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Vessel-level productivity in Commonwealth fisheries

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Abstract

The total factor productivity of the Commonwealth Trawl Sector of the Southern and Eastern Scalefish and Shark Fishery is estimated for the period 1996–97 to 2008–09 using vessel-level data and a traditional approach that captures the production decisions of fishers. The paper develops a replicable methodology and calculates benchmark productivity estimates by which future estimates for other Commonwealth fisheries can be evaluated. Productivity estimates presented in this paper are based on vessel-level financial and catch data collected by ABARES in its annual survey of the fishery and the application of the Fisher index method.

The analysis of trends in productivity offers important new information to decision-makers. Changes in the way in which fishers organise the transformation of inputs into outputs have a direct impact on firm-level economic performance. Changes in productivity at the vessel level illustrate the response of the fleet to policy settings in the fishery and, more broadly, to environmental factors. This is of particular value for fishery managers when they consider policy instruments—such as fish stocks, technology and fleet structure—that might affect the drivers of productivity growth in fisheries.

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1 Introduction

Commercial fisheries in Australia, like many other industries, are exposed to a range of external factors that can affect their profitability. Given that fish production is fuel intensive, the current cost of fuel, which is high by historical standards, has adversely affected vessel operators' profits. Increased global seafood production, largely attributable to investments in aquaculture over the past decade, has adversely affected the global prices of several products made by Australia for local and foreign markets (Mazur et al. 2010).

Lower world prices have been further exacerbated by the appreciation of the exchange rate. With the strengthening of the Australian dollar, imported products have become increasingly price competitive on local markets, while exported products have become less competitive on foreign markets. So, despite having historically been a net importer in volume terms, in 2007–08, for the first time, Australia also became a net importer in value terms (Mazur et al. 2010). Given these factors, productivity assumes increased importance in fisheries as a means of maintaining profitability in the future.

It follows that, if productivity gains are essential, the knowledge of how they arise should be of concern to stakeholders and a focus of research for economists. In the most general sense, productivity measurement is important because it captures broader trends that can be decomposed into the drivers of productivity. Identifying these drivers and their relative importance guides the actions of regulators and industry participants. In this sense, productivity indicators might be aimed at 'evaluating how the state of technology is evolving' (Felthoven and Morrison-Paul 2004) or at 'identifying changes in efficiency' (OECD 2001), among other objectives.

Productivity measurement in fisheries is undertaken in the context of the regulatory framework. Since a harvest strategy policy was formally implemented across all Commonwealth fisheries in 2007, harvests have been managed according to a target harvest of maximum economic yield. The economic objective of this framework is to maximise the net economic returns to the community over time (AFMA 2010). The concept of maximum economic yield is discussed in more detail in Kompas and Gooday (2005). To assist their decision making, fishery managers and industry stakeholders have a need for indicators of the drivers of changes in the profitability of Commonwealth fisheries. The capacity to offer this information may be considered an appealing property of a productivity measure.

While productivity, productivity measurements and their determinants have long been an issue of concern for fisheries economists, the practical concerns that complicate the choice of productivity indicator have been given little consideration in the recent literature. In particular, a scarcity of data often limits the choice of method. When data are available, the complexity of analytical methods makes the production of the indicator costly and the replication of results difficult.

Several recent studies have approached the subject through the modelling of technical efficiency. Stochastic frontier analysis by Kompas and Che (2005) and Kompas et al. (2004) related boat performance in selected Australian fisheries to a benchmark vessel given constant technology. By so doing, these studies capture only the efficiency aspect of productivity, particularly as it relates to fleet performance.

Index number profit decompositions, also benchmarked to a reference vessel, as in Kompas et al. (2009) and Vieira (2011), utilise, in the words of Balk (2003), a 'value added approach'. These studies reveal how profits arise from changes in variables that the fishery managers can and cannot influence. While these studies offer important information to fishery managers, the productivity measures they contain contrast a derived, implicit quantity index with an index of fixed inputs only.

