.007)	(0.333)	(0.191)

[a] Number of observations in parentheses in left-hand column, standard deviations (from geometric means) in parentheses below the means.

An important observation from Table 7 is that the productivity of both small and large vessels fell from 1988 to 1990, but increased for large vessels in 1991 while it continued to decline for small vessels. The fact that any vessels were able to raise productivity despite large decreases in catch due to major declines in the biomass of Cod, Haddock and Pollock (Dupont and Grafton 2001) is surprising and indicates that ITQs allowed, at least larger vessels, to adjust their operations by trading and other means to offset these biomass declines. As a result both the productivity increase from 1990 to 1991 and large increases in output prices allowed larger vessels to generate higher profits, on average, in 1991 but with much lower biomass levels than in 1988. By contrast, smaller vessels suffered much larger declines in catches in the late 1980s that lowered their initial quota allocation relative to larger vessels and this had a greater negative impact on their productivity. As a result, the productivity decline of small vessels from 1988 to 1990 and from 1990 to 1991 offset the gains in output prices such that their overall profitability fell. This particular set of results suggests that larger vessels were better placed to take advantage of a number of avenues open to them with the introduction of ITQs and could be used to predict that quota trading will tend to increase the average length of vessels in the fishery as small vessels exit and their quota is consolidated on larger and more profitable vessels. Liew (1999) provides evidence of exactly these outcomes for the Scotia-Fundy fishery, following upon the introduction of the ITQ program. She shows how concentration of quota increased between 1991 and 1998. In 1991, 162 licensees held 80% of the quota. By 1998, 80% of the quota was held permanently by 109 licensees. Furthermore, the number of vessels accounting for 80% of the fish caught by mobile gear decreased from 166 in 1991 to 61 in 1998.[13]

6. Concluding Remarks

Using a unique unbalanced data set for the periods 1988, 1990 and 1991 for the Scotia-Fundy groundfish fishery of Atlantic Canada, this paper provides validation of the usefulness of the profit decomposition method for assessing vessel-level performance. The paper adapts the methodology for the important case of a multi-species fishery in which ITQ rights are incomplete in the sense that some species are subject to them but others are not. Without imposing any assumptions on the technology of vessels, the approach gives insights into what factors may be contributing to profits and, in particular, how prices for ITQ species have differential impacts when compared to prices for non-ITQ species. Overall, we show the importance of the index profit decomposition in a multi output industry for both assessing and predicting changes in economic performance and industry structure.

The paper illustrates how the profit decomposition methodology can be applied to both *ex post* and *ex ante* types of evaluations. An *ex post* evaluation of results suggests that short-run gains associated with the introduction of ITQs come largely in the form of higher prices for quota species, thereby supporting the view that ITQ programs encourage better quality catches and, ultimately, prices. The results clearly show the differential impacts of the ITQ prices upon vessel-level profitability. *Ex ante* predictions using the profit decomposition approach suggest that larger vessels are most likely to benefit from ITQs in this fishery in terms of improved short-run profit performance. This, in turn is predicted to lead over the longer run to a reduction in the number of vessels in the ITQ fishery (as observed by Liew, 1999) and to a more efficient fleet composition and vessel size (as observed by Burke and Brander, 1999).

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[13] It might be thought that biomass reductions, leading to overall reductions in total allowable catches in the fishery, might lead to such changes in concentration. The fixed gear fishery, which is not an ITQ fishery, but fishes in roughly the same area and for the same species, has also experienced an increase in concentration levels. However, this has not been as pronounced as that in the ITQ fishery. For example, the number of vessels that accounted for 80% of the fish caught decreased from 445 in 1990 to 253 in 1998. This represents a 43% decrease compared to the 63% decrease for the ITQ fishery over the same period (Liew, 1999). This difference is attributable to the presence of the quota.

