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Demand Conditions and Dynamics in the SESSF

An Empirical Investigation

Final Report

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Cover photo: Fishing vessels tied up outside the Sydney Fish Market, January 2020, Sean Pascoe

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In submitting this report, the researcher has agreed to FRDC publishing this material in its edited form.

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Abbreviations

ABARES	Australian Bureau of Agricultural and Resource Economics and Science
ADF	Augmented Dickey Fuller Test
AIC	Akaike information criteria
ARDL	Autoregressive distributed lag
FAO	Food and Agriculture Organisation of the United Nations
GHT	Gillnet, hook, and trap
HQIC	Hannan-Quinn information criteria
H0	Null hypothesis
IAIDS	Inverse almost ideal demand system
LOP	Law of one price
MAIC	Modified Akaike information criteria
SC	Schwartz information criteria
SESSF	Southern and Eastern Scalefish and Shark Fishery
SUR	Seemingly unrelated regression
TAC	Total allowable catch
VAR	Vector autoregressive system
VECM	Vector error correction model

Executive Summary

This final report, a collaboration between economists from CSIRO, CQU and ABARES, is the first detailed analysis of the interrelationship between fish prices on the Sydney and Melbourne fish markets. In addition, the study derived empirical estimates of the own and cross-price flexibilities for the main species on the Sydney Fish Market. Using cointegration analysis, the study established that the Sydney and Melbourne markets are highly integrated, with prices of individual species moving together. Demand models were developed to examine substitutability between key fish species on the Sydney market, along with the substitutability of imports for domestic product. The demand modelling results indicate that prices of individual key fish species are sensitive to changes in their quantities landed, but less sensitive to changes of quantities supplied by other fish species. It was also found that the increased production of farmed salmon in Australia has had a substantial negative impact on the prices received for species on the Sydney Fish Market; more so than the impact of imports.

Background

The Southern and Eastern Scalefish and Shark Fishery is the main domestic supplier of fresh fish to the Sydney and Melbourne markets. The fishery is managed through a series of total allowable catches for the key species. However, how these total allowable catches affect the prices received, and hence the revenue of the fishers, is poorly understood. Understanding the sensitivity of seafood prices to various changes in demand and supply, and the interconnectedness between different products/sources of supply, is important for individual businesses making production, pricing and investment decisions. This understanding is also important for managers responsible for regulation of the common pool fish resource and policymakers interested in assessing the impact of various policy interventions.

Objectives

The project had two key objectives, namely to:

1. estimate the degree of integration between the different species and between the markets for fresh fish in Sydney and Melbourne; and
2. estimate the short-term and long-term effects of changes in quantity supplied of key species from the Southern and Eastern Scalefish and Shark Fishery on the price received on the Sydney and Melbourne fish markets

Methodology

Cointegration analysis is applied first to prices of key species on both the Melbourne and Sydney markets to establish if the markets are integrated or separate. Cointegration analysis compares price movements in the two markets over time to determine the extent to which they move together. The methods are applied to key species on the Sydney market as well as imports to determine the level of substitutability between the domestic species as well as domestic and imported supplies.

To estimate the price flexibility of fish a dynamic form of the Inverse Almost Ideal Demand System (IAIDS) was developed. The IAIDS models changes in prices of a set of species as a function of changes in landings or supplies to the market. An “aggregated” model was also developed including imports (fresh and frozen), domestically farmed salmon and the key wild-caught species in the Sydney Fish Market.

Results

Data for the Melbourne market were limited following the closure of the central market in 2010. Despite this, the results of the cointegration analysis indicate that the Sydney and Melbourne markets were highly integrated over the period of the available data. That is, prices for a given species on each market tended to move together. Hence, the two markets can effectively be considered a single market, at least for the key Southern and Eastern Scalefish and Shark Fishery species examined. Differences in prices on the markets can still exist due to differences in transport costs, but price variations beyond these transportation cost differences are temporary.

On the Sydney market, prices of most species were found to be not cointegrated (i.e., not substitutes), but some cointegration was observed. In particular, Blue-eye Trevalla was cointegrated with several species suggesting this may be a market leader or at least a highly influential species in the market.

Imports were also found to be cointegrated with many of the species on the Sydney Fish Market, particularly imports of fresh fish. This indicates a strong substitution potential between imports and domestically caught fish, with increased import supply most likely having a negative impact on prices of Southern and Eastern Scalefish and Shark Fishery species.

From the results of the aggregated demand model, the increase in the quantity of imports has had a negative effect on the price of wild-caught species on the Sydney Fish Market over the last two decades, supporting the results of the cointegration analysis. Imports of fresh fish was found to have had a significant negative impact on the prices of species in the lower valued group in both the short and long term. While no short-term impact on high valued species was found, a small but significant negative impact was found in the long term. This suggests direct competition and potential for substitution between imports of fresh fish and the lower valued domestic fish species. In contrast, imports of frozen fish were found to complement lower valued species. That is, increased imports of frozen fish were related to increased prices for these lower valued species. No significant relationship between frozen fish and higher valued species was found.

The increase in salmon production was also found to have had a negative impact of prices of both groups (high and low valued) on the Sydney Fish Market, more so that imports.

At the species level, own-price flexibilities were generally found to be between -0.3 and -0.6, indicating that prices change less than proportionally with quantity landed (i.e., are relatively price inflexible). That is, a 10 per cent increase in quantity landed, for example, of each species would result in a 3 to 6 percent decrease in its own price. Cross-price flexibilities – the impact of landings of one species on the price of another – were also found to be small, mostly between 0 and -0.1.

Implications

For purpose of illustration we provide two examples of the use of the price flexibilities in support management decision making. In the first example, we look at the consequences of the full set of TACs being met on the economic performance of the fleet (assuming it is technically feasible to do so). In the second, we look at how considering price flexibilities affects the optimal yields (target reference points) in the fishery.

We examined the revenues and costs of the trawl sector and gillnet, hook and trap (GHT) sector assuming they are able to catch the full TAC of all species. Since increased supply to the market would decrease prices, and based on the own-price flexibilities found in our study, it was found that revenue of both sectors would only increase by 20%, while the additional cost of catching the full TAC (assuming it was technically possible) would outweigh the additional revenue once prices changed given the new level of landings.

The effects of including price flexibilities in assessing target reference points was investigated using the previously developed model by Pascoe *et al.* (2020) and was modified to allow prices to vary with changes in quantity landed, based on the own and cross-price flexibilities estimated in this study. Maximising profits assuming constant prices results in the optimal fleet size decreasing by around 50% relative to 2015, while allowing prices to vary results in an even smaller fleet, lower catches and higher prices. While this may maximise profits to the industry, the higher prices result in a loss of benefits to consumers, and potentially an overall net economic loss. From this, even though most own and cross-price flexibilities estimated in the study were relatively small in absolute terms, they can have a substantial impact on what might be considered an optimal level of fishing. Maximising both producer and consumer benefits results in similar outcomes as under the current fleet size.

Recommendations

The results of this study have demonstrated the importance of considering price-quantity interactions in TAC setting, although this is not routinely factored into such analyses. This may be, in part, due to a lack of fisheries that have well developed bioeconomic models to support decision making; a lack of understanding as to the importance of considering these interactions; a lack of information on such interactions; a lack of clear objectives or direction to include consumer impacts into the TAC setting process; or combinations of the above. Given this, managers and industry may wish to consider:

- Greater use of bioeconomic models to support TAC setting will enable these interactions to be factored directly into the determination, with implications for both industry and consumers made explicit;
- Explicit consideration of price impacts in the absence of a bioeconomic modelling framework when considering changing target catch levels;
- Explicit consideration of the future price environment given likely changes in imports and domestic salmon production when making long term decisions for the fisheries; and
- Increased research into assessing price flexibilities in fisheries not previously assessed.

Keywords

SESSF; prices; cointegration; imports; Sydney fish market, demand, IAIDS, price flexibility

Introduction

Background

Important determinants of the economic performance of fisheries include the management of fisheries and dynamics within fish markets. While fishery management primarily focusses on fish stock/ecosystem management and associated institutional aspects (e.g., harvest strategies, type of industry management, regulation), markets determine the price of fish (through demand and supply) that fishers ultimately receive for their products.

Markets play a pivotal role in determining how fish, once landed, are allocated among competing users, and through their determination of prices (and thereby revenues and profits), provide incentives for fishers (and others along the supply chain) to alter their behaviour in response to changes in demand and supply conditions. Knowing the sensitivity of seafood prices to various changes in demand and supply, and the interconnectedness between different products/sources of supply, is important for: individual businesses making production, pricing and investment decisions; managers responsible for regulation of the common pool fish resource, particularly in MEY-managed fisheries; and policymakers interested in predicting the impact of various policy interventions. Knowledge of price formation in fisheries can be helpful to predict the net benefits of fishers effort, which are of importance for fishery management (e.g., harvest strategies, marketing strategies) and in designing policies relevant to rent capture in fisheries (Grafton 1995).

A recent FRDC project (FRDC 2015-202) found that managing a fishery to maximise economic profits may not equate to maximum economic returns when prices vary with the quantity landed. In such a case, maximising fishery profits may lead to a transfer of benefits from consumers to producers, and an overall net deadweight loss to society as a whole (Pascoe *et al.* 2018). Similarly, FRDC 2016-213 found that understanding the price response to quota changes may allow the use of simple cost-effective methods for developing harvest strategies in some fisheries (see also Econsearch (2012)).

Relatively few studies of market dynamics have been undertaken in Australia, and most of these are relatively dated (Pascoe *et al.* 1987b; Smith *et al.* 1998b; Bose 2004). While more recent studies have been undertaken on oysters (Schrobback *et al.* 2014) and prawns (Schrobback *et al.* 2019a) in Australia, as well as for some Australian products on international markets (Norman-López *et al.* 2014; Hoshino *et al.* 2015), studies of the price-quantity relationships for most fish species are outdated and limited in their scope.

It was with the aim of filling this research gap that the Fisheries Research and Development Corporation Human Dimension Research Sub-program proposed a suite of empirical studies, based on specific species/fisheries/markets. The first of these was proposed to focus on the key species traded through both the Sydney and Melbourne Fish Markets, to provide information relevant for the management of the Southern and Eastern Scalefish and Shark Fishery (SESSF).

To this end, this study focuses on 19 key species caught in the Southern and Eastern Scalefish and Shark Fishery which make up the majority of total gross value of landings, and much of which is sold into the Sydney and Melbourne Fish Markets.

Need

The Fisheries Research and Development Corporation Human Dimension Research Sub-program has identified the lack of information about seafood markets and price formation in Australian fisheries as a major research gap. The need for such analyses has also been discussed within the Australian Fisheries Management Authority's (AFMA) Economics Working Group, who saw such information as being essential in supporting fisheries management.

This project is an attempt to at least partly address this research gap. In doing so, the information produced will be of benefit to fisheries managers, fishers and the broader community as we move our fisheries closer to maximising net economic returns.

The focus of this study is on the markets relevant to the SESSF, which is the main supplier of fresh fish to the Sydney and Melbourne markets. To date, as noted above, only very limited empirical research has been conducted for these fisheries in Australia (Pascoe *et al.* 1987b; Smith *et al.* 1998b; Bose 2004), most of which is now relatively dated and is unlikely to be valid for current market conditions. Since the early 2000s the seafood market in Australia has changed, for example, due to increasing seafood imports and increasing domestic aquaculture production. Hence, market dynamics for products supplied by domestic fisheries may have also altered.

This case study was identified by the FRDC HDR as of high importance due to the current challenges facing the fishery in terms of unfilled quotas. One potential contributing reason that quotas are not being taken is that to do so would result in lower prices; of potential benefit to consumers but not to producers.

The study focuses on the impact of changes in supply on the price received on the markets. While the potential response of fishers to these changes in price (including avoiding large catches) is also of relevance to fishery managers, this will require further bioeconomic modelling work that is beyond the scope of this study, but may be seen as a high priority for future research.

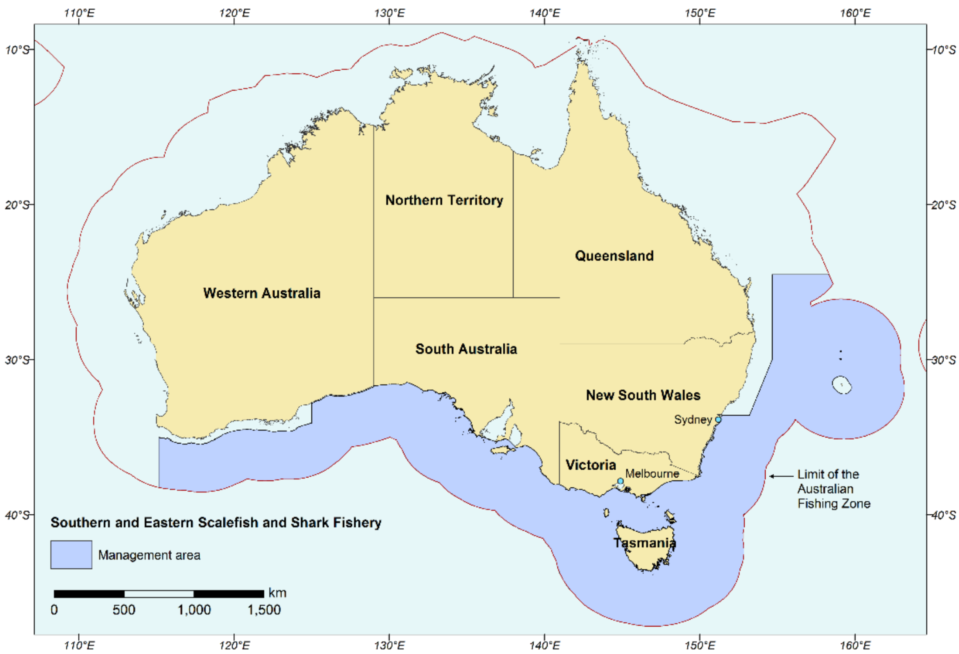
Objectives

The project has two key objectives, namely to:

1 estimate the degree of integration between the different species and between the markets for fresh fish in Sydney and Melbourne; and
2 estimate the short-term and long-term effects of changes in quantity supplied of key species on the price received on the Sydney and Melbourne fish markets.

The study focuses on the key species in the Southern and Eastern Scalefish and Shark Fishery. This is a Commonwealth managed fishery that is the main supply of domestically caught finfish to the Sydney and Melbourne markets (Figure 1).

Figure 1. The Southern and Eastern Scalefish and Shark Fishery (SESSF)



The call for proposals relating to this project also identified two key research questions to be addressed as part of this study:

- How flexible is the price of key individual species to changes in quantity landed?
- How integrated are the prices for different species, or for particular species on different markets, including imports?

Methods

Overview

Answering the above research questions requires an understanding of how prices of the different species move relative to each other, and how changes in the level of landings of each may affect the price of all other species.

The project is focused on two key economic concepts:

- *Price flexibility* refers to the percentage change in price as a result of a one percent change in quantity landed, either of itself (own-price flexibility) or the quantity of other species (cross-price flexibility).
- Species are said to be *cointegrated* if their prices move together in the longer term (although may fluctuate in the short term). In this case, they essentially form part of the same "market" (i.e., be highly substitutable).

Understanding the key market dynamics relevant to the SESSF requires econometric modelling of the relationship between quantity supplied and the prices received for the key species. These methods have been well established in the analysis of fisheries markets (e.g. Asche and Salvanes 1997; Jaffry *et al.* 1999; Asche *et al.* 2007a; Nielsen *et al.* 2012b; Sun *et al.* 2017). As most fish species compete with each other on the market, estimating the effects of changes in the quantity landed of a species on its own price and also the prices for other species requires a systems approach. The almost ideal demand system (AIDS) and its variants (i.e., inverse almost ideal demand system (IAIDS)) are the most widely used approaches for estimating the price-quantity relationship in fisheries markets (Engle *et al.* 2016).

Species that are relatively close substitutes may also be identified through the use of market integration techniques (Asche *et al.* 2004; Asche *et al.* 2007b; Hoshino *et al.* 2015). These methods identify long-run relationships between prices of different species (or the same species over different markets), and are less data intensive than demand systems. Several recent studies have used market integration techniques to determine the degree of market integration for Australian species (Norman-López *et al.* 2014; Schrobback *et al.* 2014).

The project addressed the key questions in three parts. The first part involved the compilation of an appropriate data set using information from the main markets supplied by the SESSF. Second, market integration analysis was undertaken to examine the broad interrelationships between the species on these markets as well as between these markets. Finally, demand models were developed to estimate the own and cross-price flexibilities for the key species of interest.

Data

There is no systematic data collection on seafood wholesale prices or any readily accessible database for the major Australian seafood markets. Monthly price and quantity data from the Sydney and Melbourne Fish Markets were used as representative of the seafood market. Monthly import data were also available but reported based on the international harmonised system developed by the World Customs Organization.

Sydney Fish Market data

The data for the cointegration analysis of prices for seafood caught and landed by the SESSF in New South Wales which is sold as fresh or chilled forms was obtained from the Sydney Fish Market (SFM). The data set included information about monthly value and quantities traded for 19 fish species sold within the Sydney Fish Market. The data period differs among species (Table 1), with the longest data period between February 1999 to October 2019, while the shortest data period is between July 2009 to October 2019.

Table 1. Average monthly traded quantity (kg), value (A$), and price (A$) at the Sydney fish market between February 1999 and October 2019

Species name	Data period	n	NAs	Weight (kg)	Value (A$)	Price (A$/kg)
Bigeye Ocean Perch	June 2005-Oct 2019	173	0	12,279	74,165	6.4
Blue-eye Trevalla	June 2005-Oct 2019	173	0	13,597	129,277	10.0
Blue Grenadier	Feb 1999-Oct 2019	210	39	2,391	3,738	2.0
Blue Warehou	Feb 1999-Oct 2019	216	33	1,593	5,011	3.8
Eastern School Whiting	June 2005-Oct 2019	173	0	34,755	111,764	3.3
Elephant Fish	July 2009-Oct 2019	24	97	178	259	1.8
Gemfish	Feb 1999-Oct 2019	245	4	7,443	28,494	4.1
Gummy/School Shark	Feb 1999-Oct 2019	234	15	2,507	7,044	2.8
Gummy Shark	Feb 1999-Oct 2019	245	4	1,774	5,311	2.9
Jackass Morwong	June 2005-Oct 2019	173	0	16,029	59,577	4.1
John Dory	Feb 1999-Oct 2019	245	4	10,171	99,093	10.3
Mirror Dory	Feb 1999-Oct 2019	245	4	20,992	68,239	4.1
Ocean Perch	June 2005-Oct 2019	173	0	938	3,004	3.2
Orange Roughy	Feb 1999-Oct 2019	196	53	3,391	16,296	5.6
Pink Ling	June 2005-Oct 2019	173	0	37,888	211,478	5.8
Royal Red Prawn	June 2005-Oct 2019	145	28	1,321	4,101	3.9
Saw Shark	Feb 1999-Oct 2019	245	4	4,810	7,717	1.7
School Shark	Feb 1999-Oct 2019	234	15	749	1,866	2.4
Silver Trevally	Feb 1999-Oct 2019	245	4	20,233	74,826	4.8
Silver Warehou	Feb 1999-Oct 2019	245	4	7,315	13,056	1.9
Tiger Flathead	Feb 1999-Oct 2019	245	4	61,382	335,883	5.7

Note: n indicates the number of observations, NAs indicates the number of missing values during the data period.

Data for each species were provided relating to a wide range of product forms as sold on the market, such as whole, gilled, gutted etc. In total, 41 different product forms were included in the market data. To develop a consistent price, all weights were converted to whole weight equivalents using a series of conversion factors (Table B.1 in Appendix B) that were species and process specific. These were mostly derived from conversion factors produced in AFMA (2020b), although conversion factors for some product forms were derived from the New Zealand Fisheries (Conversion Factors) Notice 2005 (No. F350) and subsequent revisions (Fisheries New Zealand 2005).[1]

Based on the ratio of value and quantity, the monthly average unit price was derived for each observation which is a common practice in the extant literature (e.g., Asche *et al.* 2012; Nguyen and Kinnucan 2018; Schrobback *et al.* 2019b).

During the reported data period the three most important species in the Sydney fish market, in terms of both average monthly quantity traded and total value were Tiger Flathead, Pink Ling, and Blue-eye Trevalla, while the top 3 species in terms of unit price were John Dory (A$10.3/kg), Blue-eye Trevalla (A$10.0/kg), and Bigeye Ocean Perch (A$6.4/kg) (Table 1). Significant missing data were observed for Elephant Fish (NAs=97), Orange Roughy (53) and in lesser extent Blue Grenadier (39) and Blue Warehou (33).

[1] These and the AFMA conversion factors were the same for the same species where they overlapped.

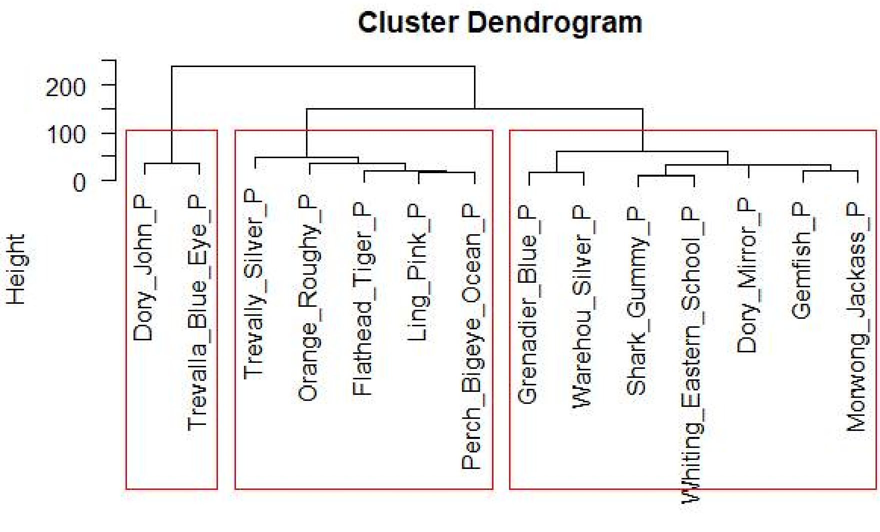
The nominal price data was logged for the cointegration analysis. Missing price values were interpolated using the Kalman method offered in the 'imputeTS' package (Moritz and Bartz-Beielstein 2017) in the R software (R Core Team 2012).

