An index number decomposition of profit change in a fishery

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Acknowledgments

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Abstract

There are many drivers that affect a fishery’s profitability over time. Without an understanding of these drivers and their relative movements, it is difficult to say if a fishery is moving closer to or further away from a biomass associated with maximum economic yield. Further complicating such interpretation is the fact that different drivers of profit can cause profit to move in different directions and with variable magnitudes over time. The key variables that influence a fishery’s profitability include prices received for catch; prices paid for inputs; vessel productivity; and the fishery’s target stock biomass. Recent actions to address stock sustainability and move fishery effort and stock levels toward more profitable levels in Australian Commonwealth fisheries have been followed by increases in profitability. However, variations in factors external to fishery management control (for example, prices of outputs and inputs) have meant that any positive effect of these management induced changes has been difficult to isolate. This paper presents an index number profit decomposition of the Australian Commonwealth Trawl Sector, a sector that supplies a substantial proportion of Australia’s domestically produced scalefish. The approach isolates...
the relative contribution of each of the above-mentioned drivers to changes in vessel level profit over time. The results reveal how changes in profit have come about due to changes in variables that fishery managers have some indirect influence over (fish stocks and productivity) and ones that fishery managers don’t have control over (output prices and input prices). The analysis represents an extension of previous work undertaken on the sector in which some previously identified issues have been further explored. These issues relate to appropriately defining the reference vessel and exploring the relationship between scale and productivity. The current paper also explores more explicitly the impact of target fish stocks on fishery productivity and profitability.
1 Introduction

Over the past two decades, management of Australia’s Commonwealth fishery resources has become increasingly more reliant on economic information. This has been driven by the Australian Fisheries Management Authority’s (AFMA) legislated objective to manage fisheries in a way that maximises the net economic returns to the Australian community from the use of these resources. More recently, the release of the Commonwealth Fisheries Harvest Strategy Policy in 2007 has put this economic objective at the forefront of fishery management decisions. This policy requires that harvest strategies (a set of rules that guide decisions on appropriate fishery harvest levels) be developed for Commonwealth fisheries that seek to maintain fish stocks at a target biomass equal to the stock size required to produce maximum economic yield (MEY). MEY refers to that point in a commercial fishery where fishing effort, catches and fish stocks are at levels that result, on average, in the net economic returns to society from the commercial use of that fishery resource being maximised (Kompas and Gooday 2005). With the implementation of harvest strategies, the demand for economic information to feed into policy decisions for Commonwealth fisheries about how best to pursue the MEY target has increased.

To accurately determine the levels of catch, effort and stock biomass that are most likely to achieve MEY typically requires a bioeconomic model. However, bioeconomic models are data intensive (requiring biological, economic and fishery-based data), complex and require a high level of technical expertise to construct and interpret. For many fisheries, these factors mean that the construction of a bioeconomic model will be difficult to justify on a cost–benefit basis.

For some of Australia’s key Commonwealth fisheries, time series estimates of net economic returns are available (Perks and Vieira 2010). Such estimates reveal the actual net economic return achieved in a given year but not the return that could have been achieved (the MEY). Changes in net economic returns over time can provide some indication of which direction profitability is moving. But without information on the causes of those movements, it is difficult to say if a fishery is moving closer to or further away from a point associated with MEY. Key variables that influence a fishery’s profitability include prices received for outputs (catch), prices paid for inputs (crew, fuel and so on), vessel productivity (the ability of each vessel to convert its inputs into outputs) and fishery stock levels (a larger stock biomass results in catches being made at lower cost). Further complicating such interpretation is the fact that different drivers of profitability can cause profit to move in different directions and at variable magnitudes over time.

Consequently, for most of Australia’s Commonwealth managed fisheries, there is an increasing need to develop other more informative but less costly tools and indicators to inform fishery management policymaking according to a MEY objective. One tool that has been recently developed that allows the different drivers of profit changes in a fishery to be assessed, quantified and compared is the index number profit decomposition method. As its name suggests, this approach allows the relative contributions of the key drivers of profit changes at the vessel level to be decomposed into its separate elements. It does this by quantifying changes in vessel level profit according to contributions from key drivers with each individual vessel’s performance being defined by an index relative to a defined reference vessel.
This approach was first applied by Fox et al. (2003) to the British Columbia halibut fishery and has since been applied to Canada’s Scotia–Fundy mobile gear fishery (Dupont et al. 2005), the Australian Commonwealth Trawl Sector of the Southern and Eastern Scalefish and Shark Fishery (formerly the South East Trawl Fishery) (Fox et al. 2006; Grafton and Kompas 2007) and the Eastern Tuna and Billfish Fishery (Kompas et al. 2009). Preliminary results were also presented for the Commonwealth Trawl Sector and the Gillnet Hook and Trap Sector by Vieira (2011). Here, the analysis was extended from the single-output based analysis used for the fishery by Fox et al. (2006) and Grafton and Kompas (2007) to a multi-output analysis, so that the relative impact of the prices of different outputs on profitability can be assessed. The current paper presents an update of the latter results for the Commonwealth Trawl Sector with a number of key differences. First, two key issues identified by Vieira (2011) are addressed—appropriately defining the reference vessel and exploring the relationship between scale and productivity. The current paper also explores more explicitly the impact of stocks on productivity and profitability, and offers stronger evidence about the impact of a recently completed government-funded vessel buyback program.
2 The fishery sector

The Commonwealth Trawl Sector is a complex multi-gear and multi-species sector. It is one of Australia’s oldest commercial fishing sectors, commencing operation off Sydney in the early 1900s. The primary harvesting method used in the sector is otter trawling, although a number of Danish seine vessels also operate. More than 100 species are routinely caught in the sector. However, five key target species constitute more than 60 per cent of the landed trawl tonnage. These are blue grenadier, tiger flathead, orange roughy, silver warehou and pink ling. The sector’s gross value of production in real terms has been in steady decline over the past decade, falling from $96.1 million in 1999–2000 to $55.9 million in 2008–09 (2008–09 dollars). A key driver of this decline has been falls in catches driven by cuts to total allowable catches in response to concerns about the sustainability of key stocks.

Management of the sector is predominantly based on output controls in the form of individual transferable quotas and total allowable catches. These were first introduced for gemfish and orange roughy in 1988 and 1990, respectively. In 1992, quota management was further expanded to a total of 16 target species, partly in response to deteriorating economic conditions across the fishery (Smith and Wayte 2004). Then, in 1998, quota management was expanded to key scalefish species in the Gillnet, Hook and Trap Sector. Quota management of all quota managed species in the trawl sector was then expanded to the Gillnet, Hook and Trap Sector with the setting of global total allowable catches across both sectors in 2001. Currently 34 species are managed under global total allowable catches that apply to all sectors in the Southern and Eastern Scalefish and Shark Fishery (Stobutzki et al. 2010a).

