Using Productivity Analysis in Fisheries Management

A Guide for Managers and Policy Makers

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Introduction

The development of indicators to measure and monitor the performance of fisheries against economic objectives continues to challenge fisheries managers. In many fisheries, the high cost of data collection relative to the value of the fishery limits the quantity and types of data that might be available to support fisheries management. Generally lowest in priority in the list of data to be collected is information on the economic performance of the fishery, as monitoring resource sustainability takes precedence.

However, basic catch and effort information may contain implicit information about the economic performance of fishing vessels and businesses. From these data, measures of productivity can be derived and, in some circumstances, may be suitable as proxy measures of the distribution of economic performance and changes in economic conditions.

The purpose in this guide is to provide an overview of productivity analysis and the role it can play in supporting fisheries management. In particular, the guide will illustrate how productivity analysis can provide information about relevant and cost-effective economic performance indicators for fisheries.

The measurement of productivity is important for understanding the economic condition of vessels, businesses, industries and regions, and how changes in productivity relate to changes in economic performance, including in response to external factors. Different productivity indicators can be derived, with the choice typically being based on the availability of data and characteristics of the fishery.

This guide is aimed at managers, policy makers, and resource assessment and management advisory groups, who may use productivity measures in assessing fisheries and management performance and monitoring harvest strategy objectives. It is not intended to be a guide as to how to derive these measures, but how to interpret the information once derived.

A detailed Final Report, including additional methodological description and a compendium of examples, is available at www.frdc.com.au/project/2019-026

What is productivity analysis?

The ability of fishers to catch fish can vary considerably across a fleet. Some of this variation in catch can be explained by differences in the vessel characteristics used by the fishers, such as engine size, boat size and the type of fishing technology employed.

In other cases, differences in the fishers themselves can affect their relative performance. Less tangible factors such as skipper skills, which in turn may be influenced by the level of experience or other individual characteristics, also matter. Understanding the relative contribution of different vessel and skipper attributes to catch is important when assessing potential outcomes of different management options that may affect these factors. These differences can be assessed through the application of economic productivity analysis.

At its simplest, productivity can be measured by the ratio of outputs produced to inputs used. Productivity analysis combines an assessment of both physical productivity of vessels (technical change) and efficiency of operation. Physical productivity examines how much physical inputs (e.g., engine power, boat size, days fished, etc.) are used to produce a given catch. Efficiency, in contrast, examines how well these inputs are used in the fishing operation. Efficiency will be strongly influenced by less tangible aspects of fisher's performance, such as skipper skill. When vessels are economically efficient, they achieve the best possible output level and mix with the least cost combination of inputs. Economic efficiency in this case relates to the combination of technical efficiency – where vessels are producing the maximum possible level of outputs given their level of inputs; and allocative efficiency – where vessels are producing the profit maximizing mix of outputs using the profit maximizing combination of inputs. Note that we refer to vessels in this guide but evaluating fishing businesses, with multiple vessels, may be appropriate in some applications.

Central to the concepts of productivity and efficiency is the existence of a production possibility frontier. This defines the maximum possible output(s) that a vessel may be expected to achieve given its level of inputs, or the maximum technically feasible productivity of the vessel for varying sets of input mix. If the vessel is not producing the maximum technically feasible catch mix with its chosen inputs, it is, by definition, operating inefficiently and there is room for improvement. Even if a vessel is technically efficient (operating on the frontier), the vessel may still not be using the least cost combination of inputs, and therefore not operating in an economically efficient way, which will lower profitability of the vessel compared to its potential.

In practice, the term 'productivity analysis' is often used to include a wide range of approaches – encompassing both efficiency and productivity analysis as well as a range of other approaches that aim to link outputs to the level of inputs (physical quantities, values and intangible) employed in its production.

While fisheries management (e.g., through input or output controls) may impact efficiency, productivity measures may also provide a measure of the performance of management in achieving economic objectives. The microeconomic foundations of productivity analysis are identical to (and usually based on) those underlying models of profit maximization. That is, a vessel needs to be operating on its technically feasible frontier before it can profit maximise by using the least cost combination of inputs. Given this, there is the potential for productivity analysis to provide useful information on the economic performance of fisheries even when detailed financial information (i.e., costs and earnings) are unavailable.

What is productivity analysis used for?

Measurement of productivity change provides insight into how firms, industries or sectors of the economy are performing through time, or in response to a specific policy change.

The use of productivity analysis in fisheries has been well established in the literature, including multiple Australian fishery case studies. For example, Pascoe et al. (2010) applied productivity analysis in the Northern Prawn Fishery to determine the ability of fishers to target individual species when Individual Transferable Quotas (ITQs) were being considered as a management option. Similarly, Pascoe et al. (2018) applied productivity analysis to refine parameters for use in the Northern Prawn Fishery banana prawn trigger.

Other Australian studies have been concerned with assessing the impacts of management change on the efficiency of the vessels (e.g. Kompas et al. 2004, Kompas and Che 2005, Fox et al. 2006, Stephan and Vieira 2013). The Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) routinely undertakes productivity analysis as part of their program to monitor economic performance of four major Commonwealth fisheries against their economic objectives. In the USA, National Oceanic and Atmospheric Administration (NOAA) periodically measures productivity change across all US catch share fisheries (Thunberg et al. 2015). A comprehensive review of the literature, including a compendium of applications to date in Australian fisheries, is available in McWhinnie et al. (2022).