For the demand model and analysis of price flexibilities, monthly product volume and quantity data for 19 fish species traded at the Sydney Fish Market was used as a proxy for prices that SESSF operators received for their product. The Sydney Fish Market is considered as one of the main market outlets for the catch of the SESSF which was why these data were considered as appropriate for the analysis. Monthly average prices for the individual species were derived based on the ratio of value and quantity which is a common practice in the literature (e.g., Asche *et al.* 2012; Nguyen and Kinnucan 2018; Schrobback *et al.* 2019b). The Sydney Fish Market data set had to be transformed into whole-weight equivalents which was described above. All prices were also converted to 2020 real prices based on the consumer price index (CPI) (see Table 2).

The time series subsequently included monthly prices (Sydney Fish Market data only) and quantity data ranging from June 2005 – September 2019 which equates to 172 observations. The SUR estimation process requires the estimation of a variance-covariance matrix across all system equations. With 19 species, this would involve the estimation of 19*18= 342 parameters (as one equation is excluded from the SUR model to avoid perfect collinearity), even excluding lagged variables. Given there are only 172 observations, there were not sufficient degrees of freedom to estimate the system with all species.

Different options to estimate the price flexibilities given the 19 species traded at the Sydney Fish Market were considered. To minimise the number of species included in the analysis, the five species with the lowest average value share supplied at the Sydney Fish Market (School Shark, Common Sawshark, Royal Red Prawn, Blue Warehou and Reef Ocean Perch) were combined into a composite "other" group. Combined, these species represent about 1.4 per cent of the total value of Sydney Fish Market sales. For the remaining species, a cluster analysis of the price data was undertaken which resulted in three relatively uneven groups by count (see Figure 2). Assuming price reflects the set of characteristics of the different species (Kristofersson and Rickertsen 2007; Hammarlund 2015), then species with similar prices are most likely to be substitutes on the market.

Figure 2. Clustering of Sydney Fish Market species based on real prices



Following the example by Eales *et al.* (1997), the Sydney Fish Market species were subsequently categorized into two groups: high value species (the two groups on the left of the Dendrogram in Figure 2) and low value species as shown in Table 2.

Table 2. Average real prices, quantities supplied and value shares of key species on the New South Wales market (June 2005- September 2019)

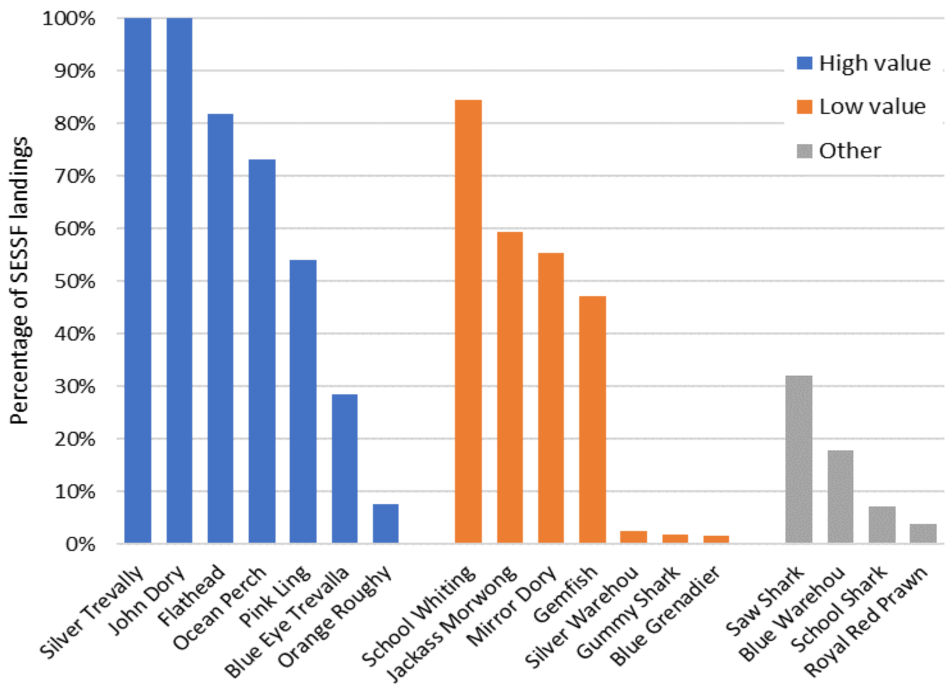
Species	Real price		Quantity		Share	
	Mean (A$/kg)	**Std. Dev.**	**Mean (tonnes)**	**Std. Dev.**	**Mean (%)**	**Std. Dev.**
Sydney Fish Market						
• *High value species*					*75.5%*	*5.3%*
○ John Dory	12.85	2.08	8.71	3.01	7.3%	1.9%
○ Blue-eye Trevalla	11.61	1.96	13.62	7.15	10.0%	4.4%
○ Tiger Flathead	7.79	1.08	56.80	13.98	29.3%	5.4%
○ Bigeye Ocean Perch	7.40	1.10	12.30	5.38	5.8%	1.6%
○ Orange Roughy	7.15	2.04	1.83	3.67	0.8%	1.4%
○ Pink Ling	6.80	1.06	37.89	15.12	16.3%	4.5%
○ Silver Trevally	6.42	2.45	16.57	9.34	6.0%	2.1%
• *Low value species*					*24.5%*	*5.3%*
○ Mirror Dory	5.36	1.47	20.54	21.74	5.6%	3.9%
○ Jackass Morwong	4.81	1.16	16.10	9.44	4.9%	2.7%
○ Gemfish	4.78	1.52	7.80	5.52	2.4%	1.5%
○ Eastern School Whiting	3.83	0.77	34.76	8.93	8.8%	2.1%
○ Gummy Shark	3.72	0.63	1.84	0.84	0.5%	0.3%
○ Blue Grenadier	2.44	1.21	1.54	1.99	0.2%	0.3%
○ Silver Warehou	2.34	0.85	4.14	3.99	0.7%	0.7%
○ Other species (aggregated)	2.93	1.11	7.85	1.76	1.5%	0.8%

Catch from the SESSF can potentially go to several different markets,[2] of which Sydney Fish Market is the main market for species caught in the New South Wales region of the fishery. Some catch is sold directly to wholesalers or retailers, while other is sold to processors. Catch is also sold through the more decentralized Melbourne fish markets, particularly catch taken in more southern parts of the fishery. This has implications for the estimation and interpretation of the derived own and cross-price flexibilities.

The proportion of catch of the key SESSF species considered sold through the Sydney Fish Market is shown in Figure 3. SESSF catch for the 2018-19 fishing year (1 May 2018 to 30 April 2019) was obtained from the AFMA Catchwatch Reports (https://www.afma.gov.au/fisheries-services/catchwatch-reports), and compared with the quantity sold through the Sydney Fish Market over the same period. For some species (Silver Trevally, John Dory, Flathead and School Whiting) there is a substantial catch taken in New South Wales State waters that also contributes to the supply to the Sydney Fish Market over and above that supplied from vessels operating in the SESSF. Quantities passing through the Sydney Fish Market, however, of five of the seven high value species and four of the seven low value species represent a sizable proportion of the SESSF catch, and hence the price formation on the market should be representative of the price formation process overall. Of the other species, Orange Roughy and Blue Grenadier are high volume fish species largely sold directly to processors; supplies to the Sydney Fish Market are most likely opportunistic. Gummy Shark are mostly sold either directly to wholesalers/retailers or though the Melbourne market, with most caught in southern waters. From the earlier market integration work, the Melbourne and Sydney markets for Gummy Shark are highly cointegrated, and the demand relationships should be similar assuming fairly constant proportions sold to each.

[2] In addition to the Sydney Fish Market, catch can be sold through the wholesale markets in Melbourne, locally through co-operatives or retail outlets, or other wholesalers in Sydney and elsewhere along the coast.

Figure 3. Percentage of SESSF catch sold through the Sydney Fish Market, 2018-19 fishing year



Melbourne Market data

At the end of 2010, the long-established Melbourne Fish Market in Footscray closed to make way for port and rail development. A new market was established in West Melbourne in 2012, with ownership passing from the Melbourne City Council to a privatised body - Melbourne Seafood Centre Pty Ltd[3]. However, market price data collection ceased after December 2010 with the closure of the council-owned market (Victorian Fisheries Authority 2019).

The data for the Melbourne fish market included information about monthly value and quantities traded for 17 fish species sold between March 1999 to December 2010. This equates to 142 monthly observations, although the data for February 2007 and May 2010 are missing for all species.

With the exception of Gemfish and Ling, all weight data were in whole weight. Gemfish data were provided as either whole and gilled and gutted, while Pink Ling data were either whole or gutted. Conversion factors were applied to gilled and gutted Gemfish and gutted Pink Ling to estimate a whole weight equivalent based on (AFMA 2020b).

The three most important species in the Melbourne fish market, in terms of both average monthly quantity traded and total value were Tiger Flathead, Blue Grenadier, and Ling, while the top 3 species in terms of the unit price were Gummy School Shark (A$9.0/kg), Blue-eye Trevalla (A$8.8/kg), and John Dory (A$6.2/kg) (Table 3).

[3] https://www.melbourneseafoodcentre.com.au/our-history

Table 3. Average monthly traded quantity (kg), value (A$), and price (A$) at the Melbourne market between March 1999 and December 2010.

Species name	Data period	n	NAs	Weight (kg)	Value (A$)	Price (A$/kg)
Blue-eye Trevalla	Mar 1999-Dec 2010	140	2	10,855	88,081	8.8
Blue Grenadier	Mar 1999-Dec 2010	140	2	80,431	330,147	4.8
Blue Warehou	Mar 1999-Dec 2010	140	2	17,328	44,837	3.4
Eastern School Whiting	Mar 1999-Dec 2010	140	2	29,399	86,812	3.0
Elephant Fish	Mar 1999-Dec 2010	140	2	1,828	3,637	2.1
Gemfish	Mar 1999-Dec 2010	140	2	14,566	41,251	2.9
Gummy/School Shark	Mar 1999-Dec 2010	140	2	26,664	235,174	9.0
Jackass Morwong	Mar 1999-Dec 2010	140	2	21,841	45,858	2.4
John Dory	Mar 1999-Dec 2010	140	2	1,309	8,067	6.2
Mirror Dory	Mar 1999-Dec 2010	140	2	10,429	25,773	2.7
Ocean Perch	Mar 1999-Dec 2010	140	2	4,793	10,984	2.5
Orange Roughy	Mar 1999-Dec 2010	140	2	24,542	110,056	5.2
Pink Ling	Mar 1999-Dec 2010	140	2	50,344	278,774	5.9
Sawshark	Mar 1999-Dec 2010	140	2	9,381	36,232	4.1
Silver Trevally	Mar 1999-Dec 2010	140	2	12,398	35,429	3.2
Silver Warehou	Mar 1999-Dec 2010	140	2	111,085	205,887	2.2
Tiger Flathead	Mar 1999-Dec 2010	140	2	133,566	539,443	4.2

Note: n indicates the number of observations, NAs indicates the number of missing values during the data period.

As with the Sydney Fish Marked data, the nominal price data was logged for the cointegration analysis, and missing price values were interpolated using the Kalman method offered in the 'imputeTS' package (Moritz and Bartz-Beielstein 2017) in the R software (R Core Team 2012).

Imports and Australian farmed salmon

Australian Bureau of Statistics monthly import data into each State were obtained from the Australian Bureau of Agriculture and Resource Economics and Science (ABARES) covering the period January 2000 to September 2019.

The Australian Bureau of Statistics reports import data based on the international harmonised system developed by the World Customs Organization (http://www.wcoomd.org/). This system assigns a standard code to a particular "type" of import or export so that cross-country comparisons and reconciliations can be made. The code includes information on product form (e.g., fresh, frozen, whole, fillets etc) as well as species or species groups. In most cases, several similar species may be included in a single code (e.g., 304200044: Frozen fish fillets (excl. hake) in packs not exceeding 1 kg), while in some cases the code is specific to a species (e.g., 304210060: Swordfish (*Xiphias gladius*) frozen fish fillets). In total, 256 different codes were included in the import data covering the period of the available data.

Over the period of the data, the harmonised system underwent several revisions, with revisions being undertaken every five years. Relevant to the import time series used in this study, the system was revised in 2002, 2007, 2012 and 2017. In most cases, the revisions resulted in more species-specific information being available in the latter years, with these species being more aggregated in the earlier period. Of particular relevance for this study is the identification of key aquaculture species (e.g., Tilapia and Catfishes) since the 2012 revision. In earlier years, some of these species categories were included with more generic categories that include both aquaculture and wild-caught species, while others were identifiable as aquaculture, resulting an apparent greater increase in aquaculture species imports than actually occurred.

For this reason, only import data after 2012 was used for the cointegration analysis. The categories were aggregated into five groups: hake (fresh or frozen), aquaculture (fresh or frozen), salmon (fresh or frozen), other fresh and other frozen. As with the Sydney and, to a lesser extent, Melbourne data, the import data needed to be converted into whole weight equivalent values as each category involved different product forms. Conversion factors were derived from FAO Coordinating Working Party on Fishery Statistics (2017) and are presented in Table B.2 in Appendix B. Given the large number of categories, only the number of each broad category assigned to a particular conversion factor is shown in Table B.2.

As for the Sydney and Melbourne market data, prices are derived from the ratio of the total product value and the total product whole weight equivalent volume for each product category.

Average monthly imported quantity, value and price (A$/kg) between January 2012 and September 2019 are summarised in Table 4. Frozen fish is by far the largest imported fish species group in terms of both quantity and value to both New South Wales and Victoria, although the unit price is much higher for fresh import (average A$6.8-7.1/kg) and salmon import (A$8.4-8.8/kg) than frozen import (A$3.2-3.4/kg). Imported aquaculture fish and imported hake prices are similar and lower (A$1.5-2/kg) than other products.

There were two missing observations for imported hake in Victoria (August 2015 and December 2017). For the purposes of the cointegration analysis, the prices relating to these missing values were interpolated using the Kalman function offered in the 'imputeTS' package in R (as for the other market data).

Table 4. Average monthly import quantity (kg), value (A$) and price (A$/kg) between January 2012 and September 2019.

Species	Data period	N	NAs	Quantity (kg)	Value (A$)	Price (A$/kg)
Victoria						
• Aquaculture	Jan 2012-Sep 2019	93	0	464,646	808,468	1.74
• Hake	Jan 2012-Sep 2019	91	2	146,530	294,927	2.01
• Other Fresh	Jan 2012-Sep 2019	93	0	369,017	2,620,308	7.10
• Other Frozen	Jan 2012-Sep 2019	93	0	1,503,665	5,119,579	3.40
• Salmon	Jan 2012-Sep 2019	93	0	86,564	733,522	8.47
New South Wales						
• Aquaculture	Jan 2012-Sep 2019	93	0	1,014,201	1,496,196	1.48
• Hake	Jan 2012-Sep 2019	93	0	633,436	962,696	1.52
• Other Fresh	Jan 2012-Sep 2019	93	0	476,275	3,217,166	6.75
• Other Frozen	Jan 2012-Sep 2019	93	0	2,614,330	8,414,758	3.22
• Salmon	Jan 2012-Sep 2019	93	0	307,532	2,711,225	8.82

The demand model also considered the impacts of imports over a longer period than the co-integration analysis. Separating out some of the different types of imports in the earlier data was not possible due to changes in the import classification system (e.g., the aquaculture species were only identifiable after 2012). For the purposes of the demand analysis import data were categorized into total frozen import quantities and total fresh import quantities (see Table 6).

The demand analysis also considered the impact of domestic farmed salmon production on Sydney Fish Market prices. Volume data for farmed salmon produced in Australia was also obtained from ABARES. Salmon is produced on aquaculture farmers and most supplied to the domestic market. The volume of Australian farmed salmon production has increased significantly over the past decade and may have affected the dynamics within the Sydney Fish Market and subsequently prices of products that the SESSF. Data for Australian farmed salmon supply was provided as a quarterly time series for the period 2013-19 and as total domestic production for the earlier years. The share of salmon supplied to the New South Wales market was derived by scaling the total domestic supply down on a per capita basis for this state (assuming equal consumption per capita across the country).

For the earlier years (2005-2012), the annual data were disaggregated into quarterly estimates based on the shares observed over the remained of the data (2103-2019) (Table 5). The salmon data was then transformed into monthly data by equally dividing the quarterly data by a factor of three as other more details information was not available.

Table 5. Quarterly distribution of domestic farmed salmon production, 2013-2019.

Quarter	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	0.2415	0.0092	26.248	< 2e-16	***
Quarter 2	-0.0265	0.0130	-2.034	0.0532	*
Quarter 3	-0.0093	0.0130	-0.713	0.4827	
Quarter 4	0.0698	0.0130	5.365	1.65E-05	***
R^2	0.7255				
Adjusted R^2	0.6912				

Note: *** Significantly different to zero at 1% level; ** Significantly different to zero at 5% level; * Significantly different to zero at 10% level

The prices included in the aggregate level demand analysis were converted into real values with 2020 as the base year (see Table 6).

Table 6. Average real prices, monthly quantities supplied and value shares of aggregated products on the New South Wales market (June 2005- September 2019)

Species	Real price		Quantity		Share	
	Mean (A$/kg)	**Std. Dev.**	**Mean (tonnes)**	**Std. Dev.**	**Mean (%)**	**Std. Dev.**
• **Sydney Fish Market**	6.53	1.27	242.28	43.3	4.7%	1.4%
• **Frozen imports**	3.14	0.41	4141.66	735.71	39.1%	5.4%
• **Fresh imports**	7.51	1.19	515.33	163.79	11.2%	1.6%
• **Australian farmed salmon**	14.62	0.72	1061.81	357.57	45.0%	6.3%

Market integration analysis

Market characteristics of seafood can be assessed by analysing the long-run relationship between prices of different fish products which are presumed to be part of one market (e.g., the Sydney Fish Market). Products are considered as part of one market if product prices have a stable long-run price relationship and hence follow the same price formation process. If there is an indication for the existence of a cointegrating relationship among product prices, the test for the Law of One Price (LOP) can determine whether these products are substitutes. If price transmission between products is perfect, price shocks for one segment of the market can affect prices of all other products within a market. Conversely, if no price transmission between products exists, the products remain unaffected by each other. In the case where price transmission between products is imperfect, changes in the price of one product only partially affect prices of the other products in the market, meaning that a degree of product differentiation persists.

To analyse a) the relationship between the prices of different fish species that are traded within the Sydney Fish Market, b) the impact imported fish prices on prices within the Sydney and Melbourne fish market, and c) the relationship of seafood prices between the Sydney and Melbourne fish markets bivariate Johansen tests (Johansen 1995) and the autoregressive distributed lag (ARDL) bounds tests (Pesaran and Shin 1999; Pesaran *et al.* 2001) were undertaken. Prior to performing the Johansen test the Augmented Dickey Filler (ADF) test (Fuller and Dickey 1979; Dickey 1981; Said and Dickey 1984) was conducted to ensure the preconditions of the price time series for this cointegration tests were fulfilled. The monthly import data ranged from January 2012 to September 2019 and hence was slightly shorter than the data set for the Sydney Fish Market (96 observations for each series). Hence, to test the relationship between imported seafood and seafood traded at the Sydney Fish Market was analysed using the shorter data set.

Augmented Dickey Fuller (ADF) Test

A precondition for the application of the Johansen test in time series analysis is that the time series must be integrated of order 1 (I(1)), meaning that the series follows a stochastic trend or a non-stationary process (a unit root). Stationarity means that the statistical properties of a time series (or the process generating it) do not change over time. Yet, this does not imply that the series cannot change over time, stationarity rather indicates that the way a time series changes does not vary over time.

The Augmented Dickey Fuller (ADF) test (Fuller and Dickey 1979; Dickey 1981; Said and Dickey 1984) was used to study the time-series properties of the available price data for all seafood products. The ADF test assesses autocorrelation in the error term, and by including the lagged values, the ADF formulation allows for testing higher order autoregressive processes (Dickey 1981).

Since the ADF test is sensitive to the selected lag length the Akaike information criteria (AIC) (Akaike 1974) and the Schwartz information criteria (SIC) (Schwarz 1978) were used to determine the optimal length of lags. Due to relatively short observation period for some species when comparing the prices at the Melbourne and Sydney fish markets (with the shortest number of overlapped observation = 67), we also used the Modified Akaike information criteria (MAIC) in addition to the standard information criteria above when conducting ADF tests comparing the two markets, since MAIC has known advantages for smaller sample sizes (Ng and Perron 2001).

The null hypothesis of the ADF test is that the series has a unit root (is non-stationary, I(1)). A p-value of less than 10% implies that the null hypothesis can be rejected, and that the series has no unit root (is stationary). A series is integrated of order one (i.e., I(1)) if the non-stationary series in levels can be made stationary by first differencing.

In the case that the null hypothesis (H0) is rejected it can be concluded that the process has no unit root, it is stationary and is characterised by a constant mean and variance. Should it be concluded that a series is stationary in its levels, it does not fulfil the prerequisite for the Johansen test and will be excluded from the analysis.

The ADF test has been implemented using the “ur.df” function in the package “urca” (Pfaff 2008) in R (R Core Team 2012) , with 3 model assumptions; in Model “none” neither an intercept nor a trend is included in the test regression. If the model is “drift” an intercept is added and if the model is “trend” both an intercept and a trend is added. The critical values were taken from Hamilton (1994) and Dickey and Fuller (1891). MAIC is not supported in ur.df function, thus Eview software was used to perform ADF tests with MAIC lag selection.

Johansen Cointegration Test

To assess the relationship between the price time series of different fish species traded in the Sydney and Melbourne fish market and across these markets and the impact of imported fish prices, the Johansen test (Johansen 1995) was used. The Johansen test has been widely applied in the context of seafood market analysis to assess whether there exists a long-run price relationship for non-stationary price time series (e.g., Asche *et al.* 2004; Nielsen 2005; Nielsen *et al.* 2007; Nielsen *et al.* 2009; 2012a; Schrobback *et al.* 2014; Hoshino *et al.* 2015).

The Johansen test is based on a unrestricted vector autoregressive (VAR) system where $y_{t,}$, a vector consisting of m price series to be tested for cointegration, is assumed to be generated by an unrestricted kth order vector autoregression in the levels of the variables:

$$y_t = \Pi_1 y_{t-1} + \cdots + \Pi_k y_{k-1} + \mu + \Omega D_t + \varepsilon_t, \quad (1)$$

with Π_i (i = 1, …, k) being *(m × m)* matrices of the parameters, μ as the constant term, Ω being the coefficient matrix of potentially deterministic regressors; D_t is an *(m × 1)* column vector containing deterministic regressors, such as a trend, and ε_t as the error term which is assumed to be normally distributed with a mean of zero.