In 2005, a harvest strategy framework was adopted for the fishery to provide a more strategic approach for determining total allowable catches. This predated the Commonwealth Fisheries Harvest Strategy Policy released in 2007, forming the basis for the policy. The framework identifies how total allowable catches should be altered when a stock declines or rises above predetermined biomass levels subject to a target of MEY. The rules that guide the setting of total allowable catches have been designed to incorporate a higher level of precaution when there is an increased level of uncertainty about stock status. The framework also improves the transparency of the catch setting process. The harvest strategy framework has been continuously revised and altered in response to a number of shortcomings identified since it was implemented (Larcombe and McLoughlin 2007).

Vessel numbers in the Commonwealth Trawl Sector have been in steady decline over the past decade with the recent government-funded vessel buyback further driving this trend. The scheme aimed to reduce excess effort in fisheries where target fish stocks were subject to overfishing or at significant risk of overfishing. The buyback resulted in a 46 per cent reduction in the number of fishing permits in the Southern and Eastern Scalefish and Shark Fishery. The overall economic impact of the buyback was assessed in Vieira et al. (2010) as having a positive impact on each sector’s profitability.
Survey-based estimates of net economic returns for the Commonwealth Trawl Sector were generally close to zero or negative between 1998-99 and 2004–05 (figure 1). Net economic returns then became positive in 2005–06 and have remained positive. Net economic returns were $3.8 million in 2008–09, or 7 per cent of the sector’s gross value in the same year (Perks and Vieira 2010).

The Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) assesses the economic performance of all Commonwealth managed fisheries in its annual Fishery status reports (see Wilson et al. 2010). Changes in net economic returns for the Commonwealth Trawl Sector have been analysed in these reports. However, no attempt has been made to quantify the relative contribution of various drivers to these changes over time. The index number profit decomposition approach that is described below is used to do this here.

![Real net economic returns in the Commonwealth Trawl Sector, 1998–99 to 2008–09](image-url)
3 Methodology

The index number profit decomposition method used follows previous applications of the approach to fisheries (for example, Fox et al. 2003; Dupont et al. 2005; Fox et al. 2006; Grafton and Kompas 2007; Kompas et al. 2009). The approach has also been applied to the telecommunications sector (Lawrence et al. 2006), to decompose growth in domestic product in an open economy (Diewert and Morrison 1986; Fox and Kohli 1998) and to decompose estimates of the output gap in a country (Fox et al. 2002). The approach and its theoretical robustness are demonstrated in significant detail by Kirkley et al. (2002) and Fox et al. (2003).

The index number profit decomposition approach

The approach uses index numbers to quantify the contribution of a variable (output prices, variable input prices, productivity and stocks) to a firm’s profit, where in the case of a fishery a firm is a vessel. The method does this in terms relative to the contribution of that variable to the profitability of some other firm (a reference firm) using index numbers. The choice of reference firm is normally based on which firm is most profitable (Fox et al. 2006), although Kompas et al. (2009) used the average firm for the most profitable year. By choosing the most profitable firm (or year), comparison of each firm’s performance can be made to what can be deemed as a more desirable level of performance. Therefore, conclusions can be drawn about what an individual firm would need to change to increase its profit. Furthermore, the comparison to best performance is conceptually consistent with other economic-based frontier approaches to productivity and efficiency analysis such as stochastic frontier analysis and data envelopment analysis (Fox et al. 2003).

The concept of using a reference firm means that the results generated by this approach can reveal information about relative firm performance and average firm performance in a sector. However, it should be noted that decomposition results for different sectors for which unique reference firms have been assumed cannot be compared. This is because the characteristics of the reference firm assumed in each decomposition will influence the results of that decomposition in different ways, making comparisons inconsistent.

The first stage of an index number profit decomposition involves estimating the profits of all firms and adjusting them for differences in the size of fish stocks over the period of analysis. In this way the contribution of fish stocks to profit can be determined. The next stage involves decomposing differences in the profit index into contributions from prices, fixed inputs and fish stocks adjusted productivity.

The first stage involves calculating the variable (excluding fixed input costs), non-zero profit of each firm by summing the product of all defined netputs and their respective prices. Netputs refer to both the outputs and variable inputs that are produced and used by a firm, where a variable input is a netput that has a negative value and an output is a netput that has a positive value. For \( N \) netputs, the variable non-zero profit, \( \pi \), for a given firm in a given period is defined as:
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\[ \pi = \sum_n^N (p_n \cdot q_n) \]  

where \( p_n \) is a vector of prices and \( q_n \) is a vector of quantities for netput \( n \). Once each firms’ variable profit has been calculated, a reference firm can be selected (or calculated if using the average firm from a given year). However, in the case of a fishery, it is normally the firm with the highest stock adjusted profit, \( \pi_s \), that is selected where:

\[ \pi_s = \pi / S \]

An aggregated price index, \( P_{a,b} \), is then defined, which compares the prices of all netputs between firm \( a \) and firm \( b \). Similarly, \( Q_{a,b} \) is defined as a quantity index that compares the quantities of all netputs between firms \( a \) and \( b \). As outlined by Fox et al. (2003), the ‘weak factor reversal test’ of Fisher (1922) requires that:

\[ \theta_{a,b} \equiv P_{a,b} \cdot Q_{a,b} \]

This shows that by using netputs for the construction of the profit index, the profit (or value) index should equal the product of the price and quantity indexes. If this condition is not satisfied by a particular choice of index number for the price or quantity index (for example, Tornqvist index), then either the price or quantity index can be defined directly, and the other index is defined indirectly. If \( P_{a,b} \) is defined directly (for example, to ensure that equation 4 is satisfied), \( Q_{a,b} \) can be defined as:

\[ Q_{a,b} \equiv \theta_{a,b} / P_{a,b} \]

Accordingly, \( Q_{a,b} \) is referred to as an ‘implicit’ index (Allen and Diewert 1981) given it is derived implicitly from the ‘direct’ definition of \( P_{a,b} \).

The definition of the implicit quantity index allows a productivity index to be derived. Put simply, productivity can be defined as some measure of the quantity of output that is produced from a given level of inputs. It therefore follows that a productivity index between two firms can be derived by taking an index of the output produced by each firm and dividing it by an index of the inputs used by each firm. The measure of productivity used here uses the implicit quantity index \( Q_{a,b} \) as the output index. The input index is based on each firm’s relative use of a fixed input \( K \) (capital). Therefore, the productivity index \( R_{a,b} \) between the same two firms is defined as:

\[ R_{a,b} \equiv \frac{Q_{a,b}}{P_{a,b}} \]
There are many ways to measure productivity, and the productivity index derived using this approach is interpreted slightly differently to more standard measures of productivity. The productivity index here represents the difference in the output quantity index between two firms that cannot be explained by differences in utilisation of the fixed input $K$ by the same two firms. As noted by Lawrence et al. (2006), this concept of productivity is based on an implicit index of output quantity formed using a ‘value-added’ or ‘gross-operating surplus’ approach. Therefore, it differs to that of standard total factor productivity measures that use a ‘gross-output approach’ and are based on a direct output quantity index. Balk (2003) provides a comparison of the two approaches. Lawrence et al. (2006) distinguish between the two types of productivity measures by referring to the measure based on the index number profit decomposition approach as capital total factor productivity. They also note that, since the input base for the latter is generally smaller than a gross-output based measure of total factor productivity, growth in the former measure will tend to be much greater than growth in the latter.