The approach taken by Felthoven and Morrison-Paul (2004) differs from these recent studies, suggesting a 'primal approach that focuses on inputs and outputs rather than modelling choices'. Their method estimates productivity parameters by modelling econometrically both standard and unconventional factors that affect production. This approach, on the other hand, models productivity directly, but it is complex and data intensive.

This paper proposes a simple, replicable method of measuring and analysing total factor productivity. The method in this paper uses vessel-level data to capture directly the effect of vessel operators' production decisions. By approaching the problem of productivity measurement in a direct manner that can be easily updated, the method contrasts with profit decompositions and stochastic frontier analysis. Updates to productivity estimates can be made once the data become available, making it possible for productivity estimation in Commonwealth fisheries to be standardised and produced on a regular basis.

In addition, the indexes that result from the method can, in conjunction with input and output price indexes, provide fishery managers and stakeholders with an appreciation of what has driven changes in fishery profitability.

This paper provides some preliminary results from the ABARES analysis of vessel-level productivity in one key Commonwealth fishery, the Commonwealth Trawl Sector of the Southern and Eastern Scalefish and Shark Fishery. The paper begins with a brief introduction to the Commonwealth Trawl Sector, with particular focus on its recent economic performance. It then introduces the methodology used to calculate the productivity indexes presented. Once the methodology is established, results are presented for the entire sector.

While this paper does not assess the reasons for productivity change over time quantitatively, it does provide some qualitative interpretations. The paper concludes by discussing productivity in the context of the legislated management target of maximum economic yield and by proposing research directions that build on this method.

2 Commonwealth Trawl Sector of the Southern and Eastern Scalefish and Shark Fishery

The Commonwealth Trawl Sector is one of four sectors in the Southern and Eastern Scalefish and Shark Fishery. It is the largest sector in catch and value terms. Activity in the sector occurs in waters south of Barranjoey Point (north of Sydney) to Cape Jervis in South Australia, taking in the Victorian, Tasmanian and part of the New South Wales coastlines. Fishers in the Commonwealth Trawl Sector target several different species using one of two methods: otter trawling is the major fishing method, while a number of Danish seine boats operate out of Lakes Entrance in Victoria.

The Commonwealth Trawl Sector is largely managed with output controls on key species in the form of individual transferable quotas and total allowable catches (TACs). Under this system, 16 individual quota species and 29 species are covered under basket or multispecies quotas (Stobutzki et al. 2010). However, more than 100 species are routinely caught in the Commonwealth Trawl Sector. A variety of complementary input controls is also used in the fishery. Boat concessions regulate which sector and/or method a vessel can use, while other controls impose area and seasonal closures and gear restrictions.

Since 2005, TACs have been determined under a harvest strategy framework that uses them to manage fisheries at target biomass levels. The rules that guide catch-setting have been designed to incorporate a higher level of precaution when there is increased uncertainty about stock status. The framework also improves the transparency of the TAC-setting process (Larcombe and McLoughlin 2007).

Catches in the sector peaked at 30 600 tonnes in 2002–03, a year when catches of orange roughy and blue grenadier were substantially higher than in more recent catches.

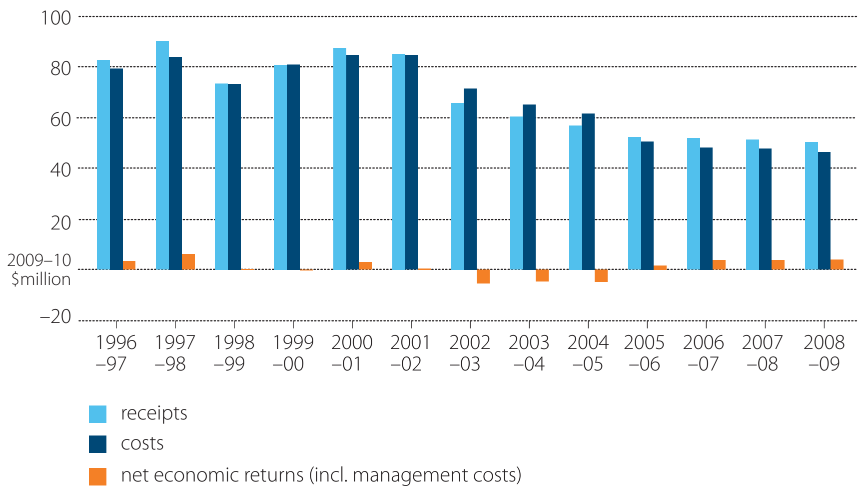
Catches then declined every year for five years following 2002–03 and reached a low of 15 200 tonnes. In 2008–09, however, catches increased by 2 per cent to 15 500 tonnes. This is approximately half the 2002–03 peak catch and reflects more conservative TAC settings and lower boat numbers. Five key species—blue grenadier (4000 tonnes), tiger flathead (2800 tonnes), silver warehou (1600 tonnes), orange roughy (600 tonnes) and ling (600 tonnes)—made up more than 60 per cent of the 2008–09 catch.