The unrestricted VAR system in the levels of the variables can be expressed in the vector error correction model (VECM) form as:

$$\Delta y_t = \Gamma_1 \Delta y_{t-1} + \cdots + \Gamma_{k-1} \Delta y_{t-k+1} + \Pi \mathrm{y}_{t-k} + \mu + \psi D_t + \varepsilon_t \quad (2)$$

where $\Gamma_1 = -(I - \Pi_1 - \ldots \Pi_i)$ for $i = 1, \ldots k\text{-}1$, and $\Pi = -(I - \Pi_1 - \ldots \Pi_k)$. Π is considered as the long-run 'level' solution to equation (1). The matrix can be decomposed into $\Pi = \alpha\beta'$, the product of two $(m\times r)$ matrices, with α indicating the speed of adjustment coefficients and β as the matrix of long-run coefficients. The rank (r) of if the matrix Π determines how many linear combinations of the m price time series in y_t are stationary.

Results generated through the application of the Johansen test are sensitive to the selected optimal lag length (k) and the assumption about the relationship (e.g., constant, trend or none). The SIC (Schwarz 1978) was selected with preference as it usually returns the smallest lag length within a range of available selection criteria (e.g., AIC (Akaike 1974), Hannan-Quinn information criteria (HQIC) (Hannan and Quinn 1979))[4].

The outcome of the Johansen test are the Maximum Eigenvalue test and Trace test. In this study, the Trace test statistic was used to test for the number of significant vectors in the system. The Trace test is considered as superior to the Maximum Eigenvalue test in terms of power for small sample sizes (Lütkepohl *et al.* 2001). The null hypothesis of the Trace test implies that the rank equal zero (H0: $r = 0$). In case the null hypothesis cannot be rejected (i.e., test statistics is less than the critical values at

[4] The Johansen Test is sensitive to the selection of the lag within the VAR model. Lag information criteria are used to select the optimal lag length for the time series in the VAR model system. The lag information criteria are goodness of fit measures which assess how well the data fits the model. There are a range of lag information criteria available, in this study we only use SIC, HQIC and AIC (Akaike 1974; Schwarz 1978; Hannan and Quinn 1979). The aim of these criteria is to select the lag that minimizes the information loss (or lag order) within a model while ensuring a good model fit (Koehler and Murphree 1988). The criteria can return different results which is due to the ways model parameters are penalized by the respective criteria. SIC and HQIC penalize the loss of degrees of freedom stricter than the AIC therefore may return lower lag orders (Hannan and Quinn 1979; Koehler and Murphree 1988).

10%, 5%, or 1% level of significance), the result implies that no cointegration relationship between the prices of the two tested variables could be found and the testing procedure would stop here. Yet, in case the null hypothesis (H0: $r = 0$) is rejected (i.e., test statistics is larger than the critical values at 10%, 5%, or 1% level of significance), the test procedure continues by assessing the test statistics result for at most one cointegrating rank ($r < =1$). If the null hypothesis (H0: $r < = 1$) cannot be rejected (i.e., test statistics is less than the critical values at 10%, 5%, or 1% level of significance) it can be concluded that the two price time series are cointegrated or are I(1), meaning there is a long-run relationship between the price series. Should this result be found, the Law of One Price should be tested. This sequential procedure would continue until the null hypothesis for a specific rank is rejected.

Yet, in case the null hypothesis for the existence of a cointegrating rank of the *m*th variable within the matrix (H0: $r < = m$) is rejected (i.e., test statistics is larger than the critical values at 10%, 5%, or 1% level of significance) the results implies that the matrix has a full rank ($r = m$). This indicates that the tested times series (m) are stationary (i.e., I(0)), and hence they are not cointegrated and do not follow a long-run relationship. Possible outcomes and implications from the trace test (Johansen test approach) are summarized in Table 7.

Price pairs that were found to be cointegrated were tested for the Law of One Price. This test was used to determine the strength of the relationship between the two cointegrated prices. To perform the Law of One Price test the restriction $\beta' = (1, -1)$ was imposed on the matrix. The derived test statistic follows a chi-square distribution, χ^2, with one degree of freedom. The null hypothesis for the Law of One Price is that the pairs are substitutes. A rejection of the null indicates that the price pairs are likely cointegrated but not to a degree that the fish products are considered as substitutes from a market perspective. Studies that have previously tested the Law of One Price in a fisheries context using the Johansen approach include, for example, Al-Jabri *et al.* (2003), Asche *et al.* (2004), Nielsen *et al.* (2009), (Hoshino *et al.* 2015) and Ankamah-Yeboah *et al.* (2017)

Table 7. Possible outcomes and implications from the trace test (Johansen test approach)

Cointegration rank (r) (Number of cointegration vector (m))	Implications
r = 0 (Π is a zero matrix)	The system is non-stationary (I(0)). There is no long-run cointegration relationship between the time series of the variables. This is the only case in which non-stationarity is correctly removed simply by taking the first differences of the variables.
0 < r < m	The system is non-stationary (I(1)). There are r cointegrating vectors or r stationary linear combinations of the time series. Here, $\Pi = \alpha\beta'$, with α an $(m \times k)$ matrix of weights and β as an $(m \times k)$ matrix of parameters determining the cointegrating relationships.
r = m (Π is a full rank matrix)	VAR is a stationary meaning all variables are stationary in the first place in their levels. Linear combinations of the variables are stationary (I(0)).

Autoregressive distributed lag (ARDL) bounds test

While the Johansen test is a popular approach to identify cointegration characteristics of time series it is only suitable for large samples (e.g., 80 observations and more) and for time series that are non-stationary. For small samples the Johansen test could lead to biased results (Pesaran and Shin 1999; Pesaran *et al.* 2001).

The autoregressive distributed lag (ARDL) bounds test is an alternative to the Johansen test that has also found application in the context of market analyses of seafood products (Schrobback *et al.* 2014; Schrobback *et al.* 2019b).

Pesaran et al.'s (2001) ARDL bounds test approach was used to estimate the relationship between the Sydney and Melbourne fish markets (n = 67). Furthermore, the ARDL approach was used to test selected results which were found to be inconclusive using the Johansen test approach for price data of the Sydney Fish Market (n=173), as well as within imports (n=93).

The ARDL bounds test approach allows, unlike Johansen's test, to estimate the existence of a cointegration relationship between variables in levels independent of whether the data series are stationary in levels (I(0)) or in first differences (I(1)). Consequently, a unit root test is not a necessary prerequisite for the estimation approach selected in this study. The basic ARDL (p,q) model for the bi-variate case can be described as:

$$y_t = \alpha_o + \sum_{i=1}^{p} \delta_i y_{t-i} + \sum_{l=0}^{q} \mu_l x_{t-l} + \varepsilon_t \tag{3}$$

The price relationship between two fish species are assessed at a time and repeated for all possible combinations. Hence, y_t is the respective depended logged fish price series in year $t=1,\ldots T,$ and α_0 relates to the constant. $i= 1, \ldots, p$ and $l = 0,\ldots,q$ represent the lag order for y_{t-i}, the autoregressive part of the dependent variable, x_{t-l} the other (explanatory) logged fish price series being compared, and ε_t is an error term. Expressed as a basic error-correction model (Pesaran *et al.* 2001; Narayan and Narayan 2005) the empirical specification becomes:

$$\Delta y_t = \alpha_0 + \sum_{i=1}^{p} \delta_i \ \Delta y_{t-i} + \sum_{l=0}^{q} \mu_l \Delta x_{t-l} + \lambda_i y_{t-i} + \lambda_l x_{t-l} + \varepsilon_t \tag{4}$$

with Δ indicating the first difference operator, δ_i and μ_l as coefficients relating of the short-run dynamics of the model and λ_i and λ_l as coefficients for the long-run relationship among the variables.

The optimal lag order was determined using the SIC, AIC, HQIC and Adjusted R-square (Ng and Perron 2001). The estimation process was repeated using a constant, a constant and a trend, and neither constant nor trend.

Once the optimal ARDL model was chosen, the bounds test for level relationships was undertaken. This was conducted using the Wald test. The derived F-statistic provided information about the joint hypothesis for no cointegration among the price variables, that is: H0: $\lambda_i = \lambda_l = 0$. The F-statistic for each price pair was compared to critical values proposed by Pesaran *et al.* (2001) (see Table 8).

Table 8. Critical values for ARDL bounds test

Assumption: No intercept, no trend, k=1		
Level of significance	Lower bound - I(0)	Upper bound I(1)
1%	4.81	6.02
2.50%	3.88	4.92
5%	3.15	4.11
10%	2.44	3.28
Assumption: Intercept, no trend, k=1		
Level of significance	Lower bound - I(0)	Upper bound I(1)
1%	6.84	7.84
2.50%	5.77	6.68
5%	4.94	5.73
10%	4.04	4.78

Source: Pesaran *et al.* (2001).

The values in Table 8 represent the critical values for a large sample size (e.g., more than 80 observations). Using these values for smaller samples could lead to an overstatement of the relationship between time-series, since these critical values tend to be lower compared to critical values for small sample sizes. Narayan (2005) and Turner (2006) both proposed critical values for small samples. In this study Narayan's (2005) critical values (Table 9) were used for comparison with the derived F-statistic since these appear to be widely accepted as exemplified by their frequent use in the literature (e.g., Tang and Nair 2002; Chen 2009; Jayaraman and Choong 2009; Schrobback *et al.* 2014; Harraf and Kisswani 2019) and their integration in time-series analysis software, such as EViews 10 (2017).

Table 9. Critical values for ARDL bounds test for a small sample size (unrestricted intercept, no trend, n=30, k=1)

Level of significance	Lower bound - I(0)	Upper bound - I(1)
1%	8.170	9.285
5%	5.395	6.350
10%	4.290	5.080

Source: Narayan (2005)

If the derived F-statistic falls outside the critical bound values, a conclusive decision regarding cointegration of the tested price series can be made without knowing the order of integration of the regressor. For example, if the analysis shows that the estimated F-statistic is larger than the upper bound of the critical values, the null hypothesis of no cointegration is rejected and it can be concluded that there is a long-run relationship present among the variables. Conversely, if the calculated F-statistic is smaller than the lower bound value, the null hypothesis cannot be rejected. In the case that the F-statistic falls between the upper and lower bound values, the result is inconclusive.

The ARDL bounds test is undertaken twice for each pair with both variables once being the dependent and independent variable within the model. Hence, the ARDL bounds test will offer two results for each pair indicating the direction of the relationship between the price time series.

If a cointegrating relationship between the price series is detected, the Law of One Price can be tested to assess whether the price transmission among fish products is perfect. If that is the case it implies that producers of one seafood product (e.g., Gummy Shark) may be affected by supply and demand of another seafood product (e.g., Blue-eye Trevalla). Testing this relationship in a bivariate form can be expressed as:

$$y_t = \beta_1 + \beta_2 x_t + \varepsilon_t \tag{5}$$

Where y_t indicates the logged prices of one prawn product and x_t the logged prices of another. β_1 is the constant, β_2 is the coefficient of the independent variable and ε_t is the disturbance term. If a perfect price transmission between cointegrated price series exists, the joint hypothesis that $\beta_1 = 0$ and $\beta_2 = 1$ must hold. If this hypothesis holds, the results indicates that the prices or two products converge in the long-run, so that:

$$y_t = x_t + \varepsilon_t \text{ , } with\ \varepsilon_t : N(0, \sigma^2) \tag{6}$$

Following the approach by Greasley and Oxley (1997) we derived:

$$z_t = y_t - x_t \tag{7}$$

and used the Augmented Dickey Fuller (ADF) test to test the null hypothesis that *z* has a unit root. If this hypothesis is rejected (the series is stationary), the results indicate the likely presence of perfect price transmission or convergence of the price pairs.

Demand analysis

The relationship between price and quantity of a product is typically examined using price elasticities, which is defined as the percentage change in quantity demanded due to a one percent change in price. However, for highly perishable goods such as fish, supply can be very inelastic in the short term, with producers essentially acting as price takers (Barten and Bettendorf 1989). In an auction market such as the Sydney Fish Market, this means that wholesale traders offer prices (after augmentation with a wholesale margin) for a fixed quantity which are sufficiently low to provide an incentive for consumers to buy the available quantity (Barten and Bettendorf 1989). In such cases, the traders set the price as a function of the available quantities with a causality going from quantity to price (Barten and Bettendorf 1989). This implies that prices adjust to clear the available supply (Eales and Unnevehr 1994). The measure that can be used to examine the level of this relationship is the price flexibility, which corresponds with percentage change in price of a product as a result of a one percent change in quantity of the product supplied to a market.

To estimate the price flexibility of fish in this study a dynamic form of the Inverse Almost Ideal Demand System (IAIDS) (Eales and Unnevehr 1994) was developed, which incorporates lagged dependent and independent variables as well as an error correction component to capture the market dynamics (Karagiannis *et al.* 2000). IAIDS are a similar (but inverse) formulation to the original Almost Ideal Demand System (AIDS) (Deaton and Muellbauer 1980). IAIDS models have been developed for several fisheries applications internationally (e.g., Dedah *et al.* 2007; Lee and Kennedy 2008; Nielsen *et al.* 2012b; Thong 2012) and in Australia (e.g., Bose 2004; Schrobback *et al.* 2014; Schrobback *et al.* 2019b), although applications of the dynamic IAIDS model has been fairly limited for a recent Australian fisheries example (e.g., Schrobback *et al.* 2014).

The static IAIDS model can be described as:

$$S_{i,t} = \alpha_i + \sum_j \gamma_{ij} \ln q_{j,t} + \beta_i \ln Q_t + \mu_t \tag{8}$$

with $S_{i,t}$ being the value share across all fish products in the market of the *i*th fish product based on the total value of all fish products supplied to the market in time *t;* $q_{j,t}$ is the quantity supplied of each product *j* in time *t;* $\ln q_{j,t}$ is the quantity supplied at time *t* and $\ln Q_t$ is a total quantity index at time *t,* where:

$$\ln Q_t = \alpha_0 + \sum_j \alpha_j \ln q_{j,t} + 0.5 \sum_i \sum_j \gamma_{ij} \ln q_{i,t} \ln q_{j,t} \tag{9}$$

While static IAIDS models are used widely in the literature (e.g., Burton 1992; Dedah *et al.* 2007; Thong 2012; Huang 2015) there is evidence that price formation is a dynamic process (e.g., Tabarestani *et al.* 2017; Schrobback *et al.* 2019b), which implies that changes to prices due to changes on quantities do not only occur in the short-run but also in the long-run. Hence, the dynamic form of the IAIDS used in this study is given by:

$$\begin{aligned}\Delta S_{i,t} = \alpha_i + \sum_j \gamma_{ij} \Delta \ln q_{j,t} + \beta_i \Delta \ln Q_t + \omega_i S_{i,t-1} + \\ \sum_j \varphi_{ij} \Delta \ln q_{j,t-1} + \theta_i \Delta \ln Q_{t-1} + \lambda_i \mu_{it-1} + \epsilon_t\end{aligned} \tag{10}$$

with $\Delta S_{i,t}$ being the change in value share between time *t* and *t-1*, $\Delta \ln q_{j,t}$ is the change in quantity supplied between time *t* and *t-1, lnQ_t* is again the logged quantity index, and $\Delta \ln Q_t$ is the change in the quantity index between time *t* and *t-1*. The dynamic IAIDS model also incorporates $\lambda_i \mu_{it-1}$, where μ_{it-1} is the residual of the static IAIDS model (Karagiannis *et al.* 2000) and $-1 < \lambda_i < 0$. Embedding the residual of the static model into the dynamic model can be considered as short memory or linear habit formation, implying that last period's consumption patterns (e.g., one-lag) is allowed to condition current allocation decisions (Karagiannis *et al.* 2000). The value of λ_i also represents the speed of adjustment in reaching equilibrium, with $\lambda_i = -1$ indicating that the system is already in equilibrium.

The use of lagged quantity variables, like in previous studies by Park *et al.* (2004) and Grant *et al.* (2010), also has an additional advantage in that it helps overcome potential endogeneity between prices and quantities in the absence of other instrumental variables (Huang 2015).

The model does not include any dummy variables for seasonality. Most of the species exhibit seasonality in their harvest time (Smith *et al.* 1998a), with this seasonal pattern is captured in the quantity supplied. Household income or expenditure for food were not included in the demand model, although the quantity index (lnQ_t) in the IAIDS model allows the estimation of the scale flexibility which have similarities in interpretation as income elasticities (Park and Thurman 1999).

A logarithmic model specification has been used widely in demand analyses (e.g., Eales and Unnevehr 1993; Jaffry *et al.* 1999; Nielsen *et al.* 2012b; Thong 2012; Huang 2015) and was selected here as it provided the best fit for the available data.

The following restrictions on the estimated coefficients were imposed on the demand system:

Homogeneity: $\sum_j \gamma_{ij} = 0; \sum_j \varphi_{ij} = 0$

Symmetry: $\gamma_{ij} = \gamma_{ji}; \varphi_{ij} = \varphi_{ji}$ for all i $\neq$ j

The share equations for the different fish products were estimated by using Seemingly Unrelated Regression (SUR) (Zellner 1962) using the non-linear "systemsfit" package in R (Henningsen and Hamann 2007; R Core Team 2012). Only (*n-1*) equations can be included in the system to avoid perfect collinearity, with the equivalent parameters for the excluded equation (where required to estimate the own and cross-price flexibilities) subsequently derived using the adding up restrictions:

Adding-up: $\sum_i \alpha_i = 1, \ \sum_i \gamma_{ij} = 0, \ \sum_i \beta_i = 0$, and
$\sum_i \varphi_{ij} = 0, \ \sum_i \theta_i = 0$

As it is an inverse demand estimation, the sensitivities between price and quantity of fish products supplied were measured as flexibilities, rather than elasticities (Houck 1965). The short-run and long-run own- and cross-price flexibility respectively can be specified as:

$$f_{i,j}^S = -\delta_{ij} + \left[\gamma_{ij} + \beta_i\left(S_j - \beta_j \ln Q\right)\right]/S_i \quad (11)$$

$$f_{i,j}^L = -\delta_{ij} + \left[\left(\gamma_{ij} + \varphi_{ij}\right)/(1-\omega_i\right) + \left[(\beta_i + \theta_{i)}/(1-\omega_i)\right]\left(S_j - \left[(\beta_j + \theta_j)/(1-\omega_j)\right] \ln Q\right)\right]/S_i \quad (12)$$

where δ_{ij} is the Kronecker delta ($\delta_{ij} = 1$ for $i = j$, $\delta_{ij} = 0$, otherwise) (Eales and Unnevehr 1994; Thong 2012). The other terms are defined as before. The own-price flexibility describes the sensitivity of changes to the supply of a good on the price of the same good. If the absolute term of the own-price flexibility is less than 1 (i.e., $-1 < f_{i,j}^S < 0$), the demand for this commodity is defined as inflexible. The cross-price flexibility of a good is the percentage change in the price of the good due to a 1% change in the quantity supplied by another good. Cross-price flexibilities with a negative sign identify substitutes, while cross-price flexibilities with a positive sign identify complement goods (Houck 1965; Eales and Unnevehr 1993). A zero cross price relationship indicates that the demand of the goods is independent (Eales and Unnevehr 1993).

The short-term and long-term scale flexibilities respectively were derived by:

$$f_i^S = -1 + \frac{\beta_i}{S_i} \quad (13)$$

$$f_i^L = -1 + \frac{\left[(\beta_i + \theta_{i)}/(1-\omega_i)\right]}{S_i} \quad (14)$$

The scale flexibility measures the change in price when there is increase in overall consumption (which is also assumed equivalent to overall supply). The "base" of the scale flexibility is -1; at which point the demand for the good is homothetic, as demand for the species is directly proportional to the demand for all species. If the scale flexibility is less than -1, the commodity can be considered as a necessary goods, while it is considered a luxury goods if the scale flexibility greater than -1 (i.e., $-1 < f_i < 0$), (Eales and Unnevehr 1994; Park and Thurman 1999).

Results

Cointegration between Melbourne and Sydney fish markets

A comparison of the prices of the main species over time at both the Melbourne and Sydney fish markets is presented in Figure 4. At face value, the two series appear to be similar for the period of overlap (2000 to 2010 for most species).

Since our interest is to test the market linkage between the two markets using the information on prices, we selected the data period where both data sets overlap (2000 to 2010). Due to the lack of overlap during this period, Elephant Fish, Offshore Ocean Perch, and Royal Red Prawn were excluded for the further analyses of their stationarity and long-run price linkages between the Melbourne and Sydney fish markets (Figure 4). Sawshark was also excluded due to the small catch/value. Since the data for Gummy Shark and School Shark are reported as "Gummy School Shark" at the Melbourne fish market, we derive the price of the combined shark species for the Sydney data so that the price series in the two markets are comparable. A total 15 species were used for the subsequent analysis.

Figure 4. Nominal prices time series for key species at the Melbourne (MEL) and Sydney (SYD) fish markets.

Stationarity of the prices at both markets

A summary of the results of the ADF test for a stationary (unit root) process for the Melbourne fish market and the Sydney fish market are reported in Table D.1 and Table D.2, respectively in the Appendix. The ADF test results with SIC tends to select shorter optimal lag length and consequently the null hypothesis of unit root process was rejected at the 5% significance level (hence stationary at level, I(0)) for all species for the Melbourne market, and 12 species out of 15 species for the Sydney market. On the contrary, 10 species for Melbourne and 12 species for Sydney are rejected at level at the 5% significance with either AIC and MAIC, but are stationary at the first difference, I(1), meeting the prerequisite for the Johansen test.

Due to concerns about the possible over-rejection of the null hypothesis of a unit root for the price pairs with smaller sample sizes (5 species are n=67), it was decided to proceed with the ARDL bounds tests for those species to determine the price linkage between the two markets, since the ARDL bounds test does not rely on the I(1) assumption.

We proceed with the Johansen test of cointegration for the rest of the 10 species pairs, even though there were mixed results for the ADF tests for some species pairs depending on which criteria were used. Having stationary variables in the system is theoretically not an issue because the Johansen test has an ability to reveal whether the price series are stationary when the result indicates a full cointegration rank (for example, having a cointegration rank, r= 2 for bivariate case) (Johansen 1996; Hjalmarsson and Österholm 2007). Moreover, we also applied the ARDL bounds tests for those species with full rank so that our results won't be affected by the assumption on first-difference stationary.

Price linkage between Melbourne and Sydney

The Johansen tests for cointegration were first carried out for the price pairs of 10 species (sample size n=142) to investigate the price linkage between the Melbourne and Sydney fish markets. When the pairwise Johansen test results indicate the price series are cointegrated, the Law of One Price test was performed to identify the strength of the linkage.