The capital total factor productivity measure in equation 6 can be redefined given equation 5 as:

$$R_{a,b} = \frac{Q_{a,b}}{K_{a,b}}$$

Which, once rearranged, defines the overall profit decomposition as:

$$\theta_{a,b} = P_{a,b} \cdot R_{a,b} \cdot K_{a,b}$$

Using equation 8, the profits of vessel $b$ can be defined in terms of the contributions of netput prices ($P_{a,b}$), productivity ($R_{a,b}$) and the fixed input ($K_{a,b}$) to variable profit compared with the contributions of the same variables to the variable profit of vessel $a$.

A stock-adjusted productivity index between vessels $a$ and $b$, $R_{s,a,b}$, can also be calculated by multiplying the productivity index by the ratio of stocks observed for vessels $a$ and $b$:

$$R_{s,a,b} = R_{a,b} \cdot (S_a / S_b)$$

where $S_a$ and $S_b$ are the fish stocks that each harvests from, respectively.

The aggregate price index ($P_{a,b}$) and the fixed input or capital index ($K_{a,b}$) in equation 8 can be further decomposed into indexes that show the contribution of each netput’s price and each capital input’s price to variable profit relative to the reference firm.

Construction of the aggregated price and capital indexes

To undertake the above decomposition, both an aggregate price index for all relevant netputs and an aggregate capital index for all fixed inputs must be calculated. Derivation of the aggregated price index is based on a price vector of netput prices specified for $M$ variable netputs for firm $b$, defined as

$$R_{a,b} = \frac{Q_{a,b}}{K_{a,b}}$$
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\[ p^b = (p_1^b, \ldots, p_N^b) \] (10)

where the quantities of netputs is denoted in the following netput vector

\[ y^b = (y_1^b, \ldots, y_N^b). \] (11)

As was noted earlier, if \( y^b > 0 \) a netput represents an output, but if \( y^b < 0 \) a netput represents a variable input. Further, the price vector (equation 10) satisfies the requirement that each element is positive (Fox et al. 2006).

As shown by Fox et al. (2003), the Törnqvist index has a number of useful properties for constructing the price indexes described in equation 8. Using the Törnqvist index, \( P_{a,b} \) can be denoted as netput price and quantity indexes and is defined by:

\[
\ln P_{a,b} = \sum_{n=1}^{N} \frac{1}{2} \left( s_n^b + s_n^a \right) \ln \left( \frac{p_n^b}{p_n^a} \right)
\] (12)

where \( s_n = (p_n y_n) / (\sum p_n y_n) \) is the profit share of netput \( n \).

The multiplicative nature of the Törnqvist index allows us to decompose the aggregate price and fixed-input indexes between vessels \( a \) and \( b \) into a product of individual price and input differences:

\[ P_{a,b} = \prod_{n=1}^{N} P_{n}^{a,b} \] (13)

where the index for each netput \( n \) is itself a Törnqvist index.

The fixed input or capital index, \( K_{a,b} \), can be derived in the same fashion as \( P_{a,b} \) where there are \( M \) fixed inputs which, for firm \( b \), have an associated price vector \( k^b \) and quantity vector \( q^b \) of netput prices. The aggregate price index for the fixed input can be derived using equation 12 by substituting in the fixed input prices and the profit shares of each fixed input. However, the application of the method to fisheries in previous works has assumed that there is only a single fixed input, so that profits are all attributed to that one single fixed input (that is, that fixed input’s profit share is unity). Therefore, calculation of the fixed input index is simplified and reduces to:

\[ K_{a,b} = k^b / k^a \] (14)

With the derivation of both the aggregated price index and the fixed input index, the profit decomposition described in equation 8 can be broken down further. Assuming that three key netputs have been defined for the decomposition—a single output (\( O \)), a fuel input (\( F \)) and a labour input (\( L \))—and, in the case of a fishery, its stock abundance (\( S \)) is known, the decomposition can be redefined as follows:

\[ \Theta_{a,b} = PO_{a,b} \cdot PF_{a,b} \cdot PL_{a,b} \cdot R_{a,b} \cdot K_{a,b} \cdot \frac{S_a}{S_b} \] (15)
The performance of firm $a$ relative to firm $b$ is decomposed into differences due to productivity ($R_{a,b}$), output prices ($PO_{a,b}$), labour prices ($PL_{a,b}$), fuel prices ($PF_{a,b}$) and vessel capital ($K_{a,b}$). $S_a$ and $S_b$ are fish stock indexes for vessels $a$ and $b$. The decomposition provides measures of relative profits over time and the contributions to relative profits from input and output prices, capital, productivity and stocks.

Aggregating stocks in a multi-species fishery

The calculation of the stock index, $S_{a,b}$, requires that stocks be aggregated into a single stock biomass estimate for all years being analysed. For a fishery that catches multiple species, an aggregate measure of the fishery’s total stock biomass over time is complicated by two things. First, the abundances of different species will move in different directions and magnitude in a given period. Second, the relationship that exists between a given species’ stock biomass and vessel profitability will vary across species. However, the key drivers of a species contribution to vessel profit are likely to be the catch of a given species and its price.

Accordingly, an aggregated measure of stock biomass can be computed from stock assessment output data for each key species, by weighting each species’ contribution to the aggregated abundance according to the quantity of catch of each species in each year and average price received for each species in each year. As shown by Kompas et al. (2009), aggregated stock biomass, $S_t$, can be defined as

$$S_t = \sum_{i=1}^{n} S_{ti} \cdot \frac{p_{ti} h_{ti}}{\sum_{i=1}^{n} p_{ti} h_{ti}} \quad (16)$$

where $S_{ti}$ is the stock abundance for species $i$ in time period $t$, $p_{ti}$ is its relevant price and $h_{ti}$ is the quantity caught in that time period.

Although an aggregated stock index that is relevant to each vessel would be ideal, such an approach is problematic because catch differences would not necessarily reflect variations in catchability across vessels (Fox et al. 2006). An alternative approach is to construct stock indexes for vessels that employ the same gear in a given year.
4 Application of the method

Data

Revenue and costs data were sourced from ABARES economic survey data for the financial years 1998–99 to 2008–09 for sampled vessels. Key variables included fish sales receipts, vessel labour costs and fuel costs. These data were combined with logbook catch and effort data and catch disposal record data on vessel departure and arrival time, both supplied by the Australian Fisheries Management Authority. ABARES fisheries statistics data that include average unit prices for key species were also used to determine prices received by vessels for their catch of individual species in each year.