Given appropriate data, the average level of efficiency, as well as the factors affecting vessel inefficiency, can be estimated. For example, changes in the level of efficiency over time can be used as a proxy for changes in economic performance (as detailed in the below sections). Going further to disentangle what drives this change – management changes; individual fisher behaviour or characteristics; or environmental or market factors – enables managers to better design future management options for the fishery.

There has been an evolution in focus in the fisheries economics literature from early attention on the direct measurement of productivity towards asking questions regarding why and how they are at such a level or changes are occurring. Several key questions were identified to be of primary importance in fisheries productivity analysis:

- How is catch, revenue, cost or profit changing over time?
- Is this because the quantity, the quality, or the values of inputs or outputs has changed? Or is this because biomass or the environment has changed?
- How does management affect outcomes? How will changing management affect fleet efficiency?
- What is the capacity and capacity utilization of the fleet? From this, what is the level of excess capacity in the fishery? Is it increasing or decreasing?
- How have inputs, outputs (catch) or fisher behavior changed when the management or biological environment changed?
- How might changes in the fleet structure affect catch?

Understanding the level, distribution and drivers of efficiency in a fishery is fundamental to achieving maximum economic yield as a fishery management objective. Further, understanding the role that different management measures may play in reducing or enhancing efficiency is fundamental to designing management systems that ensure environmental, economic, and in some instances social objectives are realised.

What are the main measures?

Productivity analysis is most simply defined as the derivation of metrics relating the amount of outputs to the amount of inputs used in their production.

There are several different productivity measures that are commonly used in fisheries analysis. These range from simple metrics such as catch per unit effort, commonly applied also in stock assessments, to more complex multi-output and multi-input measures such as technical efficiency and capacity utilization (defined below). The inclusion of economic information into the analysis provides additional information such as whether fishing firms are operating in ways consistent with maximizing profits, given fish prices and input costs.

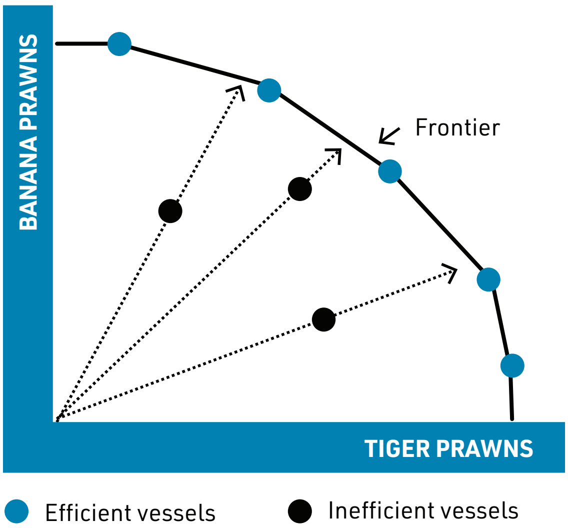
The aim of this section is to outline the key productivity measures and how they may be of relevance to fisheries management. A summary of approaches to estimate these measures is provided in the Extra Information at the end of this guide, with more detailed descriptions provided in McWhinnie et al. (2022).

TECHNICAL EFFICIENCY

Efficiency analysis is a part of productivity analysis. Technical efficiency is a relative measure of how far a given vessel's output per unit of input is from the production frontier. The production frontier is defined by the output per unit of input of the most productive (set of) vessel(s) in the fishery. Different vessels may have different fishing strategies, which needs to be taken into account. Vessels on the frontier have a technical efficiency score of 1, while those below the frontier have a score less than 1.

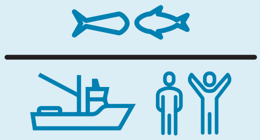
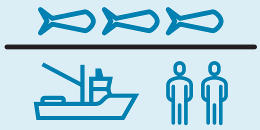
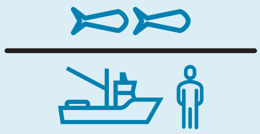
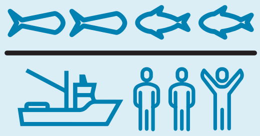
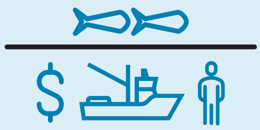
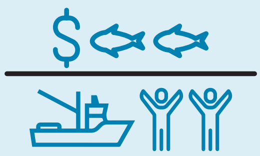
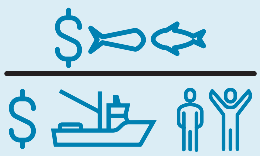
Figure 1 provides a hypothetical example of a two species prawn fishery. Some vessels in this example focus their effort more on banana prawns, while others focus on tiger prawn catch. Given the mixed nature of most fisheries, all vessels catch a mix of both species. The set of efficient vessels define the frontier. Inefficient vessels have an output mix below the frontier, even after taking into account different levels of inputs (e.g., boat size, engine power or days fished). The level of inefficiency is measured by the distance to the frontier, with some inefficient vessels being close to the frontier (with less room for improvement) and others being further from the frontier (with more room for improvement). The example here is 'output-oriented', depicting the amount of outputs that could be produced from the given inputs. An alternative depiction is 'input-oriented', showing the frontier as the least inputs that could be used to produce a certain amount of outputs.