The test results are presented in Table 10. For all pairwise cointegration tests, the null hypothesis of no cointegration vector with rank = 0 was rejected at the 5% level; hence, there is evidence of a long-term equilibrium relationship between the prices of the 10 species between the Melbourne and Sydney fish markets. However, the null hypothesis of a cointegration rank less than or equal to 1 was rejected (= full rank) for the following 6 species: Blue Grenadier, Blue Warehou, John Dory, Orange Roughy, Silver Trevally, Silver Warehou, which indicate these price series are indeed stationary. The residual diagnostics indicate no evidence of serial correction for the models considered, except for Mirror Dory where the Breusch and Godfrey (BG) Chi-square ($\chi 2$) test was rejected at 5% significance level, which indicates potential misspecification of the model.

Hjalmarsson and Österholm (2007) argue that one needs to be cautious about the interpretation of the Johansen cointegration test results since unit root tests cannot easily distinguish between a unit root and near unit root alternatives. We therefore repeated the cointegration tests with the ARDL bounds approach for those 6 species with full rank and Mirror Dory where potential misspecification of the model was found The Law of One Price test was carried out for the remaining 4 species by imposing the restriction $\beta' = (1, -1)$. The Law of One Price test for Mirror Dory between the two markets was rejected at 5% significance, while the pairwise tests for Gemfish, Gummy/School Shark, and Tiger Flathead prices were not. This indicates that there is a single market for Gemfish, Gummy/School Shark and Tiger Flathead (their prices in the Melbourne and Sydney markets can be treated as the same).

Table 10. Pairwise Johansen trace test and Law of One Price test results: Melbourne and Sydney fish markets

	No intercept no trend			Intercept only			BG
	r = 0	r ≤ 1	LOP	r = 0	r ≤1	LOP	χ^2
Blue Grenadier	32.57(4)***	10.97**		67.85(2)***	26.39		
Blue Warehou	84.03(2)***	22.53***		84.13(2)***	22.54		
Gemfish	21.35(6)**	7.52	0.22	21.65(6)**	7.6	0.03	13.55
Gummy/School Shark	32.77(3)***	6.08	1.55	33.48(3)***	6.68	1.49	24.86
John Dory	58.53(2)***	10.16**		58.63(2)***	10.31		
Mirror Dory	26.31(11)**	2.26	9.94***	60.12(5)***	3.81	14.59***	35.06**
Orange Roughy	36.93(3)***	12.39**		36.95(3)***	12.4		
Silver Trevally	55.05(4)***	9.55**		55.41(4)***	9.13		
Silver Warehou	54.17(3)***	14.35***		58.56(12)***	17.5		
Tiger Flathead	31.74(3)***	4.91	0.75	32.7(3)***	5.74	14.59	26.87

** indicates the significance at 5% significance level, *** indicate the significance at 1% level. BS = Breusch and Godfrey chi-square (χ2) test results for autocorrelation.

The ARDL bounds test was carried out for pairwise price series of 12 species, including 5 species where the number of observations was relatively small (n=67), as well as the 6 pairs that were found to be full rank (=stationary) based on the Johansen test results, and Mirror Dory. The ARDL test results (Table D.3 in Appendix D) are estimated in both directions. That is, the prices of the species in Melbourne is modelled against the prices in Sydney, and vice versa. As a consequence, there are two tests for each pair, and the Law of One Price requires cointegration to be established in each direction.

The results in Table D.3 indicate that the price of Ocean Perch in the two markets are not linked in the long term. The results for School Whiting and Silver Trevally are mixed and, therefore, inconclusive. The prices of the other 9 species in the two markets were found to be cointegrated. Of these species, the Law of One Price tests indicate that, apart from Blue-eye Trevalla, there is a single market for Blue Grenadier, Blue Warehou, Jackass Morwong, John Dory, Orange Roughy, Ling and Silver Warehou and Mirror Dory.

In summary, of the 15 species tested, 12 species were found to be linked in a long term, with the Law of One Price holding for 11 price pairs, indicating that there is a single market for these species (Table 11). These 11 species account for 57.8% of the SESSF landing by value, 62.1% by value in 2016/2017 fishing season. Since a single market was found to exist for the majority of the key SESSF species over the period of the available data, it is justifiable to use the Sydney market data for the subsequent demand analysis.

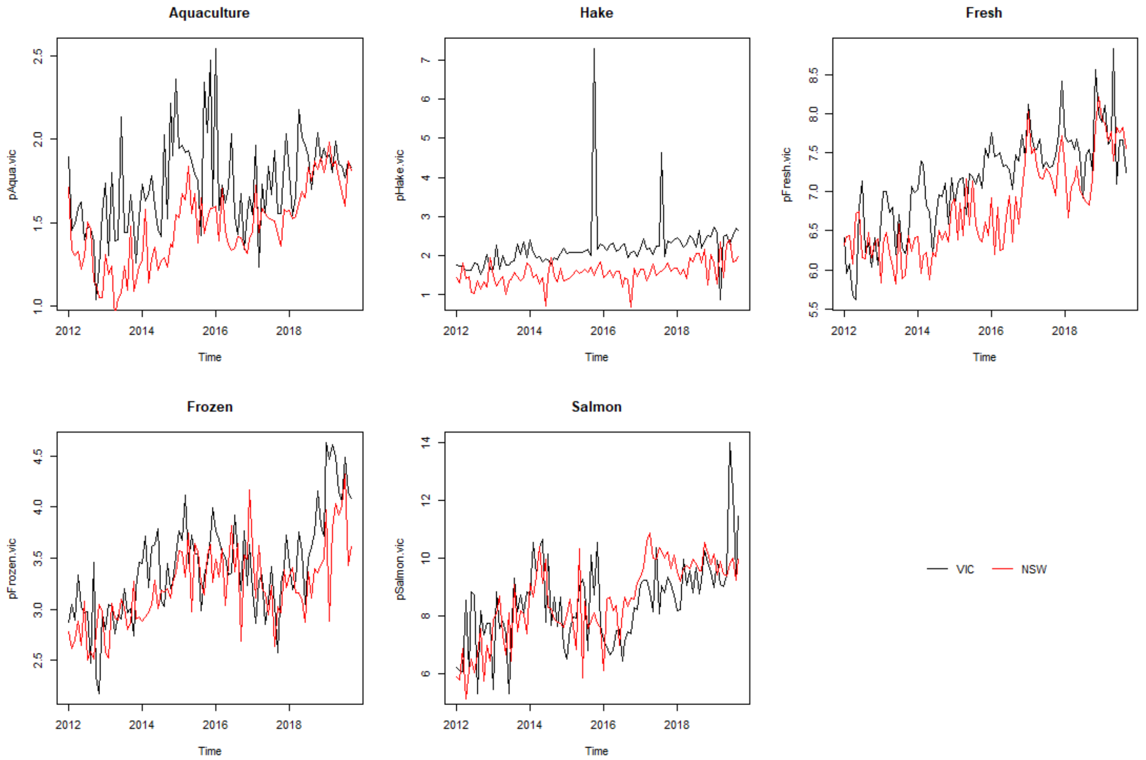
Table 11. Summary of cointegration tests (Johansen and ARDL bounds) and Law of One Price test results for the price series of 15 species between the Melbourne and the Sydney fish market.

Species	Johansen test	ARDL bounds test	LOP?
Blue-eye Trevalla		Cointegrated	No
Blue Grenadier	Cointegrated (Stationary)	Cointegrated	Yes
Blue Warehou	Cointegrated (Stationary)	Cointegrated	Yes
Gemfish	Cointegrated		Yes
Gummy School Shark	Cointegrated		Yes
Jackass Morwong		Cointegrated	Yes
John Dory	Cointegrated (Stationary)	Cointegrated	Yes
Mirror Dory	Cointegrated	Cointegrated	Yes
Pink Ling		Cointegrated	Yes
Ocean Perch		Not cointegrated	
Orange Roughy		Cointegrated	Yes
School Whiting	Cointegrated (Stationary)	Mixed (NC/I)	
Silver Trevally	Cointegrated (Stationary)	Mixed (C/NC)	
Silver Warehou	Cointegrated (Stationary)	Cointegrated	Yes
Tiger Flathead	Cointegrated		Yes

Cointegration between import prices

The price movement of imported species in New South Wales and Victoria over the time is shown in Figure 5. New South Wales (New South Wales) prices appear to be generally lower than those of Victoria but follow a similar trend. As these are composite groups, differences in prices may reflect slight differences in group composition.

Figure 5. Import prices of key species groups in New South Wales and Victoria, January 2012 to September 2019.



The ADF test results for a stationary process of the prices of the import groups in New South Wales and Victoria is presented in Table 12. Akaike (AIC) and Modified Akaike (MAIC) information criterion were used for the optimal lag selection.

The import prices of the majority of the import groups were found to be stationary at level, I(0), hence unsuitable for the Johansen cointegration tests. The cointegration relationship for the import species was therefore investigated using the ARDL bounds test approach.

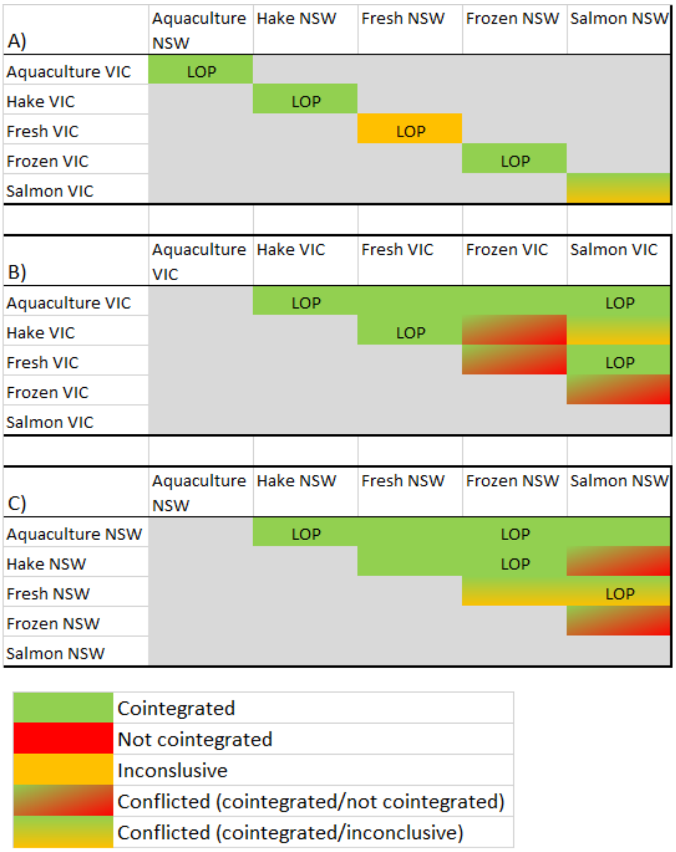
A summary of the ARDL bounds tests and Law of One Price tests for price pairs within imports is provided in Figure 6, and the detailed test results are presented in Table D.3. In general, the prices of imported fish in New South Wales and Victoria are more or less linked in the long term, although a few inconclusive and mixed results were found for some price pairs based on the ARDL results (Figure 6, Table D3).

Table 12. ADF test results for the price series of imported species based on Akaike (AIC) and Modified Akaike (MAIC) information criterion

	ADF based on AIC, Victoria				**ADF based on MAIC, Victoria**			
	Model	Lag	Level	First diff	Model	Lag	Level	First diff
Aquaculture	T	1	-4.604***		N	3	-2.369	-18.582***
Fresh	T	6	-3.709**		T	1	-5.067***	
Hake	N	5	2.491**		T	0	-9.858***	
Frozen	T	2	-2.799	-7.199***	N	2	0.495	-14.426***
Salmon	T	1	-4.552***		N	4	0.934	-16.922***
	ADF based on AIC, New South Wales				**ADF based on MAIC, New South Wales**			
	Model	Lag	Level	First diff	Model	Lag	Level	First diff
Aquaculture	T	1	-3.899**		T	4	-2.665	-16.414***
Fresh	T	1	-4.239***		T	1	-4.239***	
Hake	T	0	-9.487***		T	2	-4.713***	
Frozen	T	1	-4.205***		N	3	0.653	-17.300***
Salmon	N	4	0.635	-7.219***	C	4	-2.465	-20.531***

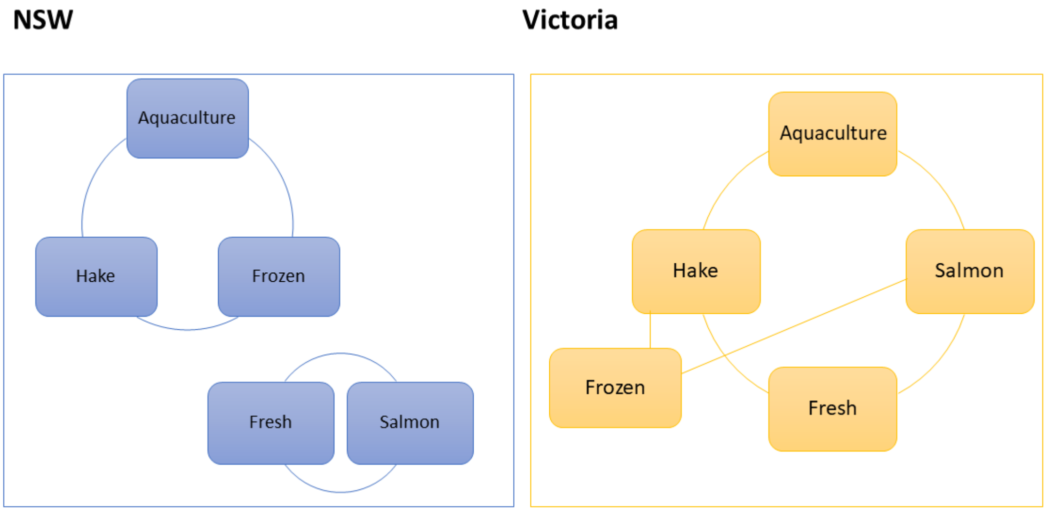
Notes: Critical values are based on Hamilton (1994) and Dickey and Fuller (1981). T= trend and linear constant, C= Constant but no trend, N= Neither constant nor trend. ** indicates that the null hypothesis of no unit root was rejected at 5% significance level, *** at 1% level, hence the series is concluded as stationary (no unit root). The optimal lag length was selected based on AIC and MIAC. Model T= Linear trend and constant, C= Constant only without trend, N = Neither trend nor constant included. We start with the most complex model (T) and if the coefficient is not significant move to the next complex model.

Figure 6. Summary of the cointegration relationships among import species.



However, not all species are close substitutes based on the Law of One Price test results. For example, the Law of One Price tests indicate that within New South Wales there are two separate groups that are close substitutes, the first group consists of aquaculture, hake, and other frozen fish; and the second group consists of salmon and other fresh fish (Figure 7). Since the prices of the first group are generally much lower than the prices of salmon and other fresh fish (Table 4), such price differences may be affecting the degree of substitutability. Such a separation however was not found in Victoria (Figure 7). Common observations in both states are as follows: aquaculture and hake; other frozen fish and hake; and other fresh fish and salmon are close substitutes in both states; while aquaculture and other fresh; and other fresh and other frozen fish are not close substitutes in both states. On the other hand, differences between the two states were found for the following pairs: aquaculture and other frozen fish are close substitute in New South Wales but are not in Victoria; other fresh fish and hake are close substitutes in Victoria but are not in New South Wales; other frozen fish and salmon are closes substitute in Victoria but are not in New South Wales (Figure 7).

Figure 7. The strength of the price linkages (substitution) among import species in New South Wales and Victoria.



Notes: The solid line indicates the price pair holds the Law of One Price (LOP), hence close substitute.

Cointegration between the Sydney market and imports

Descriptive statistics for the Sydney fish market data

Since the majority of the species had price data available after June 2005, the data period between June 2005 to September 2019 was selected to investigate cointegration relationship within the Sydney fish market. This equates to 172 observations for each species.

Descriptive statistics of the Sydney Fish Market data set for the selected data period are shown in Table 13. From the table, John Dory and Blue-eye Trevalla had the highest average unit price over the period of the data, averaging about A$11/kg whole-weight equivalent and A$10.00/kg whole-weight equivalent respectively. The lowest average unit prices over the period of the data were recorded for Blue Grenadier, Common Saw Shark and Silver Warehou, with a whole-weight equivalent price of about A$2.00/kg.

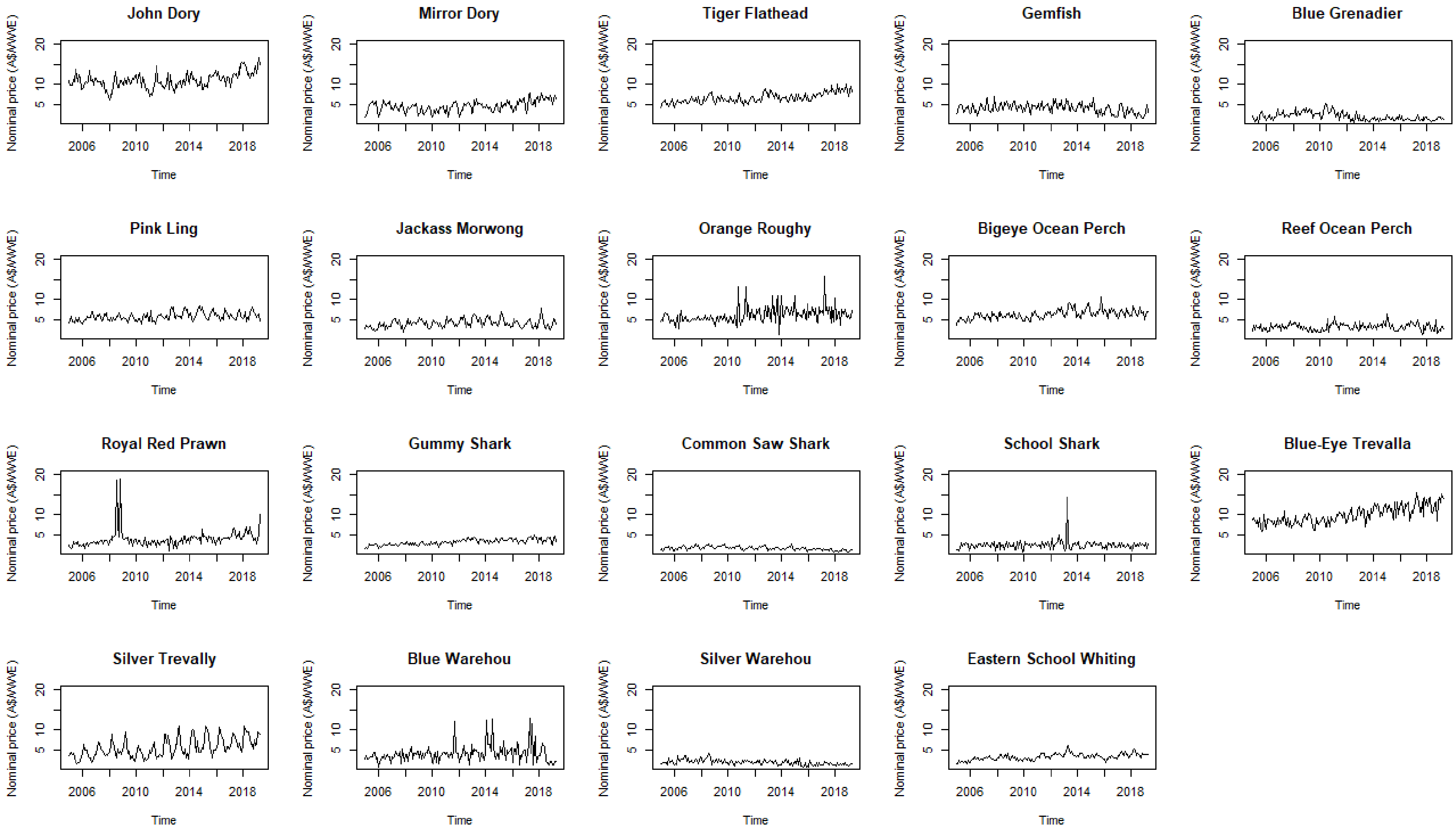
The individual dynamics of the 19 time series is shown in Figure 8. For some of the seafood species, prices were relatively flat, almost linear (e.g., Mirror Dory, Gemfish, Gummy Shark) while for other price series, greater fluctuations can be observed (e.g., John Dory, Orange Roughy and Silver Trevally).

Table 13. Descriptive statistics of nominal price data within the Sydney market (A$/whole-weight equivalent), June 2005 to September 2019.

Statistics	John Dory	Mirror Dory	Tiger Flathead	Gemfish	Blue Grenadier	Pink Ling	Morwong Jackass	Orange Roughy	Bigeye Ocean Perch	Reef Ocean Perch
Mean	10.98	4.59	6.70	4.05	2.05	5.82	4.12	6.14	6.35	3.19
Median	10.94	4.61	6.47	4.08	1.87	5.69	4.04	5.83	6.27	3.19
Maximum	16.76	7.96	10.13	6.93	5.34	8.41	7.83	15.82	10.71	6.42
Minimum	6.09	1.85	4.14	1.59	0.53	3.86	1.98	1.21	3.66	1.39
Std. Dev.	1.85	1.33	1.20	1.20	0.96	1.00	1.03	1.91	1.11	0.85
Skewness	0.28	0.04	0.52	0.09	0.91	0.50	0.55	1.63	0.62	0.57
Kurtosis	3.44	2.46	2.83	2.42	3.49	2.73	3.19	8.13	4.01	3.68
Jarque-Bera	3.55	2.09	7.93	2.66	25.57	7.66	9.02	264.67	18.39	12.64
Observations	172	172	172	172	172	172	172	172	172	172

Statistics	Royal Red Prawn	Gummy Shark	Common Sawshark	School Shark	Blue-eye Trevalla	Silver Trevally	Blue Warehou	Silver Warehou	Eastern School Whiting	[…]
Mean	3.95	3.21	1.69	2.48	10.00	5.56	4.10	1.97	3.30	[…]
Median	3.72	3.20	1.69	2.45	9.69	5.17	3.96	1.90	3.29	[…]
Maximum	19.00	4.97	2.89	14.41	15.43	11.05	12.97	4.21	6.07	[…]
Minimum	0.94	1.65	0.82	0.83	5.88	1.69	0.85	0.71	1.69	[…]
Std. Dev.	2.03	0.71	0.43	1.13	2.17	2.31	1.97	0.63	0.77	[…]
Skewness	4.77	0.10	0.27	6.77	0.40	0.58	2.05	0.74	0.41	[…]
Kurtosis	34.48	2.38	2.65	72.53	2.37	2.53	9.80	3.74	3.60	[…]
Jarque-Bera	7,755.40	3.07	3.01	35,960.00	7.31	11.24	451.10	19.58	7.47	[…]
Observations	172	172	172	172	172	172	172	172	172	[…]

Figure 8. Prices dynamics of various fish species during June 2005 to September 2019 within the Sydney market (A$/kg whole-weight equivalent).