The Commonwealth Trawl Sector is typically divided into three operation types: otter trawlers, Danish seiners and factory trawlers. Only four factory trawlers operated in the sector between 1998-99 and 2008–09 and no survey data exists for these vessels. Therefore, this sector could not be included in the analysis. Otter trawlers can be further categorised according to whether their operations focus on inshore or offshore waters. Offshore trawlers typically used to target orange roughy. However, reductions in total allowable catches of orange roughy over the past decade to address sustainability concerns have resulted in a substantial decline in the number of offshore trawlers. Consequently, offshore trawlers were also excluded from the analysis. Therefore, the analysis focused on inshore trawl vessels (referred to as trawl vessels from here on) and Danish seine vessels. A total of 43 trawl sample observations and six Danish seine sample observations were removed from the analysis because of data inconsistencies. This was particularly in relation to the price adjustment that was undertaken to allow for the multi-output analysis (explained below). This left 189 trawl vessels and 69 Danish seine vessels in the sample data set. Tables 1 and 2 contain the sample and population of the trawl sector and Danish seine sector, respectively, along with key summary statistics. The four key species caught by vessels in the trawl sample were blue grenadier, tiger flathead, pink ling and silver warehou. On average, these species accounted for 49 per cent of the average catch per vessel. The average Danish seine vessel caught mainly tiger flathead and whiting, which, on average, accounted for 90 per cent of total catch.
### Sample population and characteristics of sampled trawl vessels (mean per vessel), by financial year

<table>
<thead>
<tr>
<th>Financial year</th>
<th>Trawl sample number</th>
<th>Trawl population number</th>
<th>Mean days at sea</th>
<th>Mean vessel length (m)</th>
<th>Mean blue grenadier catch (kg)</th>
<th>Mean tiger flathead catch (kg)</th>
<th>Mean pink ling catch (kg)</th>
<th>Mean silver warehou catch (kg)</th>
<th>Mean catch of other species (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998–99</td>
<td>20</td>
<td>69</td>
<td>183</td>
<td>20.8</td>
<td>29 488</td>
<td>21 357</td>
<td>26 415</td>
<td>24 682</td>
<td>29 552</td>
</tr>
<tr>
<td>1999–00</td>
<td>21</td>
<td>72</td>
<td>185</td>
<td>21.6</td>
<td>36 436</td>
<td>29 334</td>
<td>24 682</td>
<td>27 189</td>
<td>120 634</td>
</tr>
<tr>
<td>2000–01</td>
<td>23</td>
<td>73</td>
<td>183</td>
<td>19.6</td>
<td>9 739</td>
<td>11 115</td>
<td>8 668</td>
<td>24 766</td>
<td>98 590</td>
</tr>
<tr>
<td>2001–02</td>
<td>25</td>
<td>67</td>
<td>167</td>
<td>19.8</td>
<td>6 499</td>
<td>30 933</td>
<td>10 778</td>
<td>28 466</td>
<td>100 881</td>
</tr>
<tr>
<td>2002–03</td>
<td>15</td>
<td>74</td>
<td>166</td>
<td>19.2</td>
<td>19 469</td>
<td>41 544</td>
<td>8 668</td>
<td>24 766</td>
<td>91 410</td>
</tr>
<tr>
<td>2003–04</td>
<td>14</td>
<td>75</td>
<td>170</td>
<td>19.2</td>
<td>40 299</td>
<td>53 856</td>
<td>10 998</td>
<td>24 615</td>
<td>92 694</td>
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<tr>
<td>2004–05</td>
<td>15</td>
<td>72</td>
<td>167</td>
<td>20.3</td>
<td>31 217</td>
<td>31 328</td>
<td>11 519</td>
<td>27 472</td>
<td>104 736</td>
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<tr>
<td>2005–06</td>
<td>13</td>
<td>64</td>
<td>179</td>
<td>19.0</td>
<td>24 277</td>
<td>38 881</td>
<td>12 719</td>
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<tr>
<td>2006–07</td>
<td>11</td>
<td>62</td>
<td>163</td>
<td>19.8</td>
<td>29 998</td>
<td>45 902</td>
<td>18 482</td>
<td>32 668</td>
<td>104 156</td>
</tr>
<tr>
<td>2007–08</td>
<td>6</td>
<td>38</td>
<td>191</td>
<td>20.6</td>
<td>34 744</td>
<td>47 746</td>
<td>14 869</td>
<td>41 875</td>
<td>128 158</td>
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<tr>
<td>2008–09</td>
<td>7</td>
<td>38</td>
<td>210</td>
<td>22.7</td>
<td>43 144</td>
<td>26 243</td>
<td>29 552</td>
<td>120 634</td>
<td>111 861</td>
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</table>
Sample population and characteristics of sampled Danish seine vessels (mean per vessel), by financial year

<table>
<thead>
<tr>
<th>Financial Year</th>
<th>Danish Seine Sample Number</th>
<th>Danish Seine Population Number</th>
<th>Mean Days at Sea</th>
<th>Mean Vessel Length (m)</th>
<th>Mean Tiger Flathead Catch (kg)</th>
<th>Mean Whiting Catch (kg)</th>
<th>Mean Catch of Other Species (kg)</th>
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<tr>
<td>1999–00</td>
<td>10</td>
<td>23</td>
<td>120</td>
<td>16.7</td>
<td>92,931</td>
<td>24,031</td>
<td>10,490</td>
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<td>2000–01</td>
<td>4</td>
<td>21</td>
<td>135</td>
<td>16.2</td>
<td>46,899</td>
<td>41,159</td>
<td>8,858</td>
</tr>
<tr>
<td>2001–02</td>
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<td>19</td>
<td>113</td>
<td>16.3</td>
<td>46,682</td>
<td>27,430</td>
<td>8,520</td>
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<tr>
<td>2002–03</td>
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<td>126</td>
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<td>19,771</td>
<td>8,651</td>
</tr>
<tr>
<td>2003–04</td>
<td>6</td>
<td>19</td>
<td>121</td>
<td>16.7</td>
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<td>29,021</td>
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Definition of netputs, fixed inputs and the reference firm

To undertake the decomposition, fuel and labour were defined as the key negative netputs (inputs). Fuel expenditure data were taken from ABARES survey data and combined with ABARES time series data on the average offroad diesel price in Australia which was adjusted to an onroad price. Fuel quantity was then derived by dividing each vessel’s fuel cost by the relevant diesel price.

Labour quantity was calculated based on the product of the average crew per vessel (collected in ABARES surveys) and an indicator of labour time in each of the sectors. Previous index number profit decompositions for the Commonwealth Trawl Sector by Grafton and Kompas (2007) and Fox et al. (2006) have used trawl hour data (that is, time spent pulling a trawl net through the water) to indicate labour time. However, the current study uses estimates of fishing days. Such an indicator more accurately reflects total time that crew spend working on the vessel and the lost opportunities for employment elsewhere. It is also a more relevant measure to the Danish seine sector which doesn’t use the trawl method. Annual wage rates based on the National Pastoral Award Rates for agricultural labour were used for the price of labour in each year.

Previous decompositions of the Commonwealth Trawl Sector have assumed a single positive netput (output) due to a lack of vessel level price data for individual species. This has limited the analysis by not revealing which species are most important in improving a vessel’s profitability. The current study uses the same approach used by Vieira (2011) to extend the analysis to multiple species (outputs) by using ABARES average unit price data available for key fishery species, given that species-level revenue data are not available for vessels in the ABARES survey data set. This use of average price data differs to the multi-species analysis of Dupont et al. (2005) who take a more direct approach given the availability of species level revenue and catch data by vessel which allows a direct estimation of average prices received for species per vessel.