Figure 1. Efficiency in a multi-output fishery



In Australia, technical efficiency has been estimated for the Moreton Bay Prawn Fishery (Pascoe et al. 2017), NSW Ocean Prawn Fishery (Greenville et al. 2006), Sydney Rock Oyster (aquaculture) (Schrobback et al. 2015), Tasmanian Rock Lobster (Rust et al. 2017) and a number of Commonwealth managed fisheries, including the Northern Prawn fishery (Kompas et al. 2004, Pascoe et al. 2012, Pascoe et al. 2018), Torres Strait Rock Lobster fishery (Pascoe et al. 2013), Southern and Eastern Scalefish and Shark Fishery (SESSF) (Green 2016), and Eastern Tuna and Billfish Fishery (ETBF) (New 2012).

Table 1. Pictogram of efficiency measures

Productivity		Measure of how much output is produced from inputs used
Output-oriented technical efficiency		Greater quantity of output for the same quantity of inputs
Input-oriented technical efficiency		Same quantity of output using smaller quantity of inputs
Capacity utilisation		Greater output using more variable inputs but same fixed inputs
Cost efficiency		Same quantity of output using lower cost inputs
Revenue efficiency		Higher value of output using same quantity of inputs
Profit efficiency		Highest value output and input combination

VALUE-BASED MEASURES OF EFFICIENCY

The addition of value information allows the estimation of revenue, cost, profit and allocative efficiency. Like technical efficiency, value-based measures of efficiency are based on observations from the fleet, and the level of efficiency of a vessel is again determined by the distance of the vessel to the frontier.

Revenue efficiency reflects the ability of the fisher to choose an output combination that maximises value rather than volume of catch. **Cost efficiency** reflects the ability of a firm to use different input combinations to minimise costs to produce a certain amount of output. **Profit efficiency** is calculated with a combination of reducing inputs and expanding outputs, such that the ability to maximise profits can be determined. In each case, the quantities of total outputs and inputs may be the same, but equivalent profit efficiency is potentially achieved with low costs combined lower valued outputs, or higher valued outputs and higher costs, or something in between.

Allocative efficiency is determined by the ratio of revenue or cost efficiency to technical efficiency. It reflects the fisher's ability to harvest the best (revenue maximising or cost minimising) combination of outputs (in a multi-species fishery) and inputs. Low allocative efficiency may mean that a vessel is efficient in terms of total catch, but the catch composition or input-use is not optimal given the prevailing set of prices and/or costs.

SCALE EFFICIENCY

Scale efficiency is another measure that can be obtained. This metric compares the vessel 'scale' – a combination of both physical capital (such as boat size and/or engine power) and the resultant volume of outputs – with an 'optimal' level defined as the point where returns to scale is equal to 1. Below this point, output increases more than proportionally to increased input use, and there are benefits in increasing production through increasing input use. Beyond this point, output growth increases less than proportionally to increased input use, and reduced input use is warranted.

Scale efficiency provides an indication as to how the fishery may adjust in the future by providing an indication of the optimal size of a vessel. Over time, it would be expected that vessels, as they are replaced, would move toward the optimal size and output level.

CAPACITY UTILISATION

Capacity utilisation is, like technical efficiency, a relative measure based on observed activity in the fishing fleet. Unlike technical efficiency, which considers the use of all inputs, capacity utilisation considers only the use of fixed inputs (e.g., vessel size, engine size). Capacity utilisation reflects the degree to which a vessel's potential catch given its physical inputs is being realised. Vessels that are fully utilised define the frontier and have a capacity utilisation score of 1. Those that are not fully utilised have a score less than 1.

The existence of capacity underutilisation in a fishery indicates the likely presence of excess fishing capacity. That is, the existing fleet could potentially catch more given its characteristics, or alternatively, the same catch could be taken with a smaller fleet operating at full capacity. Excess capacity is economically wasteful, contributes to overfishing pressure (Gréboval 2002), and has potential spillover implications when vessels operate in multiple fisheries. Changes in capacity utilisation over time can provide information on the effectiveness of management in controlling fishing capacity, taking care to account for multiple-fishery operations (Tingley et al. 2003).

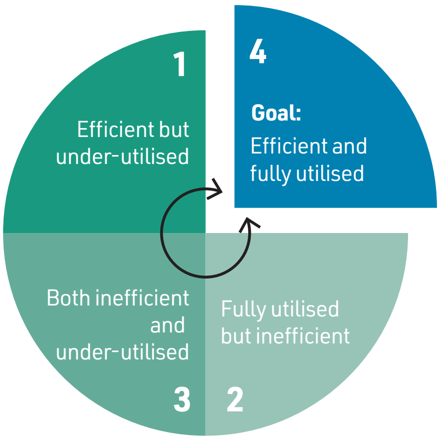
The measurement of capacity and capacity utilisation in fisheries is a key component of the FAO International Plan of Action for the Management of Fishing Capacity (FAO 1999). In Australia, capacity utilisation estimates have been used to examine the likely consequences of moving to an ITQ system in the commercial fleet operating in the Torres Strait (Pascoe et al. 2013) and Tasmanian rock lobster fisheries (Rust et al. 2017), as well as estimated for the Sydney rock oyster industry (Schrobback et al. 2015).

Combining measures

Examining technical efficiency together with capacity utilisation can provide further insight as to how total fishery output may respond to different drivers (Figure 2):

Vessels may be efficient but underutilised. That is, the vessel is not catching its potential as it is using fewer variable inputs (e.g., labour, days fished) than it could, although all inputs that are used are being used efficiently. This reflects excess capacity and latent effort in the fishery. Total catch could increase if economic conditions became more favorable. High fuel costs, for example, may result in vessels fishing less than they could. If fuel prices decreased, they can rapidly increase their fishing effort and hence catch.