Note: WWE for whole-weight equivalent.

ADF test results for the Sydney Fish Market and seafood imports to New South Wales

To test the stationary characteristics of the price time series the ADF test was undertaken. The unit root test for each logged nominal series was performed in levels and first differences for the assumptions regarding the inclusion of exogenous regressors, e.g., a) a constant, b) no constant and no trend (none), and c) a constant and a trend.

All data series were found to be non-stationary in levels but were stationary in first differences either under the assumption of no constant and no trend or assuming a constant, but not when a trend was included indicating that most series did not have that characteristic (Table C.1 and Table C.2 in the Appendix). We concluded that the non-stationary characteristic of the price time series under review fulfilled the precondition for the analysis using the Johansen test.

Bivariate Johansen test results for the Sydney Fish Market

A bivariate test was conducted for 170 price pairs of seafood traded at the Sydney Fish Market. The sample size for each of these time series was 172 observations. The results of these tests is shown in Table C.2., while Table C.3 in the appendix provides more detailed information about the bivariate cointegration test results for the Sydney Fish Market.

A summary of the results in Table 14 indicate that there are only a few species (19 out of 170 price pairs) traded within the Sydney Fish Market for which prices were found to be cointegrated (see Table 14, pairs with a “Yes” or “Yes*”). This indicates that prices of most SESSF species move independently within the market and do not affect each other. However, some significant relationships were identified, such as between the shark species, between John Dory and Silver Warehou, and between Tiger Flathead and Eastern School Whiting.

A price series that particularly stood out was that of Blue-eye Trevalla, which was found to be cointegrated with eight other species within the Sydney Fish Market and hence appears to be the species that mostly influences prices of other species in this market. The Law of One Price was identified to hold for 4 of the 8 species with which the price series of Blue-eye Trevalla is cointegrated (e.g., John Dory, Mirror Dory, Royal Red Prawn and Gummy Shark).

Interestingly, species that may be considered as relative substitutes, e.g., Gummy Shark, Common Sawshark, and School Shark, were found to have no long-run cointegration relationship of their prices.

The Johansen test was also used to assess the price relationship between seafood species traded at the Sydney Fish Market and imported seafood in Australia. Important to note is that only prices of seafood imported to New South Wales (Sydney) were used for this part of the analysis which account for the spatial aspects of fish markets. This analysis was based on 93 observations for each time series since the sample for import price data was significantly shorter than the data available for the Sydney Fish Market. The results are included in the lower part of Table 14. Further detail about the results for this part of the analysis is offered in Table C.4 in the appendix. The results indicate that there is a very high level of price cointegration between SESSF species traded within the Sydney Fish Market and imported seafood. While some of the SESSF species were only found to be cointegrated with one or two of the imported products (e.g., Tiger Flathead, Gemfish, Silver Warehou), other species appear to be price cointegrated will all imported seafood categories (e.g., Pink Ling, Royal Red Prawn).

Furthermore, the Law of One Price was found to hold for several pairs of Sydney Fish Market species and imported seafood (e.g., imported aquaculture and mirror dory, imported other fresh fish and Tiger Flathead) indicating a high degree of price transmission between these seafood products. These results indicate that the long-run price relationship of seafood traded at the Sydney Fish Market is much more affected by prices of imports than the prices of species supplied within Australia’s largest seafood market.

Table 14. Cointegration test results using the Trace test within the Johansen test approach

Sample sizes		N=172 for SFM																			N=93 for SFM, imports, AUS salmon				
	Fish Species Matrix	**JD**	**MD**	**TF**	**G**	**BG**	**PL**	**JM**	**OR**	**BOP**	**ROP**	**RRP**	**GS**	**CSS**	**SS**	**BET**	**ST**	**BW**	**SW**	**ESW**	**IA**	**IH**	**IOFRE**	**IOFRO**	**IS**
N=172	**John Dory (JD)**	X																							
	Mirror Dory (MD)	No	X																						
	Tiger Flathead (TF)	No	No	X																					
	Gemfish (G)	No	No	No	X																				
	Blue Grenadier (BG)	No [No|No]	No	No	No	X																			
	Pink Ling (PL)	No [No|In]	No	No	No	No	X																		
	Jackass Morwong (JM)	No [No|No]	No	No	No	No	No	X																	
	Orange Roughy (OR)	No	No	No	No	No	No	No	X																
	Bigeye Ocean Perch (BOP)	No	No	No	No	No	No	No	No	X															
	Reef Ocean Perch (ROP)	No [Yes|No]	No	No	No	No [In|No]	No	No [Yes*|In]	No [Yes*|No]	**Yes**	X														
	Royal Red Prawn (RRP)	No	No	No	No	No	No	No	No	No	No [Yes*|No]	X													
	Gummy Shark (GS)	No	**Yes***	No	No	No	No	No	No	Yes	No	No	X												
	Common Saw Shark (CSS)	No	No	**Yes**	No	No	No	No	No	No	No	No	No	X											
	School Shark (SS)	No [Yes|No]	No	**Yes**	No	**Yes**	No	No [In|Yes]	No	**Yes**	No [In|In]	No	No	No	X										
	Blue-Eye Trevalla (BET)	**Yes***	**Yes***	No	**Yes**	No	No	No	No	**Yes**	No	**Yes***	**Yes***	No	No [Yes|Yes]	X									
	Silver Trevally (ST)	No	No	No	No	No	No	No	No	No	**Yes**	No	No	No	No	**Yes**	X								
	Blue Warehou (BW)	No	No	No	No	No	No	No	No	No	No [In|In]	No	No	No	No [In|In]	No	No	X							
	Silver Warehou (SW)	**Yes***	No	No	No	No	No	No	**Yes**	No	No [No|In]	No	No	No	No	**Yes**	No	No	X						
	Eastern School Whiting (ESW)	No	No	**Yes**	No	No	No	No	**Yes**	No	No [In|Yes*]	No [In|Yes*]	No	No	No [In|In]	No	No	No [No|In]	No	X					
N=93	**Imported Aquaculture (IA)**	No	**Yes***	No	No	**Yes**	**Yes**	No	Yes	**Yes**	**Yes**	**Yes***	**Yes**	No	**Yes**	**Yes**	No	**YES**	No	No	X				
	Imported Hake (IH)	No	No [Yes|No]	No	No	No [No|No]	**Yes**	No	No [In|No]	**Yes**	**Yes**	**Yes**	No	No [No|In]	No [No|No]	No [Yes|No]	**Yes***	No	No [No|In]	No [In|No]	**Yes***	X			
	Imported Other Fresh Fish (IOFRE)	No	**Yes**	**Yes***	No	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes***	**Yes**	**YES**	**Yes**	No	No	**Yes***	X		
	Imported Other Frozen (IOFRO)	No	**Yes***	No	No	No [No|No]	**Yes**	No	**Yes**	No [No|No]	No	**Yes**	**Yes**	No	No [No|Yes*]	**Yes***	**Yes***	No	No	No	**Yes**	No	No	X	
	Imported Salmon (IS)	No	**Yes***	No	Yes	No [Yes|No]	**Yes**	**Yes**	**Yes**	No [No|No]	**Yes**	**Yes**	No	**Yes**	**Yes**	**Yes**	No	No [No|No]	**Yes**	No	No	**Yes**	No	No	X

Order of the variables tested is irrelevant within the Johansen test approach

Notes: "No" marked in black colour indicates that the pair is not cointegrated. "No" marked in red colour indicates a full rank result. Pair was tested again using the ARDL approach and results are shown in brackets. "Yes*" indicates cointegration of the pair and the Law of One Price was found to hold. "Yes" indicates that pair is cointegrated but Law of One Price did not hold. "No [Yes|No]" means that for the full rank results of the Johansen test, the ARDL bounds test identified that the pair was found cointegrated in one direction but not if dependent and independent variables were switched around. "In" means inconclusive result obtained through the application of the ARDL bounds test. Detailed results are presented in the appendix.

The analysis also revealed that the result for some price pairs was a full rank (*r=m*) (see Table 14, "No" marked in red colour), indicating that the time series was stationary and were not fulfilling the precondition for the application of the Johansen test. For these pairs (e.g., Blue Grenadier/John Dory, Pink Ling/John Dory), the analysis was repeated using the ARDL bounds test approach, which is not sensitive to the stationary characteristic of a time series. The summarised results for the ARDL bounds tests presented in Table 14 in red coloured brackets and are supplemented by detailed results in Table C.5 and Table C.6 in the appendix.

The ARDL bounds test results for the selected pairs indicate that some of the price pairs were cointegrated (e.g., Blue-eye Trevalla and School Shark in both directions, School Shark and John Dory in only one direction) while other pairs were either inconclusive (e.g., Eastern School Whiting and School Shark in both directions, Reef Ocean Perch and Blue Grenadier in only one direction) or did not hold a long-run relationship (e.g., Jackass Morwong and John Dory in both directions, Imported Hake and Orange Roughy in only one direction). Overall, the findings from the Johansen test results were confirmed by undertaking the additional tests for the pairs with a full rank result (from Johansen test).

Demand analysis

Impact of imports and domestic aquaculture on Sydney Fish Market prices

An "aggregated" model was developed including imports (fresh and frozen), domestic farmed salmon and the key species in the Sydney Fish Market identified above. Given the small size of the shares of individual species on the Sydney Fish Market compared with the level of imports and domestic farmed salmon, the domestic wild-caught species were aggregated into high and low value species as outlined in Table 2.

Determining the appropriate lag length to use in the IAIDS model is important to ensure the dynamics of the system are full captured. From the earlier cointegration analysis, most species and species groups became stationary with 3 or 4 lags (see above and Tables C1, C2, D1, D2). There is also a trade-off, however, between additional lags and loss of degrees of freedom.

The system was estimated with 1, 2 and 3 lags, and the AIC used to determine the optimal system. From Table 15, the system AIC was lowest with 1 lag. While the system R^2 was also lowest for 1 lag, this doesn't allow for the effects of the increased number of parameters estimated with a higher number of lags (which generally inflates the R^2 estimate) and the subsequent loss of degrees of freedom. Based on the AIC, 1 lag was chosen as the most appropriate.

Table 15. System level statistics with different lag lengths, aggregated model

Number of lags	System AIC	System R^2	Number of observations	Degrees of Freedom
1	-5381.9	0.845	171	156
2	-5334.2	0.855	170	149
3	-5301.2	0.881	169	142

Estimating the IAIDS system requires the exclusion of one equation. In this case, the low valued species equation was excluded from the estimation process. The estimated parameters for the system can be seen in Table 16. As noted previously, the equivalent parameters of the excluded equation can be derived from the adding up and symmetry conditions. This was done for the purposes of estimating the own and cross-price flexibilities.

The adjusted R^2 for each of the equations ranged from 0.73 to 0.84, suggesting the models provided reasonable estimates of the expenditure shares for each group. Further, $-1 < \lambda_i < 0$ for each model, and all values of λ_i were statistically significant. The parameter λ_i also represents the fraction of the disequilibrium that is adjusted in each period (Assarsson 1996). From Table 16, between 25% and 35% of the disequilibrium is adjusted each month, consistent with the previous cointegration analysis that indicates that most species are stationary (i.e., in the long-run equilibrium) after 3-4 months, all else being equal.

Table 16. Estimated IAIDS coefficients, aggregated model

	Fresh			Frozen			Salmon			High Value		
	Estimate	Std. Error		Estimate	Std. Error		Estimate	Std. Error		Estimate	Std. Error	
$\boldsymbol{\alpha_i}$	0.000	0.001		0.000	0.001		0.001	0.001		0.000	0.000	
$\boldsymbol{\omega_i}$	-0.472	0.050	***	-0.491	0.047	***	-0.505	0.048	***	-0.503	0.066	***
$\boldsymbol{\gamma_{i,fresh}}$	0.068	0.004	***	-0.024	0.004	***	-0.039	0.004	***	0.000	0.001	
$\boldsymbol{\varphi_{i,fresh}}$	0.034	0.005	***	-0.016	0.004	***	-0.014	0.004	**	-0.002	0.001	
$\boldsymbol{\gamma_{i,frozen}}$	-0.024	0.004	***	0.163	0.011	***	-0.139	0.009	***	-0.003	0.002	
$\boldsymbol{\varphi_{i,frozen}}$	-0.016	0.004	***	0.073	0.014	***	-0.059	0.011	***	-0.002	0.002	
$\boldsymbol{\gamma_{i,salmon}}$	-0.039	0.004	***	-0.139	0.009	***	0.201	0.009	***	-0.018	0.002	***
$\boldsymbol{\varphi_{i,salmon}}$	-0.014	0.004	**	-0.059	0.011	***	0.088	0.014	***	-0.009	0.002	***
$\boldsymbol{\gamma_{i,Highvalue}}$	0.000	0.001		-0.003	0.002		-0.018	0.002	***	0.023	0.002	***
$\boldsymbol{\varphi_{i,Highvalue}}$	-0.002	0.001		-0.002	0.002		-0.009	0.002	***	0.013	0.002	***
$\boldsymbol{\gamma_{i,Lowvalue}}$	-0.004	0.001	**	0.004	0.002		-0.005	0.002	*	-0.002	0.001	*
$\boldsymbol{\varphi_{i,Lowvalue}}$	-0.001	0.002		0.005	0.003		-0.006	0.003	+	-0.001	0.001	
$\boldsymbol{\beta_i}$	-0.016	0.005	**	0.066	0.013	***	-0.032	0.011	**	-0.009	0.003	***
$\boldsymbol{\theta_i}$	-0.004	0.005		0.036	0.013	**	-0.023	0.011	*	-0.003	0.003	
$\boldsymbol{\lambda_i}$	-0.246	0.045	***	-0.301	0.042	***	-0.309	0.043	***	-0.356	0.066	***
Adj R2	0.730			0.837			0.843			0.745		

Notes: *** Significant at 0.1%; ** significant at 1%; * significant at 5%; + significant at 10%

The derived own and cross-price flexibilities for the aggregated species groups are shown in Table 17. All own-price flexibilities are less than one, indicating that prices change less than proportionally with quantity supplied. All scale flexibilities were significantly different to -1; with frozen imports identified as a luxury good and the others considered necessities. The low valued wild-caught group had the highest (negative) scale flexibility, indicating that a general increase in fish consumption would lead to a reduction in the share of the lower valued species (i.e., the increase in consumption would largely be in the other categories, particularly frozen fish).

Most cross-price flexibilities were negative, indicating a degree of substitution between the species. That is, if the quantity of domestic farmed salmon on the market increased, then this would not only decrease its own price, but also the prices of the other groups. Domestic farmed almon is highly substitutable for the wild-caught species on the market, with the cross-price flexibilities being less than -1 for both high and low valued species. This indicates that a 1 percent increase in salmon to the market results in a greater than 1 per cent decrease in the price of these other species – a greater impact than on the price of salmon itself (a 0.6 percent decrease).

Imports of fresh fish were found to have no impact on the high valued domestic wild-caught species, but did negatively affect the prices of lower valued species (Table 17). Several of the lower valued species are sold through supermarkets and fish and chip shops (Ruello and Associates Pty Ltd 2002), where competition with fresh imports may be higher.

Counter to expectations, a positive cross-price flexibility was estimated between frozen imports and low valued wild-caught species (Table 17). That is, increasing the quantity of frozen imports increases the price of these lower valued species. Conversely, frozen imports were found to have no significant impact on the prices of higher valued domestic wild-caught species. This latter results is consistent with findings of Ruello (2011), who suggested that differences in marketing chains reduced or eliminated direct competition between frozen imports and domestic catch. The underlying rationale of the former result, however, is less obvious.

Table 17. Estimated own, cross price and scale flexibilities at the mean: Imports, Domestic farmed almon and Sydney Fish Market species

	Fresh		Frozen		Salmon		High value		Low value		Scale	
Short-run												
Fresh	**-0.446**	***	-0.139	*	-0.484	***	-0.023		-0.055	***	-1.146	+++
	(0.048)		(0.074)		(0.069)		(0.018)		(0.018)		(0.047)	
Frozen	-0.004		**-0.676**	***	-0.202	***	0.019		0.032	**	-0.831	+++
	(0.028)		(0.072)		(0.071)		(0.013)		(0.014)		(0.033)	
Salmon	-0.112	***	-0.269	***	**-0.619**	***	-0.051	***	-0.020	***	-1.072	+++
	(0.015)		(0.041)		(0.047)		(0.007)		(0.007)		(0.024)	
High value	-0.120		0.070		-1.017	***	**-0.390**	***	-0.138	**	-1.255	+++
	(0.082)		(0.164)		(0.150)		(0.059)		(0.050)		(0.050)	
Low value	-0.578	***	0.688	*	-1.075	***	-0.301	***	**-0.641**	***	-1.722	+++
	(0.178)		(0.360)		(0.349)		(0.107)		(0.159)		(0.236)	
Long-run												
Fresh	**-0.422**	***	-0.176	**	-0.446	***	-0.030		-0.051	***	-1.125	+++
	(0.049)		(0.072)		(0.068)		(0.018)		(0.021)		(0.048)	
Frozen	-0.016		**-0.696**	***	-0.172	**	0.018		0.040	***	-0.825	+++
	(0.027)		(0.069)		(0.069)		(0.013)		(0.015)		(0.031)	
Salmon	-0.104	***	-0.246	***	**-0.652**	***	-0.051	***	-0.027	***	-1.081	+++
	(0.014)		(0.041)		(0.046)		(0.007)		(0.009)		(0.023)	
High value	-0.151	*	0.056		-0.997	***	**-0.350**	***	-0.134	***	-1.229	+++
	(0.084)		(0.158)		(0.143)		(0.063)		(0.056)		(0.056)	
Low value	-0.652	***	0.852	**	-1.209	***	-0.295	**	**-0.519**	***	-1.823	+++
	(0.195)		(0.388)		(0.364)		(0.124)		(0.162)		(0.245)	

Notes: *** Significantly different to zero at 1% level; ** Significantly different to zero at 5% level; * Significantly different to zero at 10% level; For Scale flexibilities: +++ Significantly different to -1 at 1% level, ++ Significantly different to -1 at 5% level; + Significantly different to -1 at 10% level. Figures in parentheses are standard errors.

Market interactions between key species on the Sydney Fish Market

As noted previously, given the number of species under consideration it was not possible to run a single dynamic model of price formation on the Sydney Fish Market including all species. From above, we had identified three separate groups of species based on based on their prices over the period of the data, and merged the two high valued groups into a single group for the purposes of estimating the aggregate demand models. For the species level analysis, we again use these groups as the basis for the analysis, estimating the price flexibilities for species within each group with the effects of species in the other group being included as a composite quantity.

The appropriate lag length for the dynamic models was also estimated empirically as with the aggregated demand model. The earlier co-integration analysis found an optimal lag length of three for most individual species. Comparing three, two and one lags in the dynamic systems, one lag was found to the most appropriate based on the AIC for both high and low value species groups (Table 18).

Table 18. System level statistics with different lag lengths, species level models. DF = Degree of freedom

Number of lags	High Value Species				Low Value Species			
	System AIC	System R^2	N. Obs.	DF	System AIC	System R^2	N. Obs.	DF
1	-7563.8	0.866	171	150	-10930.9	0.838	171	148
2	-7506.2	0.875	170	140	-10833.9	0.843	170	137
3	-7449.0	0.881	169	130	-10729.5	0.848	169	126

The estimated coefficients for each of species' models are given in Table 19 for the high value species group and Table 20 for the low value species group. The model fits, represented by the adjusted R^2 term, were generally higher for the high value species than the low value species models, with the former ranging from 0.62 (Orange Roughy) to 0.93 (Blue-eye Trevalla) and the latter ranging from 0.45 (Silver Warehou) to 0.86 (Mirror Dory). Most of the coefficients in the high value species group were also statistically significant, whereas fewer coefficients for the low value species group were significant, indicating that interactions are stronger between the high value species than the low value species.

As with the aggregate model, $-1 < \lambda_i < 0$ for each model, and all values of λ_i were statistically significant. The fraction of the disequilibrium that is adjusted in each period varied by species. In particular, Orange Roughy, Blue Grenadier and Gummy Shark had high adjustment rates, indicating that prices converge to an equilibrium level rapidly. In contrast, John Dory, Mirror Dory and Flathead had relatively slower adjustment rates, with equilibrium requiring three or more months to be achieved.

The derived scale, own and cross-price flexibilities are given in Table 21 for the high value species and Table 22 for the low value species, and own and cross-price flexibilities are summarised in Table 23 and Table 24 for the high and low value species groups respectively. In the latter tables, only significant own and cross-price flexibilities are presented.

From the scale flexibilities (Table 21 and Table 22), most species were considered to exhibit homothetic preferences. While the values of the scale flexibilities were generally less than -1, these were mostly not significantly different to -1. Only John Dory was found to be a necessity in the short term only, and Jackass Morwong a necessity in the long run. The "other" species group was also found to be a necessity, being low value and low quantity species. Bigeye Ocean Perch was found to be a luxury good in both the short term and longer term.

The own-price flexibilities in Table 23 and Table 24 (i.e., the diagonals of the table) indicate that the relationship between own prices and own quantities supplied for all individual species at the Sydney Fish Market is negative as expected. That is, an increase in the quantity supplied negatively affects the price of the same species. This relationship varied substantially between species. For example, gummy shark was found to have a zero own-price flexibility – such that changes in quantities would not affect the price received. This most likely reflects the small proportion of the catch sold through the Sydney Fish Market, with prices being formed on other markets. In contrast, most species had an own-price flexibility in the range from -0.3 to -0.5, indicating that an increase in quantity landed would result in a less than proportional reduction in price, and an overall increase in total sales value (or revenue from the perspective of the fisher).

The own-price flexibilities for most species were also found to be larger in the long-run compared to the short-run which indicates that changes in the quantity of a product affect its price slightly stronger in the long-run than in the short-run. That is, initial price changes due to changes in supply are less than the final price change, as the market takes time to adjust to the new level of supply.