The multi-species analysis required a calculation using ‘major species’ and ‘non-major species’. Those species that make up the major proportion of revenue for the sample data set were identified as ‘major species’. Thirty-two major species were selected and prices for these species from ABARES average price data were matched to each vessel’s catch of these species. For ‘non-major species’, an aggregate price was derived and matched with each vessel’s sum of catch of these species. Using this combined data set, a proxy fishing revenue was calculated that showed a vessel’s revenue assuming it received the average prices contained in the ABARES price data set and given its species level catch. A revenue ratio was then taken of each vessel’s proxy revenue to its actual revenue reported in the ABARES survey data. Each vessel’s ‘major species’ price and the aggregate ‘non-major species’ price were then adjusted in proportion to its revenue ratio. If a vessel’s price adjustment was deemed too large, vessels were removed from the sample data set.

Key species to be included in the decomposition as netputs were identified according to their contribution to revenue. For the trawl vessels in the Commonwealth Trawl Sector, these species were blue grenadier, tiger flathead, pink ling and silver warehou. An ‘other species’ netput price and quantity was then derived for each vessel for all remaining species. Given that
the analysis presented in the current paper is extended to look at some other key issues, the multi-output results for Danish seine vessels are not presented here. For preliminary results for these vessels the reader is referred to Vieira (2011).

To maintain consistency with previous decompositions, the results also include a treatment of output in the single-output sense. Single output results for the entire Commonwealth Trawl Sector are presented first, followed by multiple output results for only trawl vessels. Derivation of the output price in the single output case simply involves dividing each vessel’s survey-based revenue by its total catch.

As done in previous decompositions of the Commonwealth Trawl Sector, the measure of fixed input quantity used is vessel length.

With the above definition of netputs, the profit decomposition can be rewritten for trawl vessels as

$$\theta_{CTS}^{a,b} = P_{BG}^{a,b} \cdot P_{TF}^{a,b} \cdot P_{PL}^{a,b} \cdot P_{SW}^{a,b} \cdot P_{Oh}^{a,b} \cdot P_{F}^{a,b} \cdot P_{L}^{a,b} \cdot R^{a,b} \cdot K^{a,b} \frac{S_a}{S_b}$$  \hspace{1cm} (17)

where $P_{BG}^{a,b}$ is the price of blue grenadier, $P_{TF}^{a,b}$ is the price of tiger flathead, $P_{PL}^{a,b}$ is the price of pink ling, $P_{SW}^{a,b}$ is the price of silver warehou and $P_{Oh}^{a,b}$ is the price of all other species and all other variables are as defined in equation 15.

### Stock biomass calculation

The aggregated stock biomass was calculated following equation 16 using the following species caught in the Commonwealth Trawl Sector: orange roughy, blue grenadier, tiger flathead, blue warehou, silver warehou, school whiting, jackass morwong, pink ling, and gemfish. These species generally accounted for around 80 per cent of the sector’s total catch and value. A separate trawl method stock abundance was calculated by combining trawl method catches of all of the above species with their stock abundances. The stock biomass estimates for these individual species were calculated by CSIRO and sourced from Day (pers. comm. 2010).
5 Results

The decomposition results are first presented as a table that lists the geometric mean of each index across all vessels in a given financial year. This table is then summarised in graphical form to reveal the key trends in mean index values over time. The mean value of each index provides information on how the characteristics of the average vessel in a year affected profitability relative to the performance of the reference vessel. Index values are also presented in graphical form at the vessel level for key components of the decomposition. This provides greater clarity about the distribution of results given that in many cases the mean values presented apply to small sample populations.

When comparing index values, if an index takes a value greater (less) than one, it implies that that index expands (contracts) the profit ratio. For netput indexes more specifically:

- an index < 1 indicates that the positive contribution of that netput’s price to profit is less than what occurs in the reference firm; and,
- an index > 1 indicates that the positive contribution of the output price to profit is greater than what occurs in the reference firm.

In the case of an output, for example, an index greater than one would suggest that prices received for that output were higher (and therefore, more favorable) than what the reference firm was paid. In the case of an input, for example, an index greater than one would suggest that prices paid for that input were less (and therefore, more favourable) than what occurred for the reference firm.

However, it should be noted that the degree to which a netput price index differs from a value of one reflects not only a firm’s relative price for that netput (relative to the reference firm) but the share of that netput in the firm’s variable profit. That is, an output price index that is less than one (indicating a lower price) will be smaller the greater that output’s share in that firm’s total output (or variable profit). Likewise, if an input price is greater than the reference firm’s, its input price index will be further below one the greater its share in the total costs of the firm (or the larger the negative contribution it makes to variable profit). This interpretation is consistent with the concept that an output or input’s relative importance to a firm’s profitability depends not only on its relative price but its relative quantity. When a netput price index is equal to one, it indicates that the contribution of that netput to profit was similar to that of the reference firm.

Results for the Commonwealth Trawl Sector

The average vessel in the most profitable year (after stock size adjustment) was selected as the reference vessel, that year being 2008–09. The mean index decomposition of all firms in a given year in the sector is displayed in table 3. For this initial part of the analysis, a single output is assumed. In all years, the input price indexes for labour ($P_L$) and fuel ($P_F$) are close to one, while the output price indexes ($P_O$) vary substantially over the period between 0.48 and 0.92. This reflects less variation in input prices, particularly for labour, and more importantly, the larger contribution of outputs to variable profit relative to inputs.
Figure 2 shows more clearly the change in relative profitability over the period of analysis and the relative importance of the different drivers of profitability. Stock adjusted profit ($\theta_s$) for the average vessel moves closer to that of the reference firm between 2005–06 and 2008–09. This is consistent with ABARES survey-based estimates of net economic returns to the sector (Perks and Vieira 2010). Once again the two input indexes are shown to be close to one for the full time series although the fuel price index does move from being greater than one to less than one post 2004–05. This suggests that relative to the fuel prices experienced by the reference firm in 2008–09, lower fuel prices were more favorable and made a positive contribution to vessel profitability prior to 2005–06.

The two key factors behind the lower profitability of firms relative to the reference firm are the price of output ($P_O$) and the stock adjusted productivity index ($R_s$)—the two indexes that on average are the furthest from 1 and also show the greatest variability. Being the furthest from 1 in the years prior to 2008–09 (the year which forms the basis of the reference firm) suggests that these two factors were the main reason why the reference firm’s profits were higher. Accordingly, movements in these two indexes are the primary driver of changes in the profit index over the full time series.