Figure 2. Possible analysis outcomes



1 Vessels may be operating at full capacity but are inefficient. Output could increase if factors driving efficiency changed, but is less responsive to changes in economic conditions. Fishers are fishing as much as possible (so operating at full capacity), but differences in technology between vessels, for example, will result in some vessels manifesting as inefficient. Adoption of these technologies will increase their efficiency and hence catch given the same input use. Similarly, differences in skill between fishers will manifest as inefficiency. Training and increased experience can increase fisher skill, resulting in higher catches given the same input use.

2 Vessels may be operating at full capacity but are inefficient. Output could increase if factors driving efficiency changed, but is less responsive to changes in economic conditions. Fishers are fishing as much as possible (so operating at full capacity), but differences in technology between vessels, for example, will result in some vessels manifesting as inefficient. Adoption of these technologies will increase their efficiency and hence catch given the same input use. Similarly, differences in skill between fishers will manifest as inefficiency. Training and increased experience can increase fisher skill, resulting in higher catches given the same input use.

3 Vessels may be both inefficient and underutilised. Output could increase either as a result of changes in the underlying economic conditions or through greater technological adoption or improved skipper skill.

4 The goal of economic efficiency requires vessels to be both efficient and fully utilised. At this point excess capacity is non-existent, and all vessels are equally efficient, resulting in the greatest possible output for a given set of inputs.

Link between management, productivity measures and economic performance

Fisheries management both affects, and is affected by, the level of diversity in productivity in the fishing fleet.

For example, a buyback of vessels will result in a reduction in total fishing effort, but this may be less than proportional to expectations. First, (as is usually the case and has been seen in Australian fisheries (Pascoe et al. 2012) the least efficient vessels are likely to be the first to leave. This results in fewer, but more efficient vessels, and an overall increase in average technical efficiency of the fleet, although it is not always the case (Walden et al. 2012). Further, if excess capacity was present (the most likely reason for a buyback), then the remaining vessels are able to increase their own capacity utilisation through increasing their fishing effort. This likely leads to an increase in economic performance in the short term and greater economic sustainability in the long term.

Other restrictions on fishing activity may reduce the efficiency of individuals, achieving reduced output but at an economic cost to the industry (Table 2).

Table 2. Examples of potential management impacts on efficiency and capacity utilisation

Change	Effect	Productivity measure	Economic performance
Exogenous (non-management) changes			
Demand increase	Revenue per unit of effort ↑	Capacity utilisation ↑	Short-term ↑ Long-term pressure to catch ↓
Fuel price rise	Cost per unit catch ↑	Capacity utilisation ↓	Short-term ↓ Long-term input-substitution ↓
Management related changes			
Stock increase	Catch ↑ Revenue per unit of effort ↑	Technical efficency ↑ Capacity utilisation ↑	Short-term ↑ Long-term ↑
Quota decrease	Total catch ↓	Capacity utilisation ↓	Short-term ↓ Long-term ↑ if stocks rebuild
Gear restriction	Catch ↓ Cost per unit catch ↑	Technical efficency ↓ Capacity utilisation ↓	Short-term ↓ Long-term ↓
Effort restriction	Time a vessel can fish ↓	Capacity utilisation ↓	Short-term ↓ Long-term ↓
Buyback	Least efficient vessels exit Remaining vessels effort ↑	Average technical efficiency ↑ Capacity utilisation ↑	Short-term ↑ Long-term ↑

Note: These are examples only and should not be generalised as outcomes may differ by fishery or time horizon.

Changes in technical efficiency and capacity utilisation can change for other reasons and measuring these changes can provide information as to likely changes in economic performance not directly related to management measures. For example, external (exogenous) causes of fish price increases, other than management of a particular fishery, may result in increased revenue per unit of fishing effort. This encourages fishers to fish more, increasing their capacity utilisation (Table 2). Similarly, changes in stock conditions – whether exogenous or management induced – will affect the measure of technical efficiency (if stocks are not included as an input).

Given this, changes in capacity utilisation and technical efficiency can provide information not only on the likely direction of economic performance change, but also the key drivers (i.e., management induced or exogenous changes). These impacts are relatively short term. For example, in the case of quota reduction impacting capacity utilisation in the short term, over time autonomous adjustment, which allows overall size of fleet to adjust without the need for further actions by managers may result in increased capacity utilization in the longer term.

What data are needed to estimate productivity measures?

Basic productivity measures can be estimated with limited data, making them appropriate for most fisheries.

Estimates of technical efficiency, capacity utilisation and scale efficiency require vessel level information only on catch (the output), effort such as days fished (a variable input) and vessel characteristics such as length or engine power (fixed inputs) (Figure 3).

If input cost and output price information is available, then value-based measures of efficiency can be estimated.

Additional information concerning individual fisher characteristics or management changes can be used to estimate inefficiency models, providing information as to how these factors affect efficiency.

Basic measures of productivity can be calculated from a single period of data. If panel data (time series of boat-level data) are available, then estimates can control for unobserved inputs and effective tracking of trends and examining the impact of external drivers is possible.