The sector's gross value of production (GVP) has followed a similar downward trend to catches. In 1999–00, GVP in real terms was $98.4 million (2009–10 dollars). In 2008–09, the value of the sector was 42 per cent lower, at $57.2 million, and the five key target species accounted for 65 per cent of GVP. If it were not for large increases in the average unit price received for catches in recent years, it is likely GVP would have been even lower. Production in this sector accounted for 18 per cent of the gross value of Commonwealth fisheries production.

The most recent survey-based estimates of net economic returns for the Commonwealth Trawl Sector are for 2008–09 (Perks and Vieira 2010). Given the size of the sector in terms of vessel numbers, net economic returns have been low. The highest estimate before 2007–08 was $6.1 million (in 2009–10 dollars), recorded in 1997–98 (figure a). In contrast, net economic losses were experienced in 2003–04 and 2004–05. More recently, however, the economic returns have been positive: $1.6 million in 2005–06 and $3.7 million in 2006–07. This positive trend continued through to 2009–10, when non-survey based estimates of net economic returns increased to $6.8 million.

These recent improvements can largely be attributed to a decline in fishery operating costs that occurred at the same time as a sharp fall in the number of active vessels operating in the fishery. The number of vessels decreased from 91 in 2004–05 to 52 in 2007–08, largely as a result of the Securing our Fishing Future structural adjustment package. Although TAC reductions resulted in lower fishery revenues, costs fell by a greater amount because of the reductions in vessel numbers.

a Real revenue, costs and net economic returns (including management costs) in the Commonwealth Trawl Sector



Source: Perks and Vieira 2010.

3 Methodology

Productivity is a measure of how effectively inputs are used to produce outputs. An increase in productivity implies that a firm has either increased its production while utilising the same inputs or they have chosen to produce the same output with fewer inputs. For fisheries, it is generally the latter option that applies, as binding controls used by management are generally designed to restrict harvests to sustainable levels. Given the size of harvest restriction, productivity growth cannot increase the total quantity of outputs produced. The producer's decision is effectively constrained to producing similar amounts with fewer inputs.

Productivity indexes can be broadly expressed as either partial measures of productivity growth (relating a measure of output to a single measure of input) or total factor productivity (relating a measure of output to all inputs).

Total factor productivity is a measure of the productivity of all inputs, or factors of production, in terms of their combined effect on output and is often accounted for by technological change or more efficient methods of producing output. Hence, a total factor productivity index measures change in total output relative to the change in use of all inputs. In this case, a total factor productivity index is preferred over partial productivity measures because partial factor productivity measures may result in the effects of technological and efficiency changes, input substitution, and technological improvements attributable to other inputs being ascribed to improvements in a particular input (Zhao et al 2010).

The total factor productivity index is the ratio of two subindexes: an output quantity index and an input quantity index. In the majority of cases, the output index comprises multiple outputs and the input index comprises multiple inputs. It is necessary to aggregate them into the separate indexes. Since the heterogeneity of inputs and outputs does not permit simply adding up units of different types of commodities, this is done by price weighting. The input index aggregates the various inputs used in fishing based on their relative contribution to total cost (cost shares); similarly, an output index aggregates the outputs based on their share of revenue. The relative changes in these two indexes measure productivity growth. Productivity growth results from increases in the output index that are greater than those in the input index and from decreases in the input index that are greater than decreases in the output index.