### Table 3: Index number profit decomposition results for the Commonwealth Trawl Sector average by year

<table>
<thead>
<tr>
<th>financial year</th>
<th>$\theta$</th>
<th>$\theta_s$</th>
<th>$P$</th>
<th>$P_O$</th>
<th>$P_L$</th>
<th>$P_F$</th>
<th>$K$</th>
<th>$R$</th>
<th>$S$</th>
<th>$R_s$</th>
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<td>1998–99</td>
<td>30</td>
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<td>0.51</td>
<td>0.65</td>
<td>0.61</td>
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<td>0.96</td>
<td>0.95</td>
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<tr>
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</tr>
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<td>0.75</td>
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<td>1.24</td>
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<td>2002–03</td>
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<tr>
<td>2005–06</td>
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<td>0.34</td>
<td>0.6</td>
<td>0.62</td>
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<td>0.78</td>
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<tr>
<td>2007–08</td>
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<td>0.67</td>
<td>0.67</td>
<td>0.76</td>
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<td>2008–09</td>
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<td>0.79</td>
<td>0.92</td>
<td>0.92</td>
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**Note**: The geometric mean is used to average over the indexes. For any vessel, the profit decomposition ‘adds up’ across each index (equation (15) holds). In this table, this property will not hold as an average of the vessel indexes is shown. The reference vessel is the average firm in 2008–09. $\theta$ is the profit index, $\theta_s$ is the stock adjusted profit index, $P$ is the aggregated price index, $P_O$ is the price of output index, $P_L$ is the price of labour index, $P_F$ is the price of fuel index, $K$ is the capital index, $R$ is the productivity index, $S$ is the stock index and $R_s$ is the stock adjusted productivity index.

**Figure 2**: Key indexes for the Commonwealth Trawl Sector, average for all vessels by financial year.

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**Note**: $\theta_s$ is the stock adjusted profit index, $P_O$ is the price of output index, $P_L$ is the price of labour index, $P_F$ is the price of fuel index and $R_s$ is the stock adjusted productivity index.
The sharp increase in the stock adjusted profit index since 2004–05 is driven mainly by an increase in the output price index. Between 2004–05 and 2008–09, the stock adjusted profit index more than doubled from a value of 0.30 to 0.79. At the same time the output price index increased from a value of 0.49 to 0.92, an increase of 89 per cent. As all data are presented in real terms, the observed increase is driven by real increases in the average price received for catch. Given that output here represents an aggregation of multiple outputs, such an increase can be driven by increases in the prices received by operators or a change in the output mix produced by operators (from more lower valued outputs to more higher valued outputs).

The stock adjusted productivity index is highly variable over the full time series but is at its highest value in the two years following 2006–07. Between 2006–07 and 2007–08, the mean productivity index increased by 54 percent from 0.61 in 2006–07 to 0.95 in 2007–08, the largest percentage increase over the full time series. It then decreased slightly in 2008–09 to 0.88, a value that is still high in historical terms. The large increase in stock adjusted productivity that occurred between 2006–07 and 2007–08 drove the increase in profitability that occurred in that year rather than output prices, the index for which remained relatively stable, declining slightly from 0.81 in 2006–07 to 0.80 in 2007–08. These changes correspond with significant regulatory and structural change in the sector partly associated with previous reductions in the total allowable catches for key species (see Vieira et al. 2010 for further details) but more importantly, the government-funded vessel buyback, which concluded in 2006–07. Therefore, these results suggest that the buyback had a substantial positive impact on the profitability of the sector via an improvement in vessel-level productivity. These productivity increases are likely to be attributable to the positive effects of reduced crowding that occurs with a lower number of vessels operating in the sector (Smith 1969; Pascoe et al. 2001) and the likely removal of the least efficient vessels given the design of the buyback process (Vieira et al. 2010).

Figures 3 to 5 show the sample distribution of index values and the median index value in each year for stock adjusted profit, stock adjusted productivity and output price, respectively. These figures confirm the trends outlined above for the mean annual index values. However, they also reveal that in terms of stock adjusted profit and productivity, there are typically one or two vessels that exhibit exceptionally high index values, particularly since 2002–03. These observations raise the mean values although the median values confirm that the same trends are still occurring. It should also be noted that these outlying data points relate to two vessels and suggest that there are a small number of ‘leading performers’ in the fishery.

The decomposition of the output price index into its key components can provide greater insight as to which species’ prices have made an increasing contribution to profitability over time. However, given the different catch compositions associated with the two methods, separate species-level decompositions are required for each method in the sector. In what follows, a multi-output decomposition is presented only for trawl vessels. Given the low sample number for Danish seiners, multi-output results for this method are not presented here. For preliminary multi-output results for this method the reader is referred to Vieira (2011).
An index number decomposition of profit change in a fishery
ABARES conference paper 11.15

3 Stock adjusted profit indexes and median index values for vessels in the Commonwealth Trawl Sector, by financial year (2009 is equivalent to 2008–09)

4 Stock adjusted productivity indexes and median index values for vessels in the Commonwealth Trawl Sector, by financial year (2009 is equivalent to 2008–09)

5 Output price indexes and median index values for vessels in the Commonwealth Trawl Sector, by financial year (2009 is equivalent to 2008–09)
Multi-output results for trawl vessels

For trawl vessels, the reference firm was assumed to be the average trawl vessel in the most profitable year, which, for this sector, was 2008–09. A separate trawl stock abundance was calculated and used for the stock index. The mean annual trawl decomposition results are displayed in table 4 and include indexes for the five key outputs: tiger flathead ($P_{TF}$), blue grenadier ($P_{BG}$), pink ling ($P_{PL}$), silver warehou ($P_{SW}$) and other species ($P_{OTH}$). The results reveal that in terms of the contribution from output prices, prices received for tiger flathead and the other species group were the main contributing factor to the higher profitability of the 2008–09 reference year given that mean index values for both these species were typically the furthest from a value of 1.

Figure 6 shows that changes in the stock adjusted profit index and productivity index for trawl vessels approximates that of the entire Commonwealth Trawl Sector sample shown in figure 2. This reflects the larger number of trawl vessels relative to Danish seiners in the sector. Once again, a large increase in the mean stock adjusted productivity index occurred for trawl vessels after the buyback, with the index increasing from 0.56 in 2006–07 to 0.93 in 2007–08.

The stock adjusted profit index for the average trawl vessel was at its lowest value of 0.22 in 2004–05. That is, 2004–05 was when profitability relative to the reference year was at its lowest. In the same year, the price indexes for tiger flathead and other species were relatively low at 0.71 and 0.75, respectively. This compares with values of 0.92 and 0.93 that occurred for each species group in 2008–09, respectively, when the profit index was also at its peak. This represents a 29 per cent increase for the tiger flathead price index and a 23 per cent increase for the other species price index. The price indexes for pink ling and blue grenadier also increased over the same period. However, the prices received for these two species, on average, made relatively less important contributions to relative profitability, as indicated by these indexes having values that are close to one. The silver warehou price index remained close to one over the full time series and made a relatively minor contribution to the fleet’s relative profitability over time.

Further observations on productivity

Stocks and productivity

Figure 7 provides more of an insight into how stocks influence productivity over time for the entire Commonwealth Trawl Sector fleet. Where the productivity index ($R$) is greater than the stock adjusted productivity index ($RS$), stocks are making a positive contribution to the profit index relative to the contribution that occurred in the reference year. The greater the difference between the two index values, the larger the contribution of stocks to vessel productivity and profitability.