Figure 3. Data type options for analysis

Technical Efficiency, Capacity Utilisation, Scale Efficiency

- Catch
- Effort (e.g. days fished)
- Vessel characteristics (e.g. length, engine power)

Allocative, Cost, Revenue, and Profit Efficiency

- Prices of, or total revenue from, each output
- Prices of, or total expenditure on, each input

Inefficiency drivers

- Fisher characteristics
- Management changes
- Environmental changes

WHAT ABOUT FISH STOCK INFORMATION?

Information on fish stock abundance is commonly used as an input in productivity analysis. Excluding fish stocks results in the effect of stock changes on outputs being captured in the efficiency measure. For the purposes of using the estimates as proxy measures for economic performance, then this is not a problem, as economic performance is also driven by stock abundance. However, if the purpose of the study is to assess drivers of efficiency or use the estimates of the production elasticities to inform management decisions, then including stock in the analysis is necessary.

Australian case studies

Three examples of the estimation and use of efficiency and productivity measures are presented below. These include a comparison between productivity measures and economic performance in the Commonwealth Northern Prawn Fishery, a similar comparison in the less data rich South Australian Prawn Fishery, and an analysis of efficiency and productivity in the Queensland Spanner Crab Fishery.

NORTHERN PRAWN FISHERY

The Northern Prawn Fishery is a Commonwealth managed multispecies fishery located in the tropical region of northern Australia. The main target species are Tiger, Endeavour and Banana Prawns, although a number of other prawn and other species are landed as byproduct. In 2019, the gross value product of the fishery was A$117.7 million, A$115.0 million of which was derived from the target prawn species (Patterson et al. 2020).

The fishery is data rich in terms of catch and effort data as well as economic data. Economic surveys of the fishery have been undertaken by ABARES since the mid-1980s, with relatively continuous surveys since the mid-1990s. This allows a direct comparison of productivity measures with economic performance measures over a long time period.

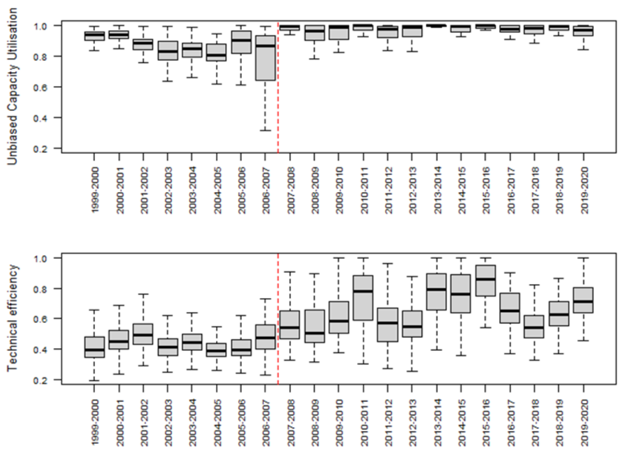
Technical efficiency and capacity utilisation was estimated over the period 1999-2000 to 2019-2020. For consistency with the available economic data, catch and effort for each vessel were aggregated to a financial year level, with separate catch values for Common Banana Prawns, Redleg Banana Prawns, Tiger Prawns, Endeavour Prawns and other prawn species.

From the results, capacity utilisation increased substantially following the buyback in 2007 (depicted by the red dashed line), as the excess capacity had been removed and the remaining vessels were able to operate at a higher level of capacity utilisation (Figure 4).

Technical efficiency also generally increased. This was partly due to the removal of less efficient vessels (Pascoe et al. 2012), but also as a result of changes in stock abundance as a result of management changes introduced following the buyback.

Information on vessel economic performance was also available over the same period to 2015-16 (Mobsby et al. 2019), with net economic returns increasing from negative values in the few years before the buyback, and substantial positive values by the end of the period. To compare the productivity measures to the economic performance measures, three different economic performance measures were considered: profit at full equity, boat cash profits and gross margins. The former takes into account both cash and

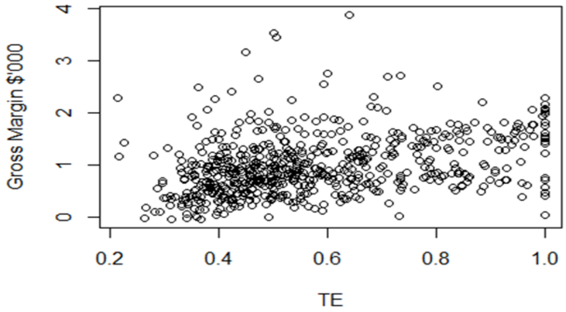
Figure 4. Changes in NPF efficiency and capacity utilisation over the last 20 years



non-cash costs (e.g., depreciation and non-paid labour), while boat cash profits only consider cash costs. Gross margins are a short-term productivity measure that consider revenue and variable costs only. Economic measures covered the period 1999-2000 to 2016-17. All economic measures were inflated to 2019-20 values using the consumer price index.

A simple comparison of individual technical efficiency and gross margin can be seen in Figure 5. While there is considerable 'noise' in the data due to differences between other vessel characteristics, a general trend can be seen.

Figure 5. Comparison of technical efficiency (TE) with vessel gross margin



The relationship between the observed vessel economic performance and their productivity measures was further examined through regression analysis, and expressed in terms of elasticities. These represent the percentage change in economic performance due to a 1% change in the productivity measure.