One factor that complicates productivity measurement is variation in the quality of inputs and outputs (Gray et al. 2010). If a vessel operator targets high-quality catch, or invests in quality controls, this should be captured in an estimation of total factor productivity through the value weight used in the output index. Since catch of a high quality attracts a higher unit value (price), the weight attached to the species in the output index would increase (assuming world prices are constant). Assuming no change in efficiency resulting from these targeting practices, vessel-level productivity would rise. However, the estimation undertaken in this paper is limited because prices have not been disaggregated into grades that correspond to qualities. Instead, an average price has been calculated for each species and this price is applied across all operators, irrespective of targeting practices and quality controls.

A similar issue arises with input quality. The quality of non-standardised inputs such as labour and repairs, and maintenance is difficult to capture accurately using a value weight. Given that vessel operators generally remunerate their labour through catch shares or pre-agreed percentages of the catch revenues, the cost of labour varies with catch. This may be accounted for by using, in the case of labour, a proxy such as an opportunity cost of labour. Such an adjustment has not been made in this paper.

Total factor productivity can be calculated using a number of formulae. Some of the most common of these are the Laspeyres index, the Paasche index, the Fisher index and the Tornqvist index. Given that the method outlined in this paper utilises a Fisher index with an Elteto-Koves-Szulc (EKS) extension, a brief outline of the method is included along with some justification for its use.

Given two periods, a base year and the current year, the Laspeyres index is defined as the sum across all goods of the base year price of a good multiplied by the current year quantity of the same good. This figure is then divided by the sum across all goods of the base year price of the good multiplied by the base year quantity of the same good. The Paasche index is similar to the Laspeyres index, although it uses current year prices, rather than base year prices, as weights.

The Laspeyres quantity index, calculated for N inputs (or outputs) between the base period (period 0) and the current period (period t), is given by equation (1):

$$Q_{0t}^{L} = \frac{\sum_{i=1}^{N} p_{i0} q_{it}}{\sum_{i=1}^{N} p_{i0} q_{i0}} = \sum_{i=1}^{N} W_{i0} \frac{q_{it}}{q_{i0}} \tag{1}$$

where q_{i0} and p_{i0} are the quantity and price of input (or output) i in the base period, q_{it} and p_{it} are the quantity and price of input (or output) i in the current period, and $W_{i0} = \frac{p_{i0} q_{i0}}{\sum_{i=1}^{N} p_{i0} q_{i0}}$ is the share of the ith item in the total value of inputs (or outputs) in the base period (Gray et al. 2010).

The Paasche quantity index, calculated for N inputs (or outputs) between the base period and current period, is given by equation (2):

$$Q_{0t}^{P} = \frac{\sum_{i=1}^{N} p_{it} q_{it}}{\sum_{i=1}^{N} p_{it} q_{i0}} = \left[\sum_{i=1}^{N} W_{it} \left(\frac{q_{i0}}{q_{it}}\right)\right]^{-1} \tag{2}$$

where $W_{it} = \frac{p_{it} q_{it}}{\sum_{i=1}^{N} p_{it} q_{it}}$ is the share of ith item in the total value of inputs (or outputs) in the current period and all other variables are as in equation (1).

The Fisher index, given by equation (3), is the geometric mean of the two indexes described above. Since the Laspeyres index is considered to be biased downward, while the Paasche index is considered to be biased upward (Gray et al. 2010), there is a disparity in each of their estimations of the quantity indexes. This disparity is called the 'Laspeyres–Paasche spread'. The fact that the Fisher index is the geometric mean of these indexes partially mitigates this problem as the two biases cancel to an extent. However, it cannot be shown that they cancel each other out perfectly.

$$Q_{0t}^{F} = \sqrt{Q_{0t}^{L} Q_{0t}^{P}} \tag{3}$$

The Tornqvist quantity index is defined as the product across all goods of the ratio of current quantities divided by base year quantities weighted by the average of the base year and current year prices. Like the Fisher index, the Tornqvist index is considered 'superlative' because of its capacity to approximate general functional forms of the production function (OECD 2001). The Tornqvist quantity index (Q) is given in equation (4):

$$Q_{t,t-1} = \prod_{i=1}^{n} \left(\frac{q_{i,t}}{q_{i,t-1}} \right)^{\frac{\omega_{i,t} + \omega_{i,t-1}}{2}} \tag{4}$$

In each period, $Q_{t,t-1}$ in equation (4) gives the index relative to the previous period. A series of annual changes can be 'chained' together to express the index relative to a base year by multiplication.