Table 19. Estimated IAIDS coefficients, High valued species

	John Dory			Tiger Flathead			Orange Roughy			Bigeye Ocean Perch			Blue-eye Trevalla			Pink Ling			Silver Trevally		
	Estimate	Std. Error		Estimate	Std. Error		Estimate	Std. Error		Estimate	Std. Error		Estimate	Std. Error		Estimate	Std. Error		Estimate	Std. Error	
$\boldsymbol{\alpha_i}$	0.000	0.001		0.000	0.002		0.000	0.001		0.000	0.000		0.000	0.001		0.000	0.001		0.000	0.001	
$\boldsymbol{\omega_i}$	-0.580	0.071	***	-0.592	0.055	***	-0.909	0.068	***	-0.670	0.065	***	-0.539	0.064	***	-0.566	0.060	***	-0.675	0.069	***
$\boldsymbol{\gamma_{i,JohnDory}}$	0.041	0.002	***	-0.010	0.002	***	0.000	0.000		-0.002	0.001	.	-0.004	0.001	***	-0.010	0.001	***	0.000	0.001	
$\boldsymbol{\varphi_{i,JohnDory}}$	0.021	0.003	***	-0.004	0.002		0.000	0.000		-0.003	0.001	**	-0.003	0.001	*	-0.004	0.002	**	0.000	0.001	
$\boldsymbol{\gamma_{i,TigerFlathead}}$	-0.010	0.002	***	0.156	0.006	***	-0.002	0.001	*	-0.017	0.001	***	-0.021	0.003	***	-0.038	0.003	***	-0.010	0.002	***
$\boldsymbol{\varphi_{i,TigerFlathead}}$	-0.004	0.002		0.087	0.011	***	0.000	0.001		-0.009	0.002	***	-0.012	0.003	***	-0.027	0.003	***	-0.005	0.002	*
$\boldsymbol{\gamma_{i,OrangeRoughy}}$	0.000	0.000		-0.002	0.001	*	0.004	0.000	***	0.000	0.000		0.000	0.001		-0.001	0.001	.	0.000	0.000	
$\boldsymbol{\varphi_{i,OrangeRoughy}}$	0.000	0.000		0.000	0.001		0.004	0.001	***	-0.001	0.000	*	0.001	0.001		0.000	0.001		-0.001	0.000	
$\boldsymbol{\gamma_{i,BigeyeOceanPerc}}$	-0.002	0.001	.	-0.017	0.001	***	0.000	0.000		0.040	0.001	***	-0.005	0.001	***	-0.007	0.001	***	-0.003	0.001	***
$\boldsymbol{\varphi_{i,BigeyeOceanPerc}}$	-0.003	0.001	**	-0.009	0.002	***	-0.001	0.000	*	0.025	0.003	***	-0.003	0.001	***	-0.004	0.001	***	-0.002	0.001	*
$\boldsymbol{\gamma_{i,BlueeyeTrevalla}}$	-0.004	0.001	***	-0.021	0.003	***	0.000	0.001		-0.005	0.001	***	0.067	0.002	***	-0.012	0.002	***	-0.004	0.001	***
$\boldsymbol{\varphi_{i,BlueeyeTrevalla}}$	-0.003	0.001	*	-0.012	0.003	***	0.001	0.001		-0.003	0.001	***	0.038	0.005	***	-0.009	0.002	***	-0.001	0.001	
$\boldsymbol{\gamma_{i,PinkLing}}$	-0.010	0.001	***	-0.038	0.003	***	-0.001	0.001	+	-0.007	0.001	***	-0.012	0.002	***	0.091	0.003	***	-0.002	0.001	
$\boldsymbol{\varphi_{i,PinkLing}}$	-0.004	0.002	**	-0.027	0.003	***	0.000	0.001		-0.004	0.001	***	-0.009	0.002	***	0.054	0.006	***	-0.002	0.001	
$\boldsymbol{\gamma_{i,SilverTrevally}}$	0.000	0.001		-0.010	0.002	***	0.000	0.000		-0.003	0.001	***	-0.004	0.001	***	-0.002	0.001		0.032	0.001	***
$\boldsymbol{\varphi_{i,SilverTrevally}}$	0.000	0.001		-0.005	0.002	*	-0.001	0.000		-0.002	0.001	*	-0.001	0.001		-0.002	0.001		0.016	0.003	***
$\boldsymbol{\gamma_{i,LowValue}}$	-0.014	0.002	***	-0.057	0.005	***	-0.001	0.001		-0.005	0.002	***	-0.020	0.003	***	-0.020	0.003	***	-0.012	0.002	***
$\boldsymbol{\varphi_{i,LowValue}}$	-0.008	0.003	**	-0.030	0.008	***	-0.004	0.001	***	-0.003	0.002	.	-0.010	0.004	*	-0.007	0.004		-0.006	0.003	*
$\boldsymbol{\beta_i}$	-0.010	0.004	*	0.008	0.012		0.004	0.007		0.011	0.003	***	0.002	0.008		-0.001	0.007		0.008	0.006	
$\boldsymbol{\theta_i}$	0.000	0.005		0.006	0.012		-0.002	0.007		0.007	0.003	*	0.007	0.008		-0.005	0.007		0.003	0.006	
$\boldsymbol{\lambda_i}$	-0.335	0.058	***	-0.377	0.065	***	-0.834	0.101	***	-0.553	0.079	***	-0.452	0.077	***	-0.542	0.077	***	-0.450	0.078	***
Adj R^2	0.824			0.845			0.622			0.926			0.871			0.901			0.808	0.824	

Notes: *** Significant at 0.1%; ** significant at 1%; * significant at 5%; + significant at 10%.

$\Delta S_{i,t} = \alpha_i + \sum_j \gamma_{ij} \Delta \ln q_{j,t} + \beta_i \Delta \ln Q_t + \omega_i S_{i,t-1} + \sum_j \varphi_{ij} \Delta \ln q_{j,t-1} + \theta_i \Delta \ln Q_{t-1} + \lambda_i \mu_{it-1} + \epsilon_t$

Table 20. Estimated IAIDS coefficients, Low valued species

	Blue Grenadier			Eastern School Whiting			Gemfish			Gummy Shark			Jackass Morwong			Mirror Dory			Silver Warehou			Other		
	Estimate	Std. Error		Estimate	Std. Error		Estimate	Std. Error		Estimate	Std. Error		Estimate	Std. Error		Estimate	Std. Error		Estimate	Std. Error		Estimate	Std. Error	
α_i	0.000	0.000		0.000	0.001		0.000	0.000		0.000	0.000		0.000	0.001		0.000	0.001		0.000	0.000		0.000	0.000	
ω_i	-0.867	0.086	***	-0.636	0.074	***	-0.456	0.075	***	-0.641	0.122	***	-0.600	0.075	***	-0.517	0.074	***	-0.613	0.080	***	-0.856	0.078	***
$\gamma_{i,BlueGrenadier}$	0.001	0.000	***	0.000	0.000		0.000	0.000		0.000	0.000		0.000	0.000		0.000	0.000		0.000	0.000		0.000	0.000	
$\varphi_{i,BlueGrenadier}$	0.001	0.000	***	0.000	0.000		0.000	0.000		0.000	0.000		0.000	0.000		0.000	0.000		0.000	0.000		0.000	0.000	+
$\gamma_{i,ESchoolWhiting}$	0.000	0.000		0.045	0.002	***	-0.002	0.001	*	0.000	0.000		-0.002	0.001	*	-0.003	0.001	***	-0.001	0.001	*	-0.001	0.001	
$\varphi_{i,ESchoolWhiting}$	0.000	0.000		0.024	0.004	***	-0.001	0.001		0.001	0.000	*	-0.001	0.001		-0.004	0.001	***	-0.001	0.001	*	0.000	0.001	
$\gamma_{i,Gemfish}$	0.000	0.000		-0.002	0.001	*	0.015	0.001	***	0.000	0.000		-0.003	0.001	***	0.000	0.001		0.000	0.000		0.000	0.000	
$\varphi_{i,Gemfish}$	0.000	0.000		-0.001	0.001		0.008	0.001	***	0.000	0.000		-0.002	0.001	***	0.002	0.001	**	0.001	0.000	*	0.000	0.000	
$\gamma_{i,GummyShark}$	0.000	0.000		0.000	0.000		0.000	0.000		0.004	0.000	***	0.000	0.000		0.000	0.000		0.000	0.000		-0.001	0.000	***
$\varphi_{i,GummyShark}$	0.000	0.000		0.001	0.000	*	0.000	0.000		0.003	0.001	***	0.000	0.000	+	0.000	0.000		0.000	0.000	*	-0.001	0.000	*
$\gamma_{i,JackassMorwon}$	0.000	0.000		-0.002	0.001	*	-0.003	0.001	***	0.000	0.000		0.029	0.001	***	-0.002	0.001	+	0.000	0.000		-0.001	0.001	
$\varphi_{i,JackassMorwon}$	0.000	0.000		-0.001	0.001		-0.002	0.001	***	0.000	0.000	+	0.017	0.002	***	0.000	0.001		0.000	0.000		-0.001	0.001	*
$\gamma_{i,MirrorDory}$	0.000	0.000		-0.003	0.001	***	0.000	0.001		0.000	0.000		-0.002	0.001	+	0.037	0.001	***	-0.001	0.000	**	0.000	0.000	
$\varphi_{i,MirrorDory}$	0.000	0.000		-0.004	0.001	***	0.002	0.001	**	0.000	0.000		0.000	0.001		0.022	0.003	***	0.000	0.000		0.000	0.000	
$\gamma_{i,SilverWarehou}$	0.000	0.000		-0.001	0.001	*	0.000	0.000		0.000	0.000		0.000	0.000		-0.001	0.000	**	0.003	0.000	***	0.000	0.000	
$\varphi_{i,SilverWarehou}$	0.000	0.000		-0.001	0.001	*	0.001	0.000	*	0.000	0.000	*	0.000	0.000		0.000	0.000		0.002	0.000	***	0.000	0.000	
$\gamma_{i,Other}$	0.000	0.000		-0.001	0.001		0.000	0.000		-0.001	0.000	***	-0.001	0.001		0.000	0.000		0.000	0.000		0.018	0.001	***
$\varphi_{i,Other}$	0.000	0.000	+	0.000	0.001		0.000	0.000		-0.001	0.000	*	-0.001	0.001	*	0.000	0.000		0.000	0.000		0.014	0.001	***
$\gamma_{i,HighValue}$	-0.001	0.001		-0.035	0.003	***	-0.010	0.002	***	-0.003	0.001	***	-0.021	0.002	***	-0.030	0.002	***	-0.001	0.001		-0.014	0.001	***
$\varphi_{i,HighValue}$	0.000	0.001		-0.016	0.004	***	-0.007	0.002	***	-0.003	0.001	***	-0.011	0.003	***	-0.018	0.003	***	-0.001	0.001		-0.011	0.002	***
β_i	0.000	0.001		-0.001	0.005		-0.002	0.003		0.001	0.001		-0.007	0.005		0.000	0.006		-0.002	0.002		-0.004	0.002	.
θ_i	-0.001	0.001		-0.004	0.005		0.003	0.003		0.001	0.001		-0.011	0.005	*	-0.002	0.006		-0.001	0.002		-0.005	0.002	*
λ_i	-0.760	0.110	***	-0.438	0.075	***	-0.542	0.078	***	-0.701	0.140	***	-0.662	0.077	***	-0.321	0.068	***	-0.433	0.080	***	-0.765	0.099	***
Adj R^2	0.670			0.803			0.749			0.775			0.790			0.858			0.457			0.845		

Notes: *** Significant at 0.1%; ** significant at 1%; * significant at 5%; + significant at 10%.

$$\Delta S_{i,t} = \alpha_i + \sum_j \gamma_{ij} \Delta \ln q_{j,t} + \beta_i \Delta \ln Q_t + \omega_i S_{i,t-1} + \sum_j \varphi_{ij} \Delta \ln q_{j,t-1} + \theta_i \Delta \ln Q_{t-1} + \lambda_i \mu_{it-1} + \epsilon_t$$

Table 21. Estimated own, cross price and scale flexibilities at the mean: High valued Sydney Fish Market species

	John Dory		Tiger Flathead		Orange Roughy		Bigeye Ocean Perch		Blue-eye Trevalla		Pink Ling		Silver Trevally		Low valued species		Scale	
Short-run																		
John Dory	-0.478	***	-0.154	***	0.002		-0.016		-0.081	***	-0.156	***	-0.007		-0.267	***	-1.156	++
	(0.041)		(0.039)		(0.012)		(0.017)		(0.023)		(0.025)		(0.019)		(0.049)		(0.069)	
Tiger Flathead	-0.024	*	-0.456	***	-0.007	*	-0.059	***	-0.068	***	-0.137	***	-0.037	***	-0.172	***	-0.963	
	(0.013)		(0.020)		(0.004)		(0.006)		(0.010)		(0.012)		(0.009)		(0.031)		(0.042)	
Orange Roughy	0.068		-0.128		-0.472	***	-0.052		-0.052		-0.045		-0.038		0.111		-0.513	
	(0.163)		(0.194)		(0.084)		(0.039)		(0.039)		(0.145)		(0.055)		(0.441)		(0.832)	
Bigeye Ocean Perch	0.002		-0.268	***	-0.010		-0.295	***	-0.096	***	-0.099	***	-0.058	***	-0.021		-0.846	++
	(0.026)		(0.034)		(0.011)		(0.021)		(0.021)		(0.023)		(0.017)		(0.050)		(0.062)	
Blue-eye Trevalla	-0.043	**	-0.195	***	0.000		-0.061	***	-0.314	***	-0.109	***	-0.046	***	-0.179	***	-0.947	
	(0.021)		(0.029)		(0.007)		(0.009)		(0.023)		(0.021)		(0.013)		(0.054)		(0.086)	
Pink Ling	-0.058	***	-0.256	***	-0.006	*	-0.044	***	-0.072	***	-0.437	***	-0.011		-0.112	***	-0.996	
	(0.014)		(0.019)		(0.004)		(0.007)		(0.011)		(0.016)		(0.009)		(0.033)		(0.049)	
Silver Trevally	0.011		-0.169	***	-0.009		-0.059	***	-0.071	***	-0.012		-0.467	***	-0.112	***	-0.895	
	(0.028)		(0.039)		(0.010)		(0.013)		(0.022)		(0.027)		(0.024)		(0.033)		(0.103)	
Long-run																		
John Dory	-0.493	***	-0.111	***	0.000		-0.033	*	-0.084	***	-0.132	***	-0.001		-0.250	***	-1.105	
	(0.040)		(0.036)		(0.009)		(0.017)		(0.021)		(0.025)		(0.018)		(0.051)		(0.079)	
Tiger Flathead	-0.018		-0.462	***	-0.003		-0.055	***	-0.069	***	-0.152	***	-0.039	***	-0.169	***	-0.968	
	(0.012)		(0.020)		(0.004)		(0.007)		(0.011)		(0.013)		(0.009)		(0.034)		(0.048)	
Orange Roughy	0.003		-0.102		-0.472	***	-0.053		-0.053		-0.104		-0.066		-0.314		-1.039	
	(0.120)		(0.172)		(0.066)		(0.034)		(0.034)		(0.146)		(0.051)		(0.375)		(0.755)	
Bigeye Ocean Perch	-0.024		-0.236	***	-0.008		-0.317	***	-0.101	***	-0.091	***	-0.054	***	-0.043		-0.873	+
	(0.025)		(0.032)		(0.010)		(0.021)		(0.021)		(0.023)		(0.017)		(0.050)		(0.069)	
Blue-eye Trevalla	-0.049	**	-0.188	***	0.008		-0.064	***	-0.302	***	-0.115	***	-0.037	**	-0.157	**	-0.904	
	(0.022)		(0.037)		(0.010)		(0.011)		(0.028)		(0.027)		(0.017)		(0.066)		(0.100)	
Pink Ling	-0.053	***	-0.282	***	-0.006		-0.042	***	-0.079	***	-0.427	***	-0.012		-0.113	***	-1.013	
	(0.013)		(0.021)		(0.004)		(0.007)		(0.011)		(0.017)		(0.009)		(0.035)		(0.056)	
Silver Trevally	0.013		-0.162	***	-0.009		-0.053	***	-0.057	**	-0.012		-0.617	***	-0.113	***	-0.905	
	(0.025)		(0.039)		(0.009)		(0.012)		(0.021)		(0.027)		(0.022)		(0.035)		(0.116)	

Notes: *** Significantly different to zero at 1% level; ** Significantly different to zero at 5% level; * Significantly different to zero at 10% level; For Scale flexibilities: +++ Significantly different to -1 at 1% level, ++ Significantly different to -1 at 5% level; + Significantly different to -1 at 10% level. Figures in parentheses are standard errors.

Table 22. Estimated own, cross price and scale flexibilities at the mean: Low valued Sydney Fish Market species

	Blue Grenadier	Eastern School Whiting	Gemfish	Gummy Shark	Jackass Morwong	Mirror Dory	Silver Warehou	Other	High Valued species	Scale
Short-run										
Blue Grenadier	-0.403 ***	-0.038	0.046	-0.005	0.022	-0.174	0.036	-0.077	-0.394	-0.988
	(0.045)	(0.170)	(0.096)	(0.033)	(0.152)	(0.113)	(0.062)	(0.086)	(0.410)	(0.611)
Eastern School Whiting	-0.001	-0.494 ***	-0.022 **	0.002	-0.030 *	-0.038 ***	-0.015 **	-0.009	-0.408 ***	-1.013
	(0.003)	(0.027)	(0.010)	(0.005)	(0.015)	(0.011)	(0.007)	(0.010)	(0.038)	(0.053)
Gemfish	0.004	-0.088 **	-0.366 ***	-0.009	-0.009	0.003	0.015	-0.013	-0.482 ***	-1.079
	(0.008)	(0.041)	(0.032)	(0.008)	(0.008)	(0.027)	(0.015)	(0.021)	(0.097)	(0.143)
Gummy Shark	-0.002	0.065	-0.037	-0.083	-0.043	-0.042	0.046	-0.181 ***	-0.491 ***	-0.768
	(0.014)	(0.091)	(0.041)	(0.062)	(0.058)	(0.042)	(0.028)	(0.056)	(0.141)	(0.184)
Jackass Morwong	0.001	-0.066 **	-0.071 ***	-0.006	-0.427 ***	-0.042 *	0.001	-0.027 *	-0.491 ***	-1.147
	(0.005)	(0.028)	(0.017)	(0.005)	(0.038)	(0.021)	(0.010)	(0.014)	(0.141)	(0.111)
Mirror Dory	-0.006	-0.058 ***	0.003	-0.005	-0.030	-0.349 ***	-0.017 **	-0.005	-0.541 ***	-1.008
	(0.004)	(0.019)	(0.012)	(0.003)	(0.021)	(0.021)	(0.007)	(0.010)	(0.069)	(0.103)
Silver Warehou	0.010	-0.214 **	0.051	0.030	0.003	-0.154 **	-0.550 ***	-0.076	-0.323	-1.224
	(0.018)	(0.095)	(0.053)	(0.019)	(0.080)	(0.058)	(0.048)	(0.048)	(0.206)	(0.295)
Other	-0.011	-0.073	-0.025	-0.060 ***	-0.094 *	-0.035	-0.035	0.173 ***	-1.107 ***	-1.268 +
	(0.011)	(0.065)	(0.033)	(0.018)	(0.048)	(0.036)	(0.022)	(0.050)	(0.111)	(0.156)
Long-run										
Blue Grenadier	-0.424 ***	-0.171	0.092	0.013	-0.060	-0.109	0.025	-0.123	-0.445	-1.202
	(0.041)	(0.160)	(0.082)	(0.029)	(0.151)	(0.095)	(0.055)	(0.079)	(0.335)	(0.553)
Eastern School Whiting	-0.004	-0.530 ***	-0.022 **	0.008	-0.034 *	-0.056 ***	-0.018 **	-0.007	-0.374 ***	-1.037
	(0.004)	(0.031)	(0.010)	(0.005)	(0.017)	(0.010)	(0.007)	(0.011)	(0.036)	(0.055)
Gemfish	0.010	-0.086 *	-0.329 ***	-0.014	-0.014	0.058 **	0.035 **	0.000	-0.487 ***	-0.966
	(0.009)	(0.048)	(0.034)	(0.009)	(0.009)	(0.028)	(0.017)	(0.024)	(0.107)	(0.166)
Gummy Shark	0.007	0.054	-0.058	-0.077	-0.052	-0.030	0.066 **	-0.188 ***	-0.599 ***	-0.766
	(0.014)	(0.062)	(0.040)	(0.065)	(0.060)	(0.041)	(0.029)	(0.057)	(0.137)	(0.189)
Jackass Morwong	-0.003	-0.079 **	-0.074 ***	-0.007	-0.456 ***	-0.039	-0.003	-0.040 **	-0.599 ***	-1.233 +
	(0.006)	(0.032)	(0.018)	(0.005)	(0.046)	(0.025)	(0.011)	(0.015)	(0.137)	(0.118)
Mirror Dory	-0.004	-0.041 **	0.022 **	-0.004	-0.025	-0.315 ***	-0.017 **	-0.010	-0.579 ***	-1.025
	(0.004)	(0.018)	(0.011)	(0.003)	(0.026)	(0.020)	(0.007)	(0.011)	(0.068)	(0.114)
Silver Warehou	0.009	-0.254 **	0.106 *	0.045 **	-0.022	-0.143 **	-0.505 ***	-0.098 *	-0.360 *	-1.224
	(0.018)	(0.101)	(0.053)	(0.020)	(0.089)	(0.057)	(0.049)	(0.051)	(0.197)	(0.309)
Other	-0.017	-0.063	-0.007	-0.055 ***	-0.125 **	-0.049	-0.040 *	-0.536 ***	-1.072 ***	-1.309 ++
	(0.010)	(0.062)	(0.030)	(0.017)	(0.048)	(0.034)	(0.020)	(0.043)	(0.095)	(0.141)

Notes: *** Significantly different to zero at 1% level; ** Significantly different to zero at 5% level; * Significantly different to zero at 10% level; For Scale flexibilities: +++ Significantly different to -1 at 1% level, ++ Significantly different to -1 at 5% level; + Significantly different to -1 at 10% level. Figures in parentheses are standard errors.