From Table 3, a 1 per cent improvement in technical efficiency results in a 0.8%, 0.9% and 0.5% in full equity profits, boat cash profits and gross margin respectively. Improving capacity utilisation results in a proportional increase (i.e., 1:1) in the first two economic measures. The R^2 measures in Table 3 provide an indication of the strength of the relationship (i.e., goodness of fit). The R^2 value is a measure of the amount of variation in the economic performance measure that is captured by the productivity measures. For example, 90% of the variation in gross margins between vessels is explained by the technical efficiency and capacity utilisation. Hence, the results are robust in relation to gross margins but still reasonably strong for the other two measures. Given this, the productivity measures can provide a relatively robust indication of changes in economic performance of the fleet when economic data are not available (i.e., between economic surveys).

Table 3. Elasticity estimates from panel data regression analysis

	Technical efficiency	Capacity utilisation	R^2
Full equity profits	0.843	1.023	0.62
Boat cash profits	0.879	1.075	0.67
Gross margin	0.546	0.651	0.90

SOUTH AUSTRALIAN PRAWNS

The Spencer Gulf and West Coast Prawn Fisheries are two of three commercial prawn fisheries in South Australia and are managed in a similar fashion. They are single-species prawn fisheries, capturing Western King Prawn, with incidental catch of Blue Swimmer Crabs and Calamari permitted to be retained and sold. In 2011, the Spencer Gulf was the first prawn fishery in Australia to be Marine Stewardship Council certified.

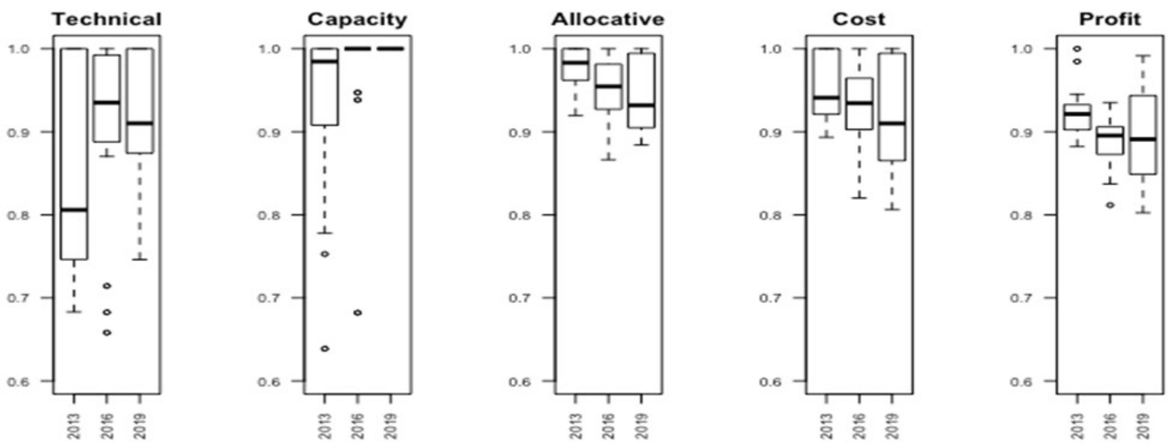
The management plans include ecological and economic objectives and have retained the underlying principles of industry-coordinated, input-controlled management that have operated since the 1990s. The Spencer Gulf and West Coast Prawn Fishermen's Association plays an important role in co-management with real-time effort decisions undertaken by a Committee-at-Sea. BDO EconSearch conducts voluntary surveys to provide economic performance indicators to help inform decisions that support economic outcomes; the data for the two fisheries are reported together due to the small fleet sizes.

Five measures of productivity are shown in Figure 6 (the median is the dark line, 25th and 75th percentiles form the boxes). The technical efficiency and capacity scores are lowest in 2013 but are high overall, due to the fleet being relatively homogenous by quantity. Note that the input restrictions make it difficult to identify a true maximum capacity. Three value-based measures of efficiency (allocative, cost and profit) are also relatively high but are falling over time and are increasing in variation. In combination, it appears that heterogeneity in economic outcomes is increasing.

When the quantity-based measures of technical efficiency and capacity utilisation are compared to direct measures of economic performance in the same way as for the NPF there is only a weakly positive relationship with gross margins, which represent a short-run measure of profits.

Economic performance, as measured by profit, depends not only on the quantities of inputs and outputs but also their prices. Therefore, as these prawn fisheries are managed by effort controls and cooperative decisions with maximum total quantities, the only mechanism for those who wish to improve profits is by lowering per-unit costs or seeking higher prices for their outputs. While no major management changes (e.g., introduction of quota management, alteration of cooperative management) have occurred in these fisheries, the increasing divergence in economic outcomes has potential implications for longer-term pressures on cooperation in the fishery. For instance, pursuit of different output markets may lead to different objectives regarding catch timing and quantity, or value of environmental improvements.