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APPENDIX A

Table A1: Profit Decompositions (1988)

Obs.	*Γ*	*R*	*PO*	*PF*	*PL*	*K*
1	0.0449	0.0297	1.3752	1.0000	5.8578	0.1875
2	0.0587	0.0267	1.2133	1.0022	6.5648	0.2750
3	0.2078	0.2346	1.4466	1.0000	2.0405	0.3000
4	0.2988	0.4352	0.9614	1.0000	1.8429	0.3875
5	0.2558	0.2821	0.8140	1.0006	2.6996	0.4125
6	0.4952	0.9325	0.9646	1.0000	1.3345	0.4125
7	0.2793	0.1915	1.3974	1.0024	2.5239	0.4125
8	0.2714	0.2025	1.2311	1.0000	2.4887	0.4375
9	0.7822	1.9035	0.8128	1.0003	1.0927	0.4625
10	0.6514	0.9518	1.0289	1.0000	1.4383	0.4625
11	0.5089	0.5036	1.2544	1.0000	1.6958	0.4750
12	0.4899	0.7456	0.9791	1.0000	1.4130	0.4750
13	0.2189	0.1709	1.0437	1.0000	2.5180	0.4875
14	0.2797	0.1927	1.4519	1.0000	1.9990	0.5000
15	0.4781	0.4514	1.2263	1.0000	1.6852	0.5125
16	0.6702	0.9389	1.1242	1.0000	1.2095	0.5250
17	0.4509	0.4416	1.2557	1.0000	1.5129	0.5375
18	0.3059	0.1497	1.7221	1.0000	2.1575	0.5500
19	0.1459	0.0868	1.2498	1.0000	2.4461	0.5500
20	0.2957	0.2049	1.1592	1.0000	2.2637	0.5500
21	0.5757	0.8514	0.9935	1.0000	1.2100	0.5625
22	0.1426	0.0629	0.9313	1.0011	4.1375	0.5875
23	0.3807	0.2515	1.4610	1.0000	1.6578	0.6250
24	0.5358	0.2992	1.3289	1.0000	1.6333	0.8250
25	0.2491	0.0811	1.3469	1.0000	2.5336	0.9000
26	0.6315	0.3316	1.2013	1.0000	1.6471	0.9625
27	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**
28	0.7714	0.4894	1.1446	1.0000	1.3434	1.0250
29	0.9494	0.5680	1.3121	1.0000	1.1991	1.0625
30	0.4887	0.2538	1.0052	1.0000	1.6655	1.1500
31	0.1680	0.0456	0.8203	1.0013	3.6615	1.2250
32	0.3363	0.1358	0.6822	1.0008	2.9314	1.2375
33	0.3628	0.1058	1.3611	1.0000	2.0352	1.2375
34	0.5594	0.2722	0.7912	1.0007	1.8877	1.3750
35	0.4760	0.2143	0.7607	1.0009	2.1221	1.3750

Γ -profit
R-productivity
PO-output price
PF-fuel price
PL-labour price
K-capital

Table A2: Profit Decompositions (1990)

Obs	Γ	*R*	*PO*	*PF*	*PL*	*K*
1	0.2437	0.4111	2.4293	0.9896	1.4092	0.1750
2	0.1691	0.1727	1.4443	0.9919	3.6432	0.1875
3	0.0786	0.0547	0.4653	0.9638	9.8736	0.3250
4	0.0947	0.0508	2.2338	0.9781	2.5263	0.3375
5	0.3124	0.2166	1.9793	0.9906	2.0287	0.3625
6	0.1109	0.0615	1.5247	0.9891	2.7314	0.4375
7	0.3098	0.1562	1.6786	0.9945	2.3762	0.5000
8	0.2848	0.2903	0.7445	0.9868	2.6053	0.5125
9	0.4553	0.3491	2.3001	0.9916	1.1156	0.5125
10	0.0791	0.0198	1.3855	0.9897	5.5481	0.5250
11	0.3163	0.2812	1.1956	0.9887	1.8124	0.5250
12	0.6266	0.5671	1.6675	0.9925	1.2422	0.5375
13	0.7231	0.6194	1.6072	0.9913	1.3633	0.5375
14	0.2518	0.1549	1.3775	0.9806	2.0929	0.5750
15	0.1826	0.1174	1.2199	0.9888	2.0221	0.6375
16	0.1883	0.0711	1.4749	0.9878	2.7974	0.6500
17	0.4483	0.2757	1.5492	0.9865	1.4185	0.7500
18	0.9564	0.7427	1.1612	0.9917	1.3978	0.8000
19	0.5813	0.4417	1.2155	0.9906	1.3051	0.8375
20	0.4040	0.1694	1.2834	0.9899	2.2408	0.8375
21	0.7021	0.6145	1.1651	0.9915	1.1467	0.8625
22	0.1877	0.0499	1.1465	0.9775	3.7325	0.9000
23	0.2461	0.0444	2.1928	0.9874	2.7695	0.9250
24	0.3982	0.1436	1.4077	0.9860	2.1034	0.9500
25	0.3036	0.1369	1.4293	0.9889	1.5892	0.9875
26	0.7451	0.3611	1.5174	0.9864	1.3786	1.0000
27	0.5112	0.2736	1.2996	0.9865	1.4396	1.0125
28	0.5142	0.1844	1.2746	0.9908	2.0305	1.0875
29	0.2926	0.0633	1.8855	0.9827	2.2672	1.1000
30	0.3705	0.0954	1.6753	0.9882	2.0173	1.1625
31	0.3310	0.0700	2.0112	0.9909	1.9374	1.2250
32	0.1414	0.0444	0.6548	0.9797	4.0112	1.2375
33	0.2612	0.0386	2.0992	0.9808	2.6583	1.2375
34	0.4306	0.2562	0.5147	0.9800	2.4234	1.3750
35	0.3385	0.1859	0.4366	0.9795	3.0960	1.3750