Since productivity, along with the factors of production, is contained within the production function, if the functional form is known, the most appropriate index can be chosen. For example, if the function is quadratic, a Fisher index is preferable; if the function is translog, a Tornqvist index is best suited. However, the exact functional form is rarely observable from fisheries data.

The Fisher index was chosen for certain characteristics that better suit it to the purposes of this report and to the underlying data. To make the estimated total factor productivity comparable across groups—that is, by size and scale—the transitive method was used to update the productivity estimation. The method used one vessel in the initial period as the numeraire and normalised other vessels' input and output according to this benchmark, which helps to set up the measurement system of inputs and outputs across vessels and over time.

The Fisher index also has limitations. While being highly useful in comparing firms at the enterprise level, it should not be used to form higher level indexes through aggregation, as it will yield inconsistent results (Diewert 1988). A second limitation is that it does not allow the substitution of outputs and inputs for each other (Coelli, et al. 1998). For example, low-grade fish may be used as bait, in which case the output is re-used as an input. This substitution would not be accounted for in the results.

The final, notable limitation of the Fisher index is that it does not satisfy the circularity axiom (Coelli et al. 1999) and allow two results to be compared indirectly through a third result. Ideally, the quantity index in the current year relative to the base year would be the same as the product of the quantity index in an intermediate year relative to the base year and the quantity index in the current year relative to the intermediate year. This has been partially corrected through an extension of the index.

In order to allow direct comparison between firms an extension of the Fisher index, the EKS index, has been used. This means that, if there are a number of firms, any two can be compared and the result will remain consistent (Elteto and Koves 1964). This can be illustrated using an example of three vessels: boats A, B and C. If boat A is found to have greater productivity than boat B, and if boat B has greater productivity than boat C, then boat A should also have a higher index than boat C. This sort of comparison, referred to as 'transitivity', is not consistent when using a Fisher index unless that has been extended through use of an EKS index. The formula to make the Fisher index transitive is given by equation (5):

$$Q_{st}^{EKS} = \left(\prod_{r=1}^{N} Q_{sr}^{F} Q_{rt}^{F}\right)^{1/N} \tag{5}$$

where Q_{st}^{EKS} is the transitive Fisher index between boats s and t when there are N boats being compared Q_{sr}^{F} is the Fisher index with boat s as the base observation, and Q_{rt}^{F} is the Fisher index with boat r as the base observation. With the EKS procedure, any two boats can be compared by dividing their respective index numbers.

4 Trends in productivity of the Commonwealth Trawl Sector of the Southern and Eastern Scalefish and Shark Fishery

The data used for the analysis presented in this paper are sourced from the dataset developed through the ABARES survey of Commonwealth fisheries. This dataset is comprehensive and can facilitate the measurement of total factor productivity for the Commonwealth Trawl Sector and other fisheries surveyed by ABARES. Ultimately, ABARES will produce a total factor productivity measure for the sector as well as by fishing method, separating the sampled vessels on the basis of whether they are otter trawl or Danish seine vessels. A summary of the data is given in table 1.

1 Vessels sampled in the Commonwealth Trawl Sector, 1996–97 to 2008–09

year	population	sample
1996–97	109	41
1997–98	109	46
1998–99	103	36
1999–2000	101	37
2000–01	106	38
2001–02	97	39
2002–03	100	20
2003–04	97	25
2004–05	91	27
2005–06	81	23
2006–07	73	19
2007–08	50	14
2008–09	52	15

These results were estimated with a Fisher index with an EKS extension (as described in section 3). Inputs were categorised as labour, fuel, repairs and maintenance, materials and services, overheads and capital. Outputs were categorised as blue grenadier, flathead, ling, orange roughy, silver warehou and other species.