Figure 6. Efficiency scores for the Spencer Gulf and West Coast prawn fisheries



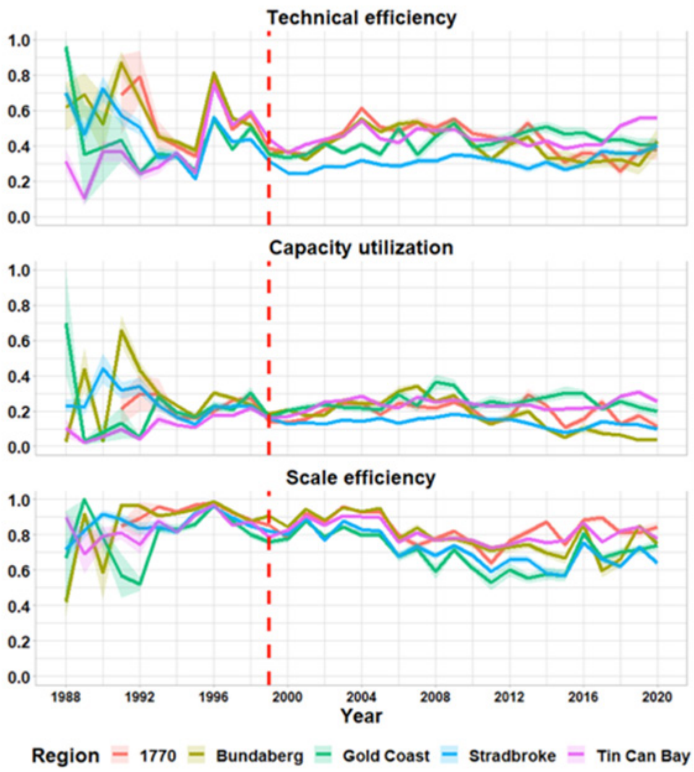
QUEENSLAND SPANNER CRAB FISHERY

The Spanner Crab Fishery is a single species fishery with its main fishing area located around south-east Queensland. The aim of this case study was to assess potential differences in the productivity of vessels operating in the fleet. Such differences may have resulted from the considerable fishery management changes introduced in 1999 (e.g., gear restrictions, decrease in total allowable catch managed through individually transferable quotas). Measures of capacity utilisation, technical efficiency, and scale efficiency were analysed.

The available data for this case study included: number of days fished, number of pots set, number of pots lifted, vessel hull units, engine power and catch as monthly observations ranging from 1988-2020. Furthermore, the data were available for five fishing regions (within the fishery's management area A). Hence, the data set offered the opportunity to conduct a temporal and spatial productivity analysis.

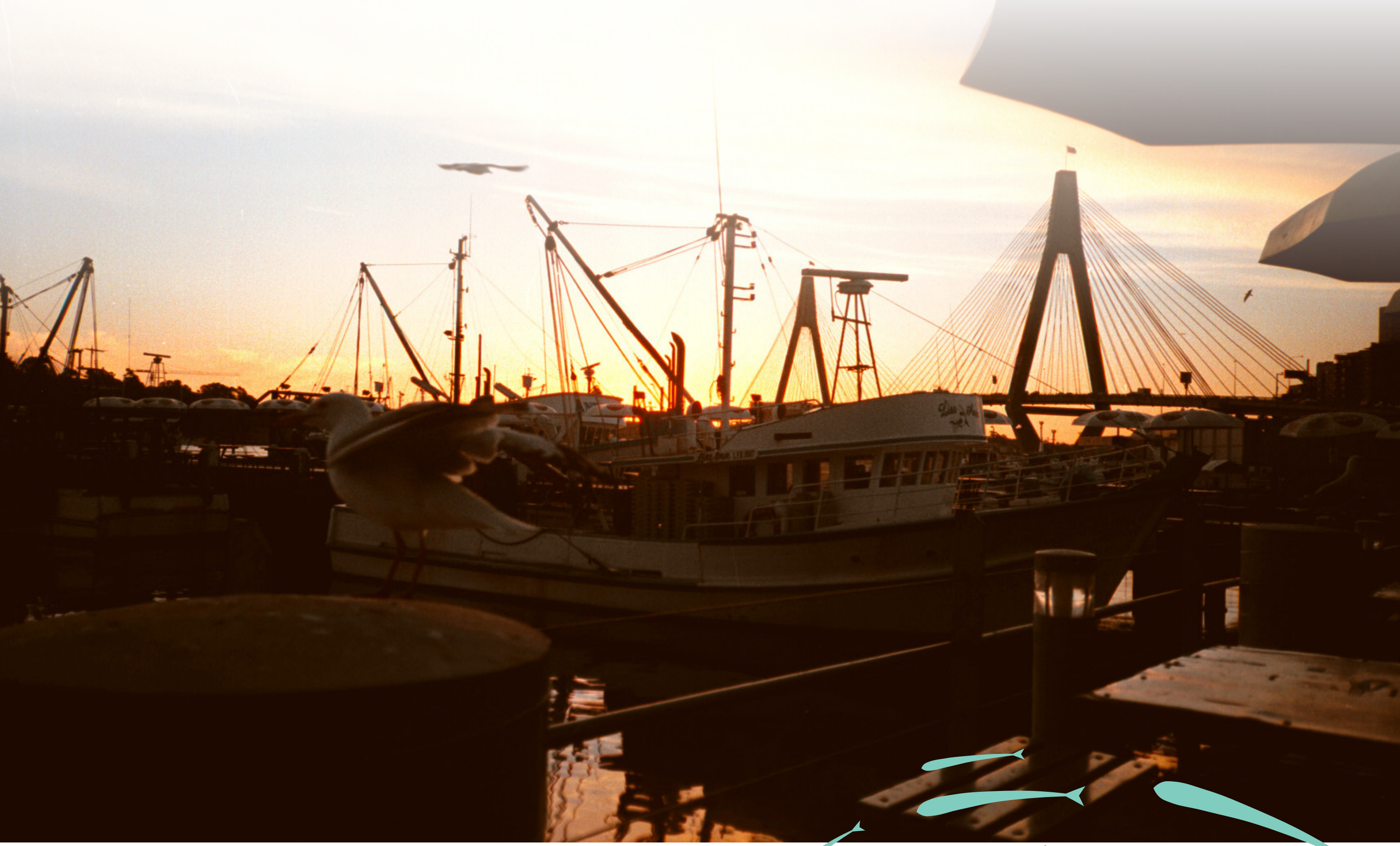
The results in Figure 7 suggest that most productivity measures have not changed considerably over time and remain relatively low across all five fishing regions after the substantial change in the management of the fishery in 1999. The exception is scale efficiency which was historically very high but slightly decreased over time across all regions. Greater annual variation in the mean scores of all four efficiency measures was observed prior to the introduced management change in 1999 compared to the results for 2000-2020. Yet, this is likely an effect of the limited annual obervations during 1988-1992.