Table 23. Short-run significant own, cross price and scale flexibilities at the mean

Short-run	John Dory	Tiger Flathead	Orange Roughy	Bigeye Ocean Perch	Blue-eye Trevalla	Pink Ling	Silver Trevally	Low valued species	
John Dory	-0.478	-0.154			-0.081	-0.156		-0.267	
Tiger Flathead	-0.024	-0.456	-0.007	-0.059	-0.068	-0.137	-0.037	-0.172	
Orange Roughy			-0.472						
Bigeye Ocean Perch		-0.268		-0.295	-0.096	-0.099	-0.058		
Blue-eye Trevalla	-0.043	-0.195		-0.061	-0.314	-0.109	-0.046	-0.179	
Pink Ling	-0.058	-0.256	-0.006	-0.044	-0.072	-0.437		-0.112	
Silver Trevally		-0.169		-0.059	-0.071		-0.467	-0.112	
	Blue Grenadier	**Eastern School Whiting**	**Gemfish**	**Gummy Shark**	**Jackass Morwong**	**Mirror Dory**	**Silver Warehou**	**Other**	**High Valued species**
Blue Grenadier	-0.403								
Eastern School Whiting		-0.494	-0.022		-0.030	-0.038	-0.015	-0.009	-0.408
Gemfish		-0.088	-0.366						-0.482
Gummy Shark								-0.181	-0.491
Jackass Morwong		-0.066	-0.071		-0.427	-0.042		-0.027	-0.491
Mirror Dory		-0.058				-0.349	-0.017		-0.541
Silver Warehou		-0.214				-0.154	-0.550		
Other				-0.060	-0.094			0.173	-1.107

Table 24. Long-run significant own, cross price and scale flexibilities at the mean

Long-run	John Dory	Tiger Flathead	Orange Roughy	Bigeye Ocean Perch	Blue-eye Trevalla	Pink Ling	Silver Trevally	Low valued species	
John Dory	-0.493	-0.111		-0.033	-0.084	-0.132		-0.250	
Tiger Flathead		-0.462		-0.055	-0.069	-0.152	-0.039	-0.169	
Orange Roughy			-0.472						
Bigeye Ocean Perch		-0.236		-0.317	-0.101	-0.091	-0.054		
Blue-eye Trevalla	-0.049	-0.188		-0.064	-0.302	-0.115	-0.037	-0.157	
Pink Ling	-0.053	-0.282		-0.042	-0.079	-0.427		-0.113	
Silver Trevally		-0.162		-0.053	-0.057		-0.617	-0.113	
	Blue Grenadier	**Eastern School Whiting**	**Gemfish**	**Gummy Shark**	**Jackass Morwong**	**Mirror Dory**	**Silver Warehou**	**Other**	**High Valued species**
Blue Grenadier	-0.424								
Eastern School Whiting		-0.530	-0.022		-0.034	-0.056	-0.018		-0.374
Gemfish		-0.086	-0.329			0.058	0.035		-0.487
Gummy Shark							0.066	-0.188	-0.599
Jackass Morwong		-0.079	-0.074		-0.456			-0.040	-0.599
Mirror Dory		-0.041	0.022			-0.315	-0.017		-0.579
Silver Warehou		-0.254	0.106	0.045		-0.143	-0.505	-0.098	-0.360
Other				-0.055	-0.125		-0.040	-0.536	-1.072

The cross-price flexibilities within each value group were relatively small in most cases (less than -0.30). Given this, the prices of species handled within the Sydney Fish Market are not very sensitive to changes in quantities supplied of other species within each value group. The negative sign for most derived cross-price flexibilities also indicates a substitute relationship between the species. However, since the cross-price flexibilities were relatively small in absolute value this cross price dynamic is likely only minor.

The cross-price flexibilities associated with some species were not significant, e.g., Blue Grenadier, Orange Roughy and Gummy Shark, which implies that quantities supplied by these species do not affect the price of the other species. Conversely, prices of these species are also not significantly affected by supplies of other species on the market. As noted previously, these species are contribute less than 1% of the value share of the market (Table 2) and also only a relatively small proportion of the catch is sold on the Sydney Fish Market. It is likely that prices of these species are more influenced by other market aspects which were not examined. For species such as Blue Grenadier and Orange Roughy, which are the top species in the SESSF in regard to their total production volume, the catch proportion sold at the Sydney Fish Market is likely too small to derive a stable (significant) cross-price flexibility as Smith *et al.* (1998a) previously argued.

Discussion

The study considered both spatial integration across the two main markets supporting the SESSF (Sydney and Melbourne) as well as the level of cointegration (substitutability) between species on these markets. In addition, the study derived empirical estimates of the own and cross-price flexibilities for the main species on the Sydney Fish Market. These different approaches provide different information on the market interactions and price formation.

Cointegration analysis

Spatial integration

Spatial integration involves the comparison of prices of the same species on different markets, as compared to different species on the same market. A finding of cointegration between the markets indicates that the prices move together, and hence the markets are said to be spatially integrated. Spatial integration implies that, essentially, there is only one market for the commodity, and that the price in one market can be used as a measure of the price for the commodity overall. This derives from spatial equilibrium theory, which suggests that markets are operating efficiently if the prices on each for a given commodity differ no more than their transport cost (Samuelson 1952). Cointegration analysis is increasingly being applied to examine the spatial integration of seafood markets, including assessing the level of integration between local and international markets (e.g. Setälä *et al.* 2008; Mafimisebi 2012; Bukenya and Ssebisubi 2014; García-Enríquez *et al.* 2014).

From the results of this study, the prices of most species on the Melbourne and Sydney fish markets were found to be cointegrated over the period of the available data, indicating that the markets are efficient and that prices converge in the long-run on both. While prices of some species were not cointegrated across the two markets (prices of Ocean Perch in the two markets were found to be not linked in the long term, while the results for School Whiting and Silver Trevally were inconclusive), this does not necessarily mean that the markets overall are not efficient and operating in spatial equilibrium. McNew and Fackler (1997) showed that factors such as stochastic transport rates, and fluctuating differences in regional supply and demand conditions (e.g., seasonal differences in consumer preferences for some species between the two markets) may result in lack of apparent cointegration in otherwise well-integrated markets.

Given this, it is reasonable to assume that the two markets are well integrated. Supplies of the different species to the different markets, therefore, are more a function of the location that it is caught (i.e., to minimise the transport cost) rather than fishers targeting different markets in order to increase the prices received. For example, most Shark (both Gummy and School) are sold through the Melbourne market, being the closest market to where most of the catch is taken. There is no benefit in sending the catch caught in the southern waters to Sydney (and the higher transport cost could result in a lower net return). Conversely, shark caught closer to Sydney would benefit through sale through the Sydney Fish Market rather than sending it to Melbourne.

Market integration also has implications for the demand model. Developing the demand model on the basis of prices on the Sydney Fish Market alone is likely to provide reliable estimates of the price flexibilities of the key species.

The available data for the Melbourne fish market were only available up until 2010. After that, the single Melbourne market was privatised and other competing markets were established. Given the Melbourne market was found to be operating efficiently (in terms of price formation) as a single market, there is no reason to suspect that increased competition on the market would decrease this efficiency. This, however, cannot be verified given the unavailability of price data post-2010.

Species level integration

Cointegration between species provides information on the relative degree of market substitution. Species that are cointegrated are potential substitutes on the market, while those that satisfy the criteria of the Law of One Price (LOP) are essentially perfect substitutes. That is, their prices are determined not just by their own quantity supplied to the market, but also the quantities supplied of their substitute species.

The findings for the analysis of seafood traded within the Sydney Fish Market indicate that prices of most species are developing independently of the prices of other species (Table 14). The exception was Blue-eye Trevalla which was found to be cointegrated with eight other seafood species (out of 18 possible options). Considering that Blue-eye Trevalla is a high value species (see Table 2), it can be concluded that this species may be the market leader with respect to prices within the Sydney Fish Market.

The very small number (6 out of 170 pairs) of seafood products for which the Law of One Price could be identified to hold further indicates that most products traded within the Sydney Fish Market are not considered as identical goods. Some substitutability between some species is expected to occur, although this is also influenced by other factors.

The results also indicate that there is a high degree of price cointegration between seafood traded at the Sydney Fish Market and seafood imports (Table 14). Due to changes in import classifications, a "detailed" analysis of import prices was only possible using data from 2012. This could only be compared with Sydney Fish Market data, as Melbourne data were not available after 2010. However, given the established market integration between the Sydney and Melbourne markets, it is expected that the results are equally valid for both markets.

This implies that prices within the Sydney Fish Market are likely more affected by external price dynamics (e.g., imports) than price dynamics within the market. However, this relationship varied by species, with most species' prices being cointegrated with those of fresh fish imports, and many being cointegrated with the other import groups. This implies that the price dynamics within at the international seafood market likely affect prices for fish products that are produced and consumed in Australia. However, as the Law of One Price could not be confirmed for most of the cointegrated domestic and imported products, it can be assumed to some degree of product differentiation persists and that international seafood price dynamics are not passed through proportionally to domestic products. Studies in other countries which investigated the impact of import prices on the prices of domestically produced seafood reported similar findings (e.g., Norman-López and Asche 2008; Asche *et al.* 2012).

Only two species – John Dory and School Whiting – were found to not be cointegrated with any imports. In contrast, Blue-eye Trevalla - the market price leader – was cointegrated with all imported fish categories, except (partially) imported hake.

Imported aquaculture fish species other than farmed Salmon (e.g., Basa) and Royal Red Prawns were found to be cointegrated and substitutes (Table 14). The finding appears to contradict results presented by Schrobback *et al.* (2019b) who concluded that imported prawns were not cointegrated with Australian wild-caught prawns. An explanation for this finding could be that Schrobback *et al.* (2019b) undertook their analysis based on a composite good, which included several wild prawn species caught in Australia and not only Royal Red Prawn as in the present study. Royal Red Prawn are only a small component of the composite domestic prawn production which Schrobback *et al.* (2019b) considered as wild-caught domestic prawn. While imported aquaculture in the present study is also treated as a composite good, it mainly consists of Tilapia and Catfish/Basa and does not include farmed prawns/shrimp. Royal Red Prawns are also largely marketed as meat (rather than whole) at the retail/wholesale level and used as ingredients in other dishes rather than consumed on their own. In this regard, they are more closely related to fish such as imported Basa. Hence, differences in findings between this study and Schrobback *et al.* (2019b) is not surprising.

The results of the study also differ to previous studies on the impact of imports on wild-caught fish prices. For example, Ruello (2011) suggested that imports are more likely to complement wild-caught catch as they provide a market that would otherwise not be filled by domestic production, thereby increasing seafood consumption overall. Similarly, the Seafood Origin Working Group (2017) suggested that the price and characteristics of low-cost imported seafood such as basa and hoki are more in competition with cheaper proteins such as chicken and mince rather than Australian wild-caught seafood.

Demand modelling

While it is important to ensure that any demand system model developed includes the key cointegrated species, lack of cointegration does not necessarily mean lack of substitutability. For example, Schrobback *et al.* (2019a) found a small but significant cross price effect between imports and domestically produced Australian prawns (aquaculture and wild caught) despite no cointegration being found.

Given the limited data, the demand modelling was undertaken at different levels with different groups of fish. An "aggregate" market model was initially developed that included imports (fresh and frozen), Australian farmed Salmon and Sydney Fish Market species grouped into a high or low value group based on a cluster analysis of price. Due to changes in the import codes over time, more aggregated import categories were necessary as it was not possible to identify many species individually in the earlier half of the available time series.

Models were also estimated for the high and low valued species groups at the individual species levels. These were estimated within the Sydney Fish Market. While imports may have impacted on the overall prices over time, the use of shares in the demand systems (rather than price per se) reduces the need to include imports directly into the systems (assuming the impact of the change in imports is relatively equal across the different species within the species group).

The impact of imports

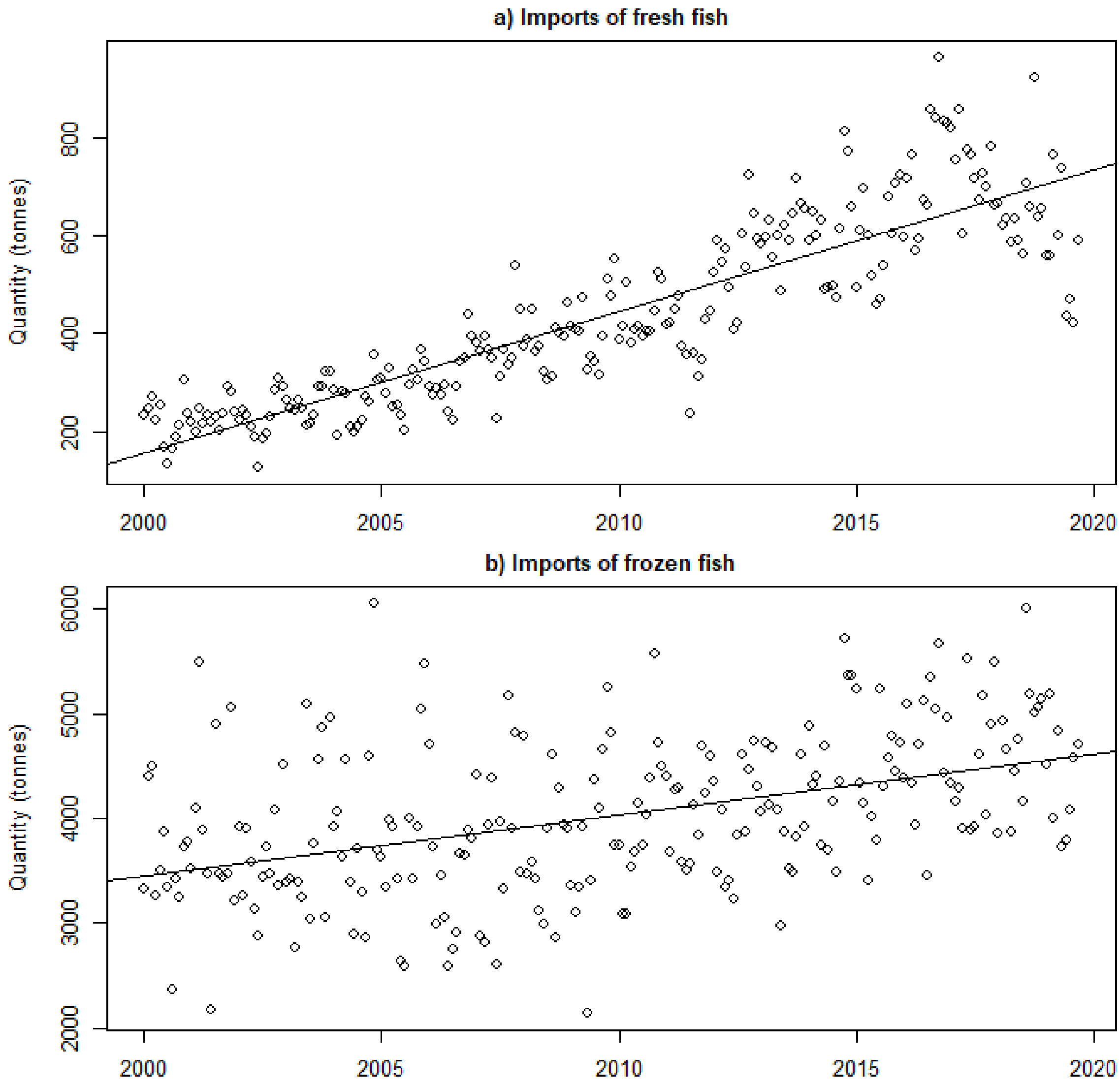
A priori, it would be expected that increased supply of imported product would have a negative impact on the price of domestically produced product, as the increased total supply of fish on the market would be expected to decrease prices of all fish. Such impacts have been observed in other fish commodities both within Australia (e.g. Schrobback *et al.* 2019a) and elsewhere (e.g. Muhammad *et al.* 2010; Tabarestani *et al.* 2017). Other studies have also found that the introduction of "new" imported species, such as Tilapia and Basa which have both increased in the last decade in particular, can lead to a structural shift in the market (Norman-López and Asche 2008; Asche *et al.* 2012). However, previous Australian studies have suggested that fish imports into Australia do not significantly affect domestic fish prices (Ruello 2011; Seafood Origin Working Group 2017). A much earlier study by Pascoe *et al.* (1987a) also included imports in the assessment of price-quantity relationships for the Sydney Fish Market, but found that the cross-price flexibility between their composite fish product and imports was not significant.

Our results run counter to those of the previous studies that suggest that fish imports have not affected prices of domestic product. The results of the aggregated demand model indicate that the quantity of imports does have an effect on the price of wild-caught species on the Sydney Fish Market. While significant relationships between imports and domestic product was found in this study, this effect was not consistent across all species. From Table 17, imports of fresh fish was found to have a substantial negative impact on the prices of species in the lower valued group in both the short and long term (the long term in this case being around 3-4 months after the initial change). While no short-term impact on high valued species was found, a small but significant negative impact was found in the long term. This indicates direct competition and potential for substitution between imports of fresh fish and the lower valued species on the Sydney Fish Market in particular.

In contrast, imports of frozen fish were found to complement lower valued species, more consistent with the general findings of Ruello (2011) but applicable to frozen fish only. Again, no significant relationship between frozen fish and higher valued species was found. Both fresh and frozen imports were found, however, to have a significant impact on the price received for domestic farmed salmon, with long-run cross-price flexibilities of -0.104 and -0.246 respectively.

While the magnitude of the cross-price flexibilities in Table 17 appear small in absolute levels, the change in the level of imports over the period of the data was substantial (Figure 9). Since 2000, imports of fresh fish have increased on average by 6.9% a year, while imports of frozen fish have increased by 1.4% a year.

Figure 9. Imports of a) fresh and b) frozen fish into New South Wales



Compounded over the almost 20 years of the data, the growth in fresh fish imports would have reduced prices of low valued fish species (in real terms) by approximately 59%[5] all other things being equal. However, this would have been offset partially by the positive effects of the increased frozen

[5] The cross-price flexibility is a measure of the price change of product *x* due to a 1% change in the quantity of product *y* and is more correctly only applied at the margin (i.e., a small change). An approximation for larger changes can be made by assuming an exponential decay rather than linear. In this case, the decline can be approximated by 1-exp(-0.652 * 0.068 * 20), with the values in the exponential function being the cross-price flexibility, the average annual change and the number of years respectively.

fish imports, which – on their own – would have increased prices by 27%. The combined effect of these two opposing impacts represents a net decline of around 32% over the last 20 years in real prices. As this is less than the rate of inflation over this period (2.4% on average[6]), fishers would have realised a small increase in nominal prices, but an overall decline in real prices.

For high valued species, the increase in fresh fish imports would have resulted in a decline in real prices of approximately 19%, all other things being equal. Again, this is less than the rate of inflation over this period, so fishers would have experienced an increase in nominal prices even though real prices decreased.

While it is apparent that seafood imports were detrimental to domestic producers of seafood, they may have positively impact on consumers through the decrease in the prices of domestically produced seafood given a likely net decrease of seafood supply in such case. Increasing domestic seafood prices could also negatively affect consumer demand. Hence, more detailed research may be needed to examine the potential net-benefit of import for Australia (Nielsen *et al.* 2007).

The potential for labelling, both ecolabeling and appellation-style labelling, has been considered as an option to improve consumer demand for domestic wild-caught product. For example, seafood sold at food services (e.g., restaurants, pubs) currently remains exempt in Australia labelling, including country of origin (Australian Government 2016). Improved consumer awareness about the impact of seafood imports on local fishing industries may contribute to their willingness to pay a premium for domestically produced fish products (Zander and Feucht 2018). While the price benefits of certification to fishers are still debatable, recent evidence exists (van Putten *et al.* 2020) that such programs improve social licence, which will have longer term implications for domestically caught fish on the market.

The impact of Australian farmed salmon

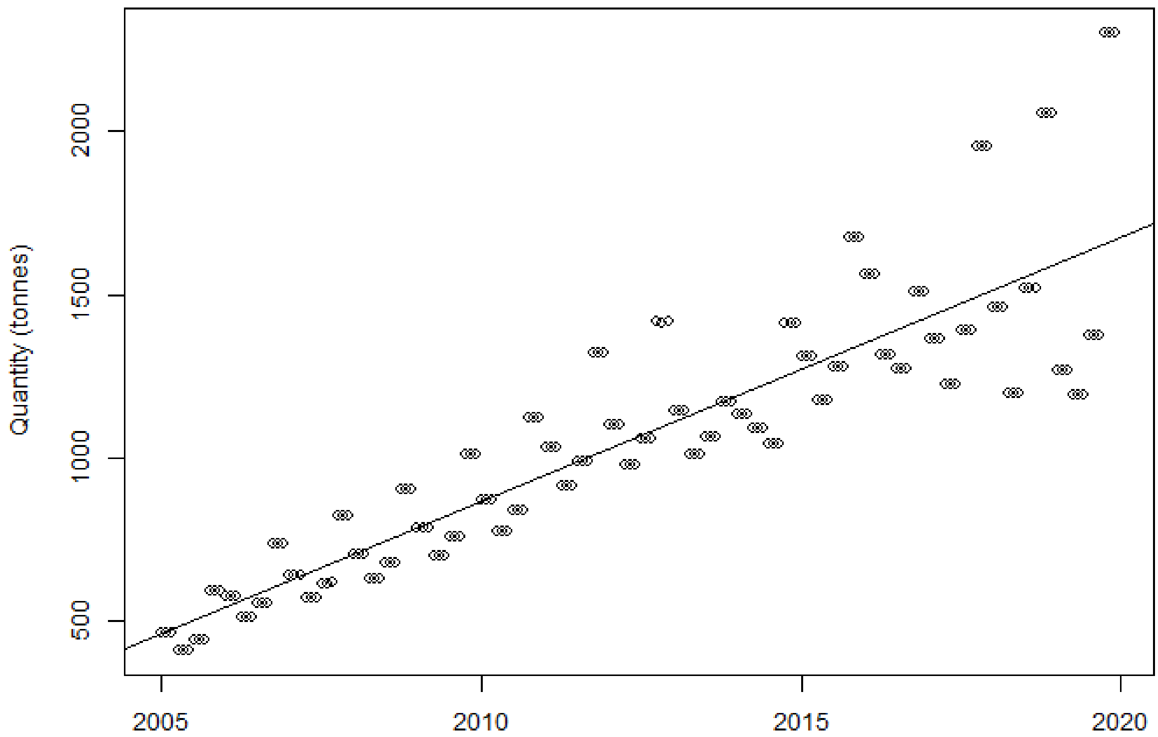
Concurrent with the growth in fresh imports, the production of Australian farmed salmon has also grown at an average rate of 8.2% a year over the time period of the data (Figure 10). Changes in the quantity of salmon was found to have a proportionate impact on the price of the high valued species group on the Sydney Fish Market, with long-run cross-price flexibilities of -0.997, and a greater than proportionate impact on the lower valued species, with a cross-price flexibility of -1.209 (Table 17).

Again, assuming an exponential decay to provide an approximation of the impact of domestic farmed salmon on Sydney Fish Market prices, we estimate that, since 2005, increased salmon production may have reduced prices of the higher valued species by approximately 70% in real terms, or 7% in nominal terms. Similarly, prices of the lower valued species may have declined by 77% in real terms, or 14% in nominal terms, all other things being equal.

This is most likely an overestimate of the impact of salmon on Sydney Fish Market prices over the last 15 years, as the cross-price flexibility is also affected by market share ,and the exponential decay assumption provides only an approximation of the impact, the reliability of which decreases as the size of the impact increases. The estimates from the model were based on the average share over the period of the data. In the earlier years, the share of salmon on the market would have been substantially lower, and its impact on prices of domestic wild-caught fish also lower. However, as the share increased over time, its impact would also have increased.