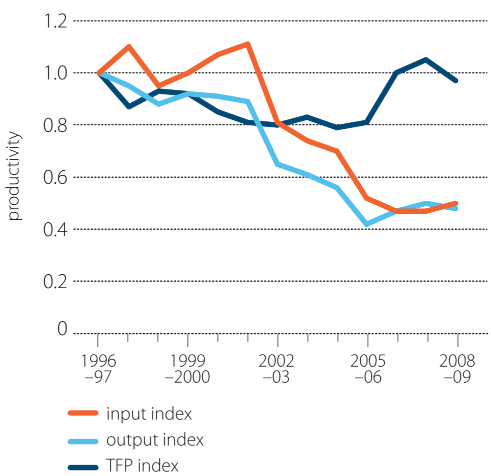
Interpretations of productivity trends are usually best done over relatively long periods. Short-term influences, such as the effect of climate variability on fishery production and the deferral of input expenditure in low-income years, have an impact on the productivity estimates produced using index number approaches and are not accounted for explicitly in total factor productivity measurements. To reduce the effect of these short-term fluctuations, productivity trends are presented for the Commonwealth Trawl Sector, over the 12 years from 1996–97 to 2008–09.

Between 1996–97 and 2004–05, total factor productivity in the Commonwealth Trawl Sector fell by 19 per cent (figure b). This equates to a decline of 1.9 per cent a year. Since 2004–05, however, the trend has been upward. Between 2004–05 and 2008–09, productivity increased by 20 per cent in total and at an average of 6.6 per cent a year. These results are broadly consistent with results presented in Vieira et al. (2010).

Since changes in total factor productivity are driven by relative changes in the outputs produced by the set of inputs, analyses of input and output indexes illustrate the drivers of change in total factor productivity. In this case, the slight declines in the input index since 2005–06, in combination with the considerable improvements in output index, prompted the convergence of the two indexes and resulted in an increase in productivity in the sector.

Input use in the Commonwealth Trawl Sector generally followed a downward trend since 2001–02. This trend is broadly consistent with the decline in the number of active vessels in the sector (table 1). However, in recent years the decline in input usage has not been as rapid as the decline in boat numbers. Between 2005–06 and 2008–09, boat numbers fell from 81 to 52 active vessels, a decline of 36 per cent. Over the same period, the input index effectively stabilised, recording a decline of just 4 per cent over three years.

b Productivity indexes for the Commonwealth Trawl Sector, 1996–97 to 2008–09
(1996–97 base year)



On the other hand, there have been recent changes in the quantity of outputs generated in the sector. In the years to 2005–06, the output index decreased by 52 per cent at an average of 5.2 per cent a year, reflecting a period of stock rebuilding in the fishery and tight TAC settings. However, since 2005–06 there has been a 14 per cent increase in the output index at an average of 4.8 per cent per year.

Productivity indexes, such as those estimated in this study, require careful interpretation and their limitations should be recognised. They cannot, for example, offer a benchmark of optimal performance in the same way that stochastic production frontier analysis or data envelopment analysis can. Rather, in the case of boat-level indexes, they gauge the performance of vessels relative to an arbitrary standard. This standard is generally set at either the most profitable or the average boat.

Given that the recent history of the Commonwealth Trawl Sector has included a tightening of TACs to improve fish stocks as well as the Securing our Fishing Future structural adjustment package of late 2006 (DAFF 2006)—which included a reverse tender process targeted at the less efficient vessels in the fishery—the recent productivity improvements in the sector are to be expected. However, the sector is likely to require ongoing productivity gains to sustain profits and competitiveness in an operating environment characterised by increasing international competition and growing pressures from external factors such as high fuel costs.

5 Discussion

For changes in an index to be indicative of fishery performance, it is important to identify the context and source of any growth. This information makes it possible to make inferences about economic performance, but these inferences are strictly limited by conditions in the fishery.