Prior to 2002–03, the aggregated stock biomass for key target species was higher than levels that prevailed in 2008–09, the reference year. The higher aggregated stock levels in these earlier years meant that the average productivity of vessels was higher. The major driver of these higher aggregated stock levels in earlier years was the biomass of blue grenadier, which declined from 1999–2000. Lower stock levels in 2002–03 and 2003–04 had a negative influence on relative productivity. With the exception of 2006–07, the aggregated stock index has remained relatively stable since 2004–05.
4

Index number profit decomposition results for trawl vessels in the Commonwealth Trawl Sector

<table>
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<th>$\theta$</th>
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<th>$P_{BG}$</th>
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<th>$P_{SW}$</th>
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<td>0.93</td>
<td>1</td>
<td>0.97</td>
<td>0.88</td>
</tr>
<tr>
<td>2008–09</td>
<td>7</td>
<td>0.72</td>
<td>0.72</td>
<td>0.84</td>
<td>0.92</td>
<td>1</td>
<td>0.99</td>
<td>1</td>
<td>0.93</td>
<td>1</td>
<td>1</td>
<td>0.97</td>
<td>0.88</td>
<td>1</td>
<td>0.88</td>
</tr>
</tbody>
</table>

Note: The geometric mean is used to average over the indexes. For any one vessel, the profit decomposition 'adds up' across each index (equation (17) holds). In this table, this property will not hold as an average of the vessel indexes is shown. The reference vessel is the average firm in 2008–09. $\theta_S$ is the stock-adjusted profit index, $\theta$ is the profit index, $P$ is the aggregated price index, $P_{TF}$ is the tiger flathead price index, $P_{BG}$ is the blue grenadier price index, $P_{PL}$ is the pink ling price index, $P_{SW}$ is the silver warehou price index, $P_{Oth}$ is the other species price index, $P_L$ is the price of labour index, $P_F$ is the price of fuel index, $K$ is the capital index, $R$ is the productivity index, $S$ is the stock index and $R_S$ is the stock-adjusted productivity index.
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It should be noted that the large increase in stock adjusted productivity that occurred between 2006–07 and 2007–08, attributed to the buyback, is also partially attributable to the impact of the fall in the stock index in that year. That is, the productivity increase that occurred in the first year after the buyback occurred is actually larger than what the unadjusted productivity index \( R \) would suggest given that it occurred at the same time as a slight decline in the aggregated stock abundance index. This further strengthens the evidence that the buyback boosted productivity and benefited profitability in 2007–08, a year in which constant output prices and a slight decline in the aggregated stock index would have prevented an increase in profit occurring otherwise.

### Scale and productivity

Analysis of vessel-level data on the relationship of vessel-level stock adjusted productivity to other characteristics of vessels can provide some insights into some of the key influencing factors that explain a vessel’s relative productivity performance. One key characteristic observed by previous authors that have applied this method (Fox et al. 2006) is vessel length. Figure 8 shows that for the Commonwealth Trawl Sector, the relationship between stock adjusted productivity and vessel scale in terms of vessel length is not very strong. However, it does appear that smaller vessels tend to have lower productivity while larger vessels tend to be able to achieve higher levels of productivity. This is consistent with larger vessels being able to stay out at sea longer and store a larger amount of catch on a given fishing trip.

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**6** Stock adjusted profit index, "productivity index" and key output indexes for trawl vessels in the Commonwealth Trawl Sector, average per vessel by financial year

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**7** Comparison of mean stock adjusted and non-adjusted productivity indexes with reference to the aggregated stock index for the Commonwealth Trawl Sector, average for all vessels by financial year

Note: \( \theta_s \) is the stock adjusted profit index, \( P_n \) is the tiger flathead price index, \( P_{nt} \) is the blue grenadier price index, \( P_{psw} \) is the silver warehou price index, \( P_{ott} \) is the other species price index and \( R_s \) is the stock adjusted productivity index.
Figure 9 presents a scatterplot of the stock adjusted productivity index values for all observations against each vessel’s time spent fishing in a year (days fished). As is shown, there appears to be a far stronger positive relationship between time input in the fishery and a vessel’s productivity. Such a relationship, suggests increasing returns to scale exist in the fishery whereby scale is determined by the amount of time a vessel spends operating in the fishery. However, a more accurate interpretation takes into account the way the decomposition approach measures productivity.

Under the current approach, productivity is calculated by taking a firm’s relative residual output (relative to the reference firm) and dividing it by its relative fixed input endowment as measured by vessel length. The denominator of this productivity calculation does not capture an operator’s relative use of its fixed input endowment in terms of time spent fishing. This is despite the fact that higher use of that fixed input endowment will likely result in higher catch. Given that only labour and fuel are included as variable inputs in the approach, higher catches that result from increased fishing time will translate to a higher level of residual output in the productivity calculation. This means that a firm’s relative use of its fixed input is not captured in the measure of productivity but the higher residual output that results from increased fishing time is captured. Therefore, the productivity index will be positively correlated to how long a vessel operated in the fishery as measured by number of days fished.

It is important to be aware of this issue if the sample that is being analysed is heterogeneous in terms of time spent fishing. In the case of the Commonwealth Trawl Sector, the sector is highly heterogeneous given that the number of days fished ranged from less than 20 days to as high as 300 days. This means that comparisons of productivity between vessels will not necessarily
represent a vessel’s relative ability to convert inputs into output. Instead, it is more likely to represent a vessel’s relative time spent fishing. This issue potentially presents a limitation in previous applications of the index number profit decomposition approach to fisheries when it has been used to measure productivity.

It should be noted that the results presented here are based primarily on mean index values. As a result, if a similar distribution in fishing times occurs across sampled vessels through time, the trends in productivity identified here should still be a reliable indicator of productivity changes in the sector. However, this issue should be further explored.
6 Discussion and conclusions

Comments on the approach

The index number profit decomposition approach is a relatively new method that offers a way of assessing a fishery’s economic performance. As has been demonstrated, its usefulness lies in its ability to represent the relative importance of key drivers to changes in profitability over time. However, there are some issues associated with the way the method has been used here that need to be discussed.

A key issue that has come out of the current analysis is the measure of capital used to calculate the fixed input index and, further, its impact on the productivity index. The current study follows previous studies (Fox et al. 2003; Dupont et al. 2005; Fox et al. 2006; Grafton and Kompas 2007; Kompas et al. 2009) in assuming a single fixed input, the quantity of which is measured by vessel length. While the assumption of a single capital input simplifies the decomposition to some degree, the link between vessel length and its impact on a vessel’s harvest production is disputable. ABARES survey data include estimates of the market value of the vessel and the year of manufacture and replacement cost of capital items on the vessel. Application of a capital price index to these data could be a more relevant approach to incorporating the fixed input into the decomposition and, more importantly, the productivity index. However, the author acknowledges issues with measuring capital that have been discussed by previous authors (such as Griliches 1963; Jorgensen 1996; Diewert and Lawrence 2000).