Figure 7. Changes in efficiency measures for the five regions of the Queensland spanner crab fishery 1988-2020



Notes: Results presented as annual mean scores with shaded standard errors (of the means). Dashed line indicates the year at which significant changes to the fishery management were introduced.

Overall, the findings suggest that the change in fishery management had little effect on the productivity of the Spanner Crab fleet, potentially with the exception of scale efficiency. This could be due to other restrictions or economic incentives that prevents fishers from more efficient operations in this single-species fishery. Additional data (e.g., revenue, profit, costs, skipper skills) and analysis is needed to assess the causes for the low technial efficiency and capacity utilisation over time and whether the decrease in scale efficiency is indeed due to management changes or if it may be caused by other factors. From an operational perspective the results suggest that there is a high level technical inefficiency and excess capacity (e.g., vessel hull units, engine power) present within the spanner crab fishery which should be addressed to increase its economic performance.



Conclusions

The regular estimation of productivity measures can provide useful information on the economic health of the fishery. This guide presents a set of case studies using productivity measures that focus on measuring technical efficiency and capacity utilisation. The estimation of these types of measures requires data that are readily available for most fisheries.

While the strength of the relationship between fisheries may vary, improvements in technical efficiency and capacity utilisation generally correspond to improvements in economic performance. While they should not necessarily replace economic data collection, they provide a means to understand more real time changes in economic performance. Regular inclusion of technical efficiency and capacity utilisation measures into fishery monitoring programs can highlight potential problems that are not otherwise apparent. For example, decreasing capacity utilisation suggests increasing levels of excess capacity, which may in turn require a management response, depending on the cause.

Estimating production functions, where appropriate, also provides additional information (see Extra Information on next page). The coefficients of the estimated models reflect the relationship between inputs and outputs, allowing the effects of any changes in input restrictions on catch or efficiency to be assessed before they are implemented. Inefficiency models can also be developed to assess the impact of fisher characteristics, management changes and/or environmental factors on efficiency. Value-based measures of productivity may also be possible and can assist in identifying potentially diverging trends in quantities and values.

Productivity measures are typically relative and therefore fishery specific. Similarly, the approach that is best suited to estimate the productivity measure depends on the nature of the fishery (e.g., single versus multi-species) and the specific measures of interest (technical efficiency, capacity utilisation or production elasticities).

The purpose in this guide is to provide potential users of productivity measures a basic understanding of what they represent, how they are measured and what they can be used for. It is not intended to be a guide as to how to estimate the metrics, which is a task for economists working with managers, industry and policy makers.

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EXTRA INFORMATION: METHODS TO MEASURE EFFICIENCY

There are three main methods for the estimation of technical and other measures of efficiency and capacity utilisation: Data Envelopment Analysis (DEA); Stochastic Frontier Analysis (SFA); and Stochastic Distance Functions. The purpose of this guide is not to cover how they can be implemented, but to highlight the advantages and disadvantages of each, and how these may affect the resultant measures. While the methods are not directly dependent upon what data is available, which measures of efficiency can be estimated will depend on the available data, as discussed above.

	Data Envelopment Analysis	Stochastic Frontier Analysis	Stochastic Distance Function
Description	• A non-parametric (not statistical) approach to identify the frontier as the 'envelope' around the best vessels' ratios of outputs to inputs • Measures of efficiency calculated relative to the frontier envelope	• A parametric (econometric) approach that statistically estimates the production function of a single output • Measures of efficiency calculated as the distance from the frontier	• A parametric approach that statistically estimates the production function but allows for multiple outputs • Measures of efficiency calculated as the distance from the frontier
Advantages	• Multiple outputs can be included • Allows for different production behaviour because no need to specify production function • Most appropriate for estimating capacity and capacity utilisation • Straightforward estimation of allocative and scale efficiency	• Explicitly considers random error in output and removes 'noise' from efficiency estimates • Direct estimation of the production function can give extra information to managers about the relationship between inputs and output • Can jointly estimate the effect of external changes (e.g., management or environment)	• Multiple outputs can be included • Explicitly considers random error • Can estimate the level of substitution between outputs
Disadvantages	• Does not allow for random error in production • Efficiency estimates tend to be lower but trends similar	• Need to calculate an aggregate measure of output if the fishery is multispecies • Need to specify production function	• Need to specify production function • Estimation mechanics are more complex
Recommended for use when ...	• There are multiple outputs • Capacity and capacity utilisation are of interest	• There is a single species • Technical efficiency is the focus • Production function estimation is of interest	• The degree of targeting specific species is of interest

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Using Productivity Analysis in Fisheries Management

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