Productivity in fisheries is generally sensitive to four main drivers (Wood and Newton 2007). Primarily, growth in productivity is likely to result from technological changes that increase the amount of outputs generated by a given quantity of inputs. The same would be true if producers were to adopt existing technologies they were not able, for any reason, to access previously. Given a model (such as the one presented here) that does not control for trends in stocks, an increase in the abundance of fish is also likely to prompt a productivity gain. Finally, changes in fleet structure and a shift toward more productive vessels—whether through autonomous adjustment as a result of concession trade or through an adjustment package—may also result in productivity gains throughout the fishery.

Productivity is not the same thing as profitability, and productivity indexes are not easily incorporated into the standard models against which fishery performance is assessed. Productivity is independent of prices. Once prices of outputs and inputs are incorporated, changes in the price of outputs relative to the price of inputs may mean it is rational to produce at a point inconsistent with the highest achievable levels of productivity.

While productivity is a measure of the amount of output produced per unit of input, profitability is maximised where the difference between revenues and costs is greatest (a point referred to in the fisheries economics literature as 'maximum economic yield'). Profits may well be maximised at a point different to the point that offers the highest productivity.

Increasing profits do not necessarily signal increasing productivity. Instead, they may result from movements in the total cost and revenue curves wholly attributable to changes in the terms of trade. A fishery's terms of trade is a ratio of the average price received by an operator for their output to the average price paid for their input (Sheng et al. 2010). O'Donnell (2008) argues that profitability can be written as the product of an index of an operator's terms of trade and a multiplicatively complete total factor productivity index. This implies that changes in the terms of trade may in the short term prompt vessel operators to maximise profits by choosing combinations of inputs and outputs that do not maximise productivity. A complete discussion of the decomposition of total factor productivity indexes is available in O'Donnell (2008) and O'Donnell (2010).

The inclusion of prices ensures that the point of the highest attainable productivity cannot be easily observed in the standard representation of maximum economic yield. However, the effects of productivity changes on the economic performance of a fishery can be assessed through the analysis of output and input price indexes and the total factor productivity index presented in this paper. Similar to how index number profit decompositions decompose profits, the decomposition of this index into specific output and input indexes isolates drivers of productivity. Including an analysis of terms of trade in the fishery makes it possible to estimate how price change and productivity change each contributes to profits.

So, while at the firm level productivity gains can be generally regarded as positive to economic performance, it is important for fishery managers not to subordinate the idea of sustainably maximising economic returns from the fishery to the idea of increasing productivity. Doing so is likely to involve locating the fishery away from a harvest level that maximises economic yields. This would conflict with the fishery manager's legislated objective of maximising economic returns to the Australian community from the management of Australian fisheries (AFMA 2010). Policy initiatives designed to improve productivity should occur in the context of binding controls that have maximum economic yield as a target harvest level.

6 Future directions

The method presented in this paper has the potential to be extended in three key directions. One extension that is likely to have an effect on the results represented in this paper is stock adjustment. While annual variations in natural stock abundance and weather, as well as differences in sampling procedures for financial performance estimates, can introduce a tolerable degree of short-term variability or 'noise' into the index, it is important to account for any systematic change in the operating environment. Stock adjusting, or controlling for long-term changes in fish stocks, establishes productivity as a function of technological progress rather than environmental change.

A second future direction would be to identify productivity by fishing method. Given that in the Commonwealth Trawl Sector, fishers are either otter trawlers or Danish seiners, calculating productivity by method would highlight the effect on productivity of method choice, as well as any related technological advances that are method specific. This extension has been precluded from this paper by data constraints; however, it is certainly a possible future extension.

Finally, the focus of this paper is to present a productivity measurement method applicable to fisheries and easily replicable. Of particular interest would be a deconstruction of the index presented in this paper into the specific output and input indexes. This would further identify the specific drivers of productivity change. This extension would be augmented through some analysis of the terms of trade faced by vessel operators in Commonwealth fisheries. Also of interest would be econometric analyses of productivity trends to establish whether there is a structural break in the data, especially around 2004–05, when total factor productivity in the Commonwealth Trawl Sector appears to have moved from a negative to a positive trend. Analysis of this type constitutes a necessary area for future research.

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