Potentially more important is the omission of a measure of each firm’s relative use of its capital endowment. This ‘relative use’ has been discussed in terms of the number of days a vessel operated in a given year. As has been shown, vessel productivity shows a strong positive correlation with days fished in a given year. This is because the more time a vessel spends operating in a fishery, the greater level of catch a vessel is likely to achieve. The productivity measure used here captures such an increase in harvest but does not fully capture the increase in use of the fixed input. As a result, if there are two vessels of the same size and one operated for a longer time and has a higher catch as a result, it will have a higher relative productivity. This is misleading, as the vessel that operated for fewer days may have achieved a higher daily catch rate, for example. In other industries (such as manufacturing or mining) it may be reasonable to assume that each firm uses its fixed inputs for a similar amount of time. Therefore, measurement of productivity using such an approach is likely to provide more meaningful firm-level productivity results that can be compared across firms. In the case of a fishery in which individual firms typically have very different operating times within a given year, such intra-firm comparisons might be problematic.

This issue is a cause for concern for using this approach for fisheries. Accordingly, this aspect of the approach should be further investigated. An approach that takes into account relative fixed input use across firms may address this issue.

As pointed out in the results, the analysis of productivity presented here has primarily focused on average firm performance over time. So while the approach to measuring productivity may
not allow consistent comparisons between firms, the changes in average productivity over time are still likely to be a good indicator of key changes that have actually occurred in the sector over time. For that reason, conclusions with respect to the impact of the buyback on productivity should still hold.

The choice of reference firm is a fundamental component of the analysis that also has a major bearing on the usability of the results. In a previous application of the method to the Commonwealth Trawl Sector by Vieira (2011), the most profitable firm was assumed as the reference firm. However, this was problematic for the multi-species analysis of the trawl method results, as the reference firm specialised in tiger flathead. Therefore, it was posited that the analysis may not have represented the key drivers of profitability for a vessel that didn't specialise in tiger flathead. That is, the choice of reference vessel automatically defined and/or restricted what the decomposition could show. This is particularly relevant for a multi-species fishery like the Commonwealth Trawl Sector.

The current analysis used the average vessel in the most profitable year as the reference firm. While it still showed tiger flathead prices as a key driver of relative profitability, its importance relative to other species declined. For example, in the trawl sector in 2005–06, the mean index for tiger flathead prices presented here had a value of 0.84, while the analysis presented in Vieira (2011) had a lower mean index value for tiger flathead of 0.73. Despite this, both sets of results had a mean index value for blue grenadier in 2005–06 of 0.92. Therefore, the current results indicate that the contribution of blue grenadier prices to profitability relative to flathead in 2005–06 is greater in the current results compared to the results presented in Vieira (2011). Observations such as these demonstrate the importance of selecting an appropriate reference firm. This is important when looking at multiple outputs as the reference firm’s relative output mix will determine how accurately each output’s contribution to profitability is quantified in average terms. More broadly, these observations also demonstrate that comparisons of results between fisheries for which unique reference firms have been assumed is not entirely appropriate.

Fox et al. (2006) discuss the issues with assuming a single price for a multi-output sector, which has been the most common approach when applying the index number profit decomposition method to fisheries. The approach taken here has provided both a single-output decomposition and a multi-output decomposition using average price data for the relevant sector and making adjustments given each vessel’s catch (by key species group) and total reported revenue. This approach captures both the relative price differences between firms (also shown in the single-output analysis) but also captures the price differences between different outputs (species) over time. The relevance and theoretical validity of using average price data to decompose output price changes into key output categories needs further investigation. However, the values of all other indexes as well as the aggregated netput price index remain unchanged in the multi-output context relative to the single-output case. This demonstrates that the actual results don’t change in the multi-output context, just the level of detail to which the results are reported.

There may also be a question over the stock biomass estimates used in the analysis and their relevance to the performance of vessels in the fishery. The stock assessment data available for Commonwealth Trawl Sector species was only in the form of total biomass estimates (which
was used) and spawning biomass. Ideally, for the purpose of determining the contribution of stock biomass to a vessel’s profitability, the exploitable biomass would be most relevant. That is, the biomass of fish that fall within the population or size parameters caught by the sector. The relevance of the biomass estimates to the population that is actually targeted and caught is likely to vary across species. For example, eastern school whiting recruit into the Commonwealth Trawl Sector at an age of between two and three years, while orange roughy recruits into the fishery at an age of between 24 and 42 years (Stobutzki et al. 2010b). This demonstrates that the relevance of biomass estimates used in the analysis will depend on the age at which a species recruits into the fishery and the age cohort structure of the biomass estimate that is used. Of course, in the absence of any other data about stocks, the data that were available and used provide more information about the effects of biomass on profitability than would otherwise be possible.

Concluding remarks

Use of the index number profit decomposition method has provided some important insights into the key driving factors behind profit changes for the Commonwealth Trawl Sector. The recent buyback, for example, appears to be a major driver behind increased profits since 2006–07. This has been realised through an improvement in vessel level productivity, with fewer, more efficient vessels remaining after the buyback. These vessels continue to harvest a similar sized resource and, therefore, are able to achieve higher output from the inputs they invest in the fishery. This improvement in productivity in the post-buyback period is consistent with productivity improvements for this sector observed by Vieira et al. (2010) and Perks et al. (2011). The results were also able to demonstrate how average vessel productivity (and profitability as a result) were lower in a period when the management instrument (output controls in the form of individual transferable quotas) was not being used in conjunction with appropriate management settings. That is, total allowable catches may have been set too high and were non-binding.

The two key factors behind the lower profits for all firms relative to the 2008–09 reference year were shown to be the price of output \((P_o)\) and the stock adjusted productivity index \((R_s)\). For trawl vessels, it was shown that tiger flathead and the ‘other species’ output category were the key contributors (other than productivity) to changes in profitability. Observations with regard to the MEY objective can also be made for recent years. Substantial profit improvements have occurred since 2005–06. The key drivers of these improvements have been output price increases and increases in vessel-level productivity (particularly since the buyback). At the same time, the stock index suggests that stock levels are more favourable than what they were in low profit years (2002–03 to 2004–05). This has occurred with a large reduction in the amount of capital (vessels) invested in the fishery through the exit of vessels prior to the buyback (largely in response to low returns) and then through the buyback. Although price increases have been a major factor behind the improvement in profitability, the remaining evidence, taken together, would suggest that the fishery since 2005–06 is moving toward MEY.

A potential issue around vessel productivity measurement has been identified that is associated with the impact of relative capital use and how it determines productivity. This issue needs to be better understood and further investigated. Despite this, the index number
profit decomposition approach is well suited to providing information about the historical performance of vessels in a fishery. The approach is not able to fulfill the role of a bioeconomic model whereby a given harvest level can be determined that is most likely to result in the fishery achieving MEY. However, it can provide decision-makers with a greater amount of information about whether a fishery’s current operating environment is conducive to relatively high profits. When used together with other indicators of a fishery’s operating environment (such as current management settings and effort levels), the approach provides a greater amount of information about the impact of previous decisions and how current decisions will affect the future profitability of managed fisheries. Such information can demonstrate to fishery managers, policymakers and industry what management actions are likely to have a positive impact on economic performance and therefore, should be pursued.
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An index number decomposition of profit change in a fishery
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