Table A3: Profit Decompositions (1991)

Obs	Γ	R	PO	PF	PL	K
1	0.0741	0.0472	1.5142	0.9567	6.6755	0.1625
2	0.1686	0.1660	2.9186	0.9634	2.0637	0.1750
3	0.1174	0.0987	2.2357	0.9642	2.9445	0.1875
4	0.1446	0.1020	1.9663	0.9657	3.9843	0.1875
5	0.0641	0.0286	2.0684	0.9785	4.4200	0.2500
6	0.1462	0.1337	1.5615	0.9617	2.2401	0.3250
7	0.1162	0.0540	2.1815	0.9563	3.0534	0.3375
8	0.2930	0.3447	2.0668	0.9779	1.2462	0.3375
9	0.3023	0.1736	2.3800	0.9711	2.0783	0.3625
10	0.1170	0.0585	1.8178	0.9583	3.0630	0.3750
11	0.2317	0.1713	1.5425	0.9576	2.3632	0.3875
12	0.4293	0.4136	1.7717	0.9813	1.4927	0.4000
13	0.0815	0.0310	1.0587	0.9162	6.5654	0.4125
14	0.0552	0.0087	2.6923	0.9675	5.8836	0.4125
15	0.2842	0.1187	2.7604	0.9678	1.7932	0.5000
16	0.4236	0.3054	2.3384	0.9767	1.1852	0.5125
17	0.0691	0.0109	2.1130	0.9123	6.2657	0.5250
18	0.3682	0.2484	1.8521	0.9721	1.5686	0.5250
19	0.5872	0.4289	2.0430	0.9801	1.2722	0.5375
20	0.6421	0.3839	1.7594	0.9810	1.7619	0.5500
21	0.4012	0.2510	1.8511	0.9647	1.5566	0.5750
22	0.2101	0.1096	1.7421	0.9721	1.7755	0.6375
23	0.7074	0.6259	1.4204	0.9745	1.0887	0.7500
24	0.6796	0.3187	2.3288	0.9725	1.1768	0.8000
25	0.6559	0.2819	2.3694	0.9739	1.2038	0.8375
26	0.4828	0.1355	2.0827	0.9757	2.0932	0.8375
27	0.8002	0.3455	2.4417	0.9764	1.1263	0.8625
28	0.4393	0.1460	2.0705	0.9724	1.6610	0.9000
29	0.4352	0.0932	2.7887	0.9723	1.8624	0.9250
30	0.6771	0.4249	1.4412	0.9777	1.1452	0.9875
31	0.5039	0.1595	2.0429	0.9527	1.6227	1.0000
32	0.6557	0.3593	1.4766	0.9689	1.2597	1.0125
33	0.4175	0.0906	2.3417	0.9669	1.9619	1.0375
34	0.8048	0.2195	2.0144	0.9807	1.7065	1.0875
35	0.4342	0.0912	2.7587	0.9654	1.6254	1.1000
36	0.7275	0.1885	3.0236	0.9794	1.0638	1.2250
37	0.6762	0.1549	2.4098	0.9756	1.5001	1.2375
38	0.7559	0.4601	0.7986	0.9650	1.5505	1.3750