[6] The cumulative impact of inflation over this period was to increase prices by 63% https://www.rba.gov.au/inflation/measures-cpi.html

Figure 10. Estimated supply of Australian farmed salmon into New South Wales



These changes also assume that the amount of salmon consumed in New South Wales was proportional to its population and the total production, and that the distribution of production across quarters in the earlier years were similar to those in more recent years. While these assumptions may have affected the estimate of the cross-price flexibility, the general upward trend in salmon aquaculture supply is the dominant driver of these estimates.

The results of this study differ substantially with those elsewhere. In most studies, the global growth of farmed salmon and other aquaculture has been generally found to have had little impact on the prices of wild-caught species (e.g. Clayton and Gordon 1999; Jaffry *et al.* 2000; Regnier and Bayramoglu 2017) unless farmed product is the same species. Asche *et al.* (2001) concluded that farmed species did compete with wild catch of the same species, but not with other species. Similarly, Nielsen *et al.* (2009) found that fresh salmon on the European market competed with imported frozen salmon, but not other species. In contrast, in our study, we find a strong substitution relationship between domestically produced farmed salmon and wild-caught fish on the market from the demand analysis, as well as between imported salmon and many species on the Sydney Fish Market through the cointegration analysis.

Own and cross-price flexibilities

The results indicate that prices of SESSF species traded at the Sydney Fish Market do not develop independent of quantities supplied. The findings indicate that prices of individual species respond relatively sensitively to changes in the quantities of the same product (own-price flexibility) but less sensitive to changes of quantities supplied by other species handled within this market (cross-price flexibility). This broadly confirms the findings from the cointegration analysis in the first part of the project which found that prices of species traded in the Sydney Fish Market mostly develop independently of each other.

The results for the short-run own-price flexibilities within the Sydney Fish Market broadly confirm the findings of previous studies by Bose (2004) and Smith *et al.* (1998a), although the present study found slightly higher own-price flexibilities (see Table 25). Disparities across the results of studies could be due to differing modelling approaches (e.g., Smith *et al.* (1998a) use OLS) and the length and the period covered by the time series used for the analysis (e.g., Smith *et al.* (1998a) uses daily price and quantity data over the period of April 1992 – March 1996, Bose (2004) uses monthly data covering March 1990 – December 1996).

Table 25. Comparison of short-run own-price flexibilities for Sydney Fish Market across studies

Species	Smith et al. (1998)*	Bose (2004)	Pascoe et al. (2020)	
			Short-term	Long-term
Blue-eye Trevalla	-0.030	-0.330	-0.314	-0.302
John Dory	+0.080	-0.499	-0.478	-0.493
Mirror Dory	-0.040	-0.336	-0.349	-0.315
(Bigeye) Ocean Perch	-0.160	+0.017^	-0.295	-0.317
Pink Ling	-0.100	-0.303	-0.437	-0.427
Gemfish	-0.230	-0.298	-0.366	-0.329
Blue Warehou	-0.040	-0.540	-	-
Silver Warehou	-0.410	-0.509	-0.550	-0.505
Jackass Morwong	-0.310	-0.437	-0.427	-0.456
Tiger Flathead	-0.520	-0.749	-0.456	-0.462
Silver Trevally	-0.570	-0.632	-0.467	-0.617
Eastern School Whiting	-0.610	-0.743	-0.494	-0.530
Blue Grenadier	-	-0.334	-0.403	-0.424
Orange Roughy	-	-0.227	-0.472	-0.472
Data period	04/1992 – 03/1996	03/1990 – 12/1996	06/2005 –09/2019	
Total observations	545 to 1,152	78	172	
Data frequency	Daily	Monthly	Monthly	
Method	OLS	IAIDA, SUR	IAIDA, SUR	

Notes: *Relatively high standard errors were reported by Smith *et al.* (1998a) which they argue may have affected the robustness of their results. Model fit was also reported to be poor in some cases. ^ Bose (2004) argues that positive own-price flexibility for ocean perch may be due to an collinearity issue in the data.

Pascoe *et al.* (1987a) also undertook an analysis in which all Sydney Fish Market species were aggregated into a composite fish product. The short-run own-price flexibility for the composite fish product that these authors derived was -0.579, which is broadly in line with the findings of the present study.

Substitutability between species

A negative cross-price flexibility indicates substitutability between species on the market. In most cases, cross-price flexibilities were either negative or not significant, indicating a substitution relationship or no relationship. For several low valued species, however, a complementary relationship was found in the long-run estimates of cross-price flexibilities (Table 24). For example, the supply of Silver Warehou had a positive impact on the price of Gemfish and Gummy Shark. Similarly, Gemfish had a reciprocal positive relationship with both Silver Warehou and Mirror Dory. These positive cross-price flexibilities were small, indicating only a weak complementary relationship.

For most species, the negative cross-price flexibilities were also relatively small i.e., less than -0.1. This means that a 10% change in supply of one species will result in less than a 1% change in the price of the other. The key exceptions to this were Tiger Flathead, Pink Ling and, to a lesser extent, Blue-eye Trevalla – all high valued species. This is in contrast to the cointegration analysis which indicated that Blue-eye Trevalla was likely a market leader. From the demand analysis, Blue-eye Trevalla was an influential species, but changes in Tiger Flathead supply had the greater impact on the prices of other high valued species.

For the low valued species, cross-price flexibilities were mostly small. The only exception to this was Silver Trevally, the price of which was also affected by the supply of Eastern School Whiting, Mirror Dory and Silver Warehou.

Prices of all low valued species were affected by the (aggregate) supply of higher valued species, with cross-price flexibilities ranging from -0.360 to -0.599. In contrast, the impact of low valued species on the higher valued species was much lower, with cross-price flexibilities in the range -0.11 to -0.25. This again suggests that the higher valued species drive the market to a large extent, with Tiger Flathead in particular being influential. This is again in contrast to the cointegration analysis, which found only limited cointegration between Tiger Flathead and other species.

Scale flexibilities

Scale flexibilities indicate the degree to which the price of a species changes when the total quantity of fish on the market increases or decreases. A value of -1 indicates that the price changes in proportion to total supply (a homothetic good); a value of <-1 indicates that the price changes more than proportional to change in total supply (an income inferior good, essentially the same as a necessity good in a quantity dependent demand system) and a value of >-1 indicates that the price changes less than proportional to changes in total supply (an income superior good, essentially the same as a luxury good in a quantity dependent demand system) (Park and Thurman 1999).

From the demand modelling, most species were found to be homothetic (Table 21 and Table 22). That is, prices move proportional to total quantity supplied. While the values of the scale flexibilities were generally less than -1, these were mostly not significantly different to -1. In contrast, John Dory was found to be a necessity in the short term only (i.e., not in the long term), and Jackass Morwong a necessity in the long-run (but not in the short term). The “other” species group was also found to be a necessity, this consisting of low value and/or low quantity species.

Bigeye Ocean Perch was found to be the only significant luxury good, with the scale flexibility being >-1 in both the short term and longer term. Although scale flexibilities were not explicitly estimated by Smith *et al.* (1998b), reported prices under average, high and low total market volume conditions for the key species showed least variation for Ocean Perch (both species combined) than the other species examined (Smith *et al.* 1998b), supporting the result that the species is a luxury good.

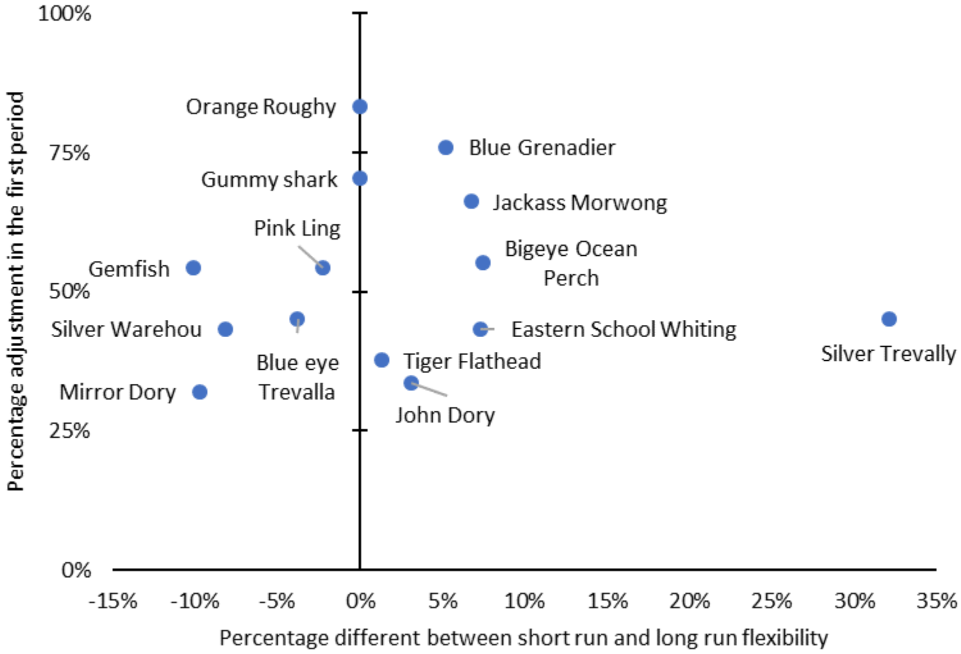
How long is the long-run?

For most species, the time to reach an equilibrium was relatively short i.e., 2-4 months, assuming nothing else changed in the meantime. For some species (e.g., Orange Roughy, Blue Grenadier and Gummy Shark), over 70% of the adjustment took place in the first time period.

The relationship between long-run and short-run own-price flexibilities was mixed, with about half of the species having a larger initial price change in the short term than in the long term, with the other half having the opposite (Figure 11). With the exception of Silver Trevally, the long-term price flexibilities were within 10% of the short-term flexibility, indicating that any further adjustment to prices was limited. This is also consistent with the short adjustment period. The long-term own-price flexibility for silver trevally, however, was over 30% higher than the short-term value, indicating that prices continue to adjust over time in response to a change in quantity supplied, all other things being equal.

The short time period to reach equilibrium and the similarity between short-term and long-term flexibilities indicates that the market is efficient in terms of price formation in response to quantity change. Some habit formation exists that affects the dynamics of the market, although this is fairly limited.

Figure 11. Speed of adjustment and differences between short and long-run own-price flexibilities



Other potential modelling approaches

The analysis in this study applied the dynamic inverse almost ideal demand (IAIDS) model approach. Other modelling systems have also been developed to estimate price flexibilities in fisheries and other agricultural commodities. These including variants of the Rotterdam model, applied by Sun *et al.* (2019) to model the Japanese tuna market, and a linearised version of the inverse almost ideal demand system (LIAIDS), used by Kesavan and Buhr (1995) to model meat demand in the US. As noted above, the earlier study by Bose (2004) estimated the demand models for the Sydney Fish Market as a system of log-linear equations estimated using seemingly unrelated regression (Zellner 1962). Asche *et al.* (2007a) reviewed the different approaches and found that both the Rotterdam model and the IAIDS model had advantages over the use of log-linear models in that they were able to impose theoretical consistency in the estimation process (e.g., homogeneity and symmetry). Both the Rotterdam and IAIDS models were found to be equally as appropriate, with the latter being somewhat easier to estimate (Asche *et al.* 2007a).

Implications for the management of the SESSF

While the analysis has focused on price formation on the market, the results have implications for the management of the SESSF. We provide two examples of the use of the price flexibilities in support management decision making. In the first example, we look at the consequences of the full set of TACs being met on the economic performance of the fleet. In the second, we look at how considering price flexibilities affects the optimal yields (target reference points) in the fishery.

Impact of catching the full TAC on prices and vessel profitability

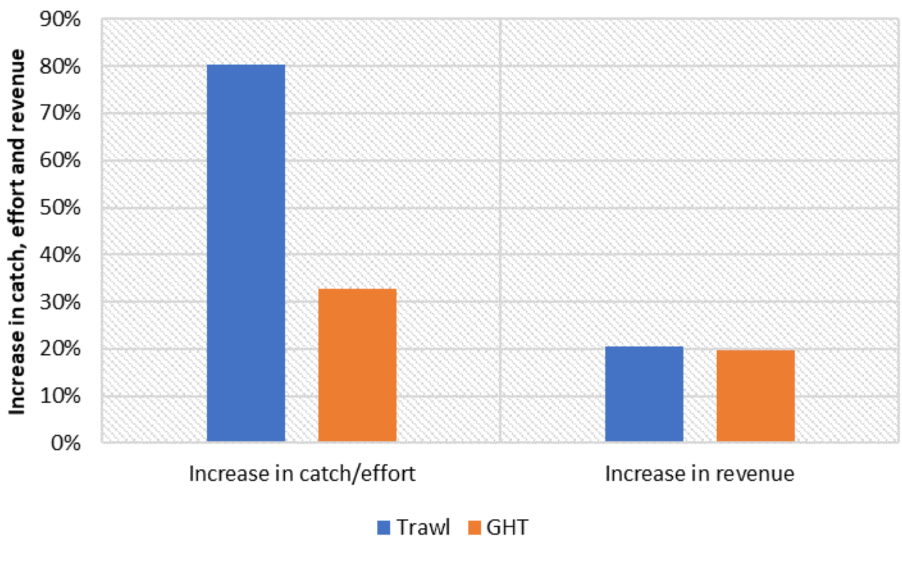
Over recent years, the SESSF has been characterised by the fleet catching less than the TACs. In the 2019 fishing year (the last year for which the market information was available), catches of the key species examined in this study were, on average, only 52% of their permitted catch level, ranging from 7% (Silver Warehou) to 94% (Gummy Shark) (AFMA 2020a). Potential explanations for this undercatch include reduced stocks of key species and associated catch rates, failure of stocks to recover as anticipated, climate change, livelihood choices of fishers, and inconsistent quota setting (due to individual TACs being set individually and ignoring the multispecies nature of the fishery) (Knuckey *et* *al.* 2018). Knuckey *et al.* (2018) also considered economic factors, particularly prices (which were considered low possibly due to competition with imports) and fishing costs (which were considered high), but concluded that these factors were probably not a major driver of the undercatch.

In this study, we do not aim to provide an explanation for the undercatch, but look at what the implications of catching the full TAC might be on the economic performance of the fleet. This required a number of assumptions. First, we assume also that taking the full TAC is technically possible. We also assume that increasing catch requires a proportionate increase in fishing effort, with this based on the change in total catch (i.e., ignoring individual species).

Information on the catch and the TACs for each of the key species for the 2019 fishing year was derived from AFMA (2020a) economic information on the fleets was derived from Bath *et al.* (2018). The economic information available covered two fleets: the trawl sector and the gillnet, hook and trap (GHT) sector For simplicity, catches of all shark species and Blue-eye Trevalla were allocated to the GHT sector, as well as one third the catch of Pink Ling. The catches of all other of the species (and the remainder of the Pink Ling catch) considered in the demand modelling were allocated to the trawl sector. This is not entirely realistic, as the trawl sector also catches some of the species fully allocated to the GHT, although most of the catch of these species is taken by the GHT. Similarly, some of the catch allocated to the trawl sector is taken by vessels in the GHT.

Changes in revenue of each sector was estimated using the catches and TACs relating to the 2019 fishing year (AFMA 2020a), and applying the average prices from Table 6 and the long-run own-price flexibilities from Table 24 (cross price effects were not included for simplification). Given this, catch of the trawl sector (and the associated effort to produce this) would increase by 80%, while catch (and effort) of the GHT sector would increase by 33% (Figure 12). However, increased supply to the market would decrease prices, and based on the own-price flexibilities found in our study, revenue of both sectors would only increase by 20% (see Appendix F for full details).

Figure 12. Estimated change in catch, effort and revenue if TACs were caught



The most recent available detailed cost and earnings information on the fishery related to 2014-15 (Bath *et al.* 2018). For the purposes of illustration, we apply the proportional increase in revenue to the fishing revenue of these vessels. We also adjust variable costs to reflect the increase in fishing effort required to take the higher level of catch. Crew costs are increased by the same proportion as fishing revenue (as crew are generally paid on the basis of the value of the catch), while freight, fuel, packaging and repairs were increased by the proportional increase in catch (assumed linearly related to fishing effort).

Given these assumptions, boat cash income of the trawl sector would decline on average and become negative (Table 26). That is, the additional cost of catching the full TAC (assuming it was technically possible) would outweigh the additional revenue once prices changed given the new level of landings. Full equity profits would also decrease, although remain positive. In contrast, vessels in the GHT sector would have experienced an increase in both boat cash income and full equity profits. Gummy Shark was a major component of the catch of this sector, and the demand model results found no price-quantity relationship (i.e., a zero own-price flexibility). As a result, the increase in catch resulted in a proportionally higher increase in revenue (compared to the trawl sector). As costs were relatively low for this sector, the gain in revenue was sufficient to more than offset the higher costs (Table 26).

Table 26. Potential changes in financial performance, SESSF average per vessel (A$)

	Trawl sector		GHT	
	2014–15 actual	all TACs caught	2014–15 actual	all TACs caught
Revenue				
Seafood receipts	974,260	1,173,791	451,816	540,514
Non-fishing receipts	79,148	79,148	12,422	12,422
Total cash receipts (a)	**1,053,408**	1,252,940	464,237	552,936
Costs				
Administration	14,440	14,440	7,160	7,160
Crew costs	346,377	346,377	189,974	227,269
Freight and marketing expenses	143,940	259,467	3,278	4,353
Fuel	169,575	305,678	49,809	66,140
Insurance	31,788	31,788	12,607	12,607
Interest paid	18,477	18,477	5,393	5,393
Licence fees and levies	25,232	25,232	18,864	18,864
Packaging	4,074	7,344	127	169
Repairs and maintenance	76,971	138,749	53,595	71,166
Other costs	132,602	132,602	104,684	104,684
Total cash costs (b)	**963,476**	**1,280,154**	445,490	**517,804**
Boat cash income (c=a-b)	**89,931**	**-27,215**	18,747	**35,132**
less Depreciation (d)	33,523	33,523	27,899	27,899
Boat business profit (e=c-d)	53,487	-60,738	-9,152	7,233
plus Interest, leasing and rent (f)	100,145	100,145	63,519	63,519
Profit at full equity (g=e+f)	153,631	39,407	54,367	70,752
Boat capital (h)	486,493	486,493	488,921	488,921
All capital (incl. quota and license) (i)	2,172,147	2,172,147	1,232,442	1,232,442
Rate of return to boat capital (g/h %)	32	8	11	14
Rate of return to all capital (g/i %)	7	2	4	6

Derived from Bath *et al.* (2018)

From the above, for the trawl fleet there are clearly no benefits in catching the full TAC once market effects are taken into account. For the GHT sector, there are potential financial benefits to vessel owners, although whether the crew would be prepared to work 33% more to gain an additional 20% of income may be questionable.

The above analysis is largely illustrative only, as the vessel economic information are dated, the assumptions about increased revenue and effort relate to more recent differences between catch and TACs, and the technical feasibility of catching the whole TAC is also uncertain. We have assumed a linear relationship between the increase in catch and the increase in effort required to take the catch, whereas this relationship may be non-linear (i.e., the marginal cost of capture may increase as we get closer to the TAC). Nevertheless, the results suggest that economic forces may also be a key factor contributing to the TAC undercatch, as it may not be economically viable to catch more than is currently being caught.

Estimating MEY

The Commonwealth Harvest Strategy Policy (Department of Agriculture and Water Resources 2018) identifies achieving maximum net economic returns from the fishery as a key objective of Australian fisheries management. This is generally taken to represent the maximum economic yield (MEY), which is the combination of catch, effort and biomass that maximises the profits across the fishery. Currently, target reference points used as a guide to achieve MEY are based on a biomass proxy, although ideally fishery specific targets would be identified through some form of bioeconomic model.

Several models of the SESSF have been developed over time (Baulch and Pascoe 1992; Punt *et al.* 2002a; Punt *et al.* 2002b; Kompas and Che 2006; Fulton *et al.* 2007; Pascoe *et al.* 2020) although these have not been sufficiently robust to be used in formal management decision making. Instead, they have been used for assessing different management policies or harvest strategies on a relative, rather than an absolute, basis. The latter of these models (Pascoe *et al.* 2020) includes the key species examined in this study as well economic information on the key fleets. An optimisation form of the model can be used to estimate a fishery-wide maximum economic yield, although this is most appropriately used to compare outcomes under different conditions rather than as an absolute measure of MEY.

For the purposes of illustrating the effects of including price flexibilities in assessing target reference points, the model of Pascoe *et al.* (2020) was modified to allow prices to vary with changes in quantity landed, based on the own and cross-price flexibilities estimated in this study. The baseline of the model was 2015, and was developed based on 2015 costs, prices, catches and fleet structures. The model included 11 metiers – combinations of fishing gear, area fished and target species (Biseau and Gondeaux 1988; Biseau 1998). These included six trawl metiers (two New South Wales – inshore and offshore; two Eastern Bass Strait; one Tasmanian and an offshore trawl metier targeting blue grenadier); two Danish seine metiers (Eastern and Central Bass Strait); two gillnet metiers (east and west) and one hook (line) metier.

The model was first run with the 2015 level of effort and fleet structure to estimate the equilibrium conditions given this fixed structure. The model was then run allowing fleets to vary but holding prices constant at their 2015 level (i.e., assuming zero price flexibilities), and also run with prices varying from their 2015 levels based on changes in catch and the own and cross-price flexibilities estimated in this study. The models were run with the objective of maximising long-run (equilibrium) fishery profits, consistent with the current harvest strategy policy. Finally, an earlier study suggested that when prices vary, maximising fishery profits may result in a loss to consumers through higher prices (Pascoe *et al.* 2018), and that a more appropriate target to maximise net economic returns to the broader community may be to maximise the sum of profits (producer surplus) and consumer surplus (benefits to consumers).

The effect of these assumptions on the optimal fleet size and structure can be seen in Figure 13. Maximising profits assuming constant prices results in the optimal fleet size decreasing by around 50% relative to 2015. However, allowing prices to vary results in a small fleet (Figure 13), lower catches and higher prices (Figure 14). However, while this resulted in higher profits to the fishing industry (Figure 15), it also resulted in a net loss of consumer surplus due to the higher prices being paid by consumers.

Maximising both producer and consumer surplus results in a larger optimal fleet relative to maximising fishery profits alone (Figure 13), lower prices (Figure 14) and lower fishery profit (Figure 15), but an overall higher net economic return.

Figure 13. Fleet size and structure under different model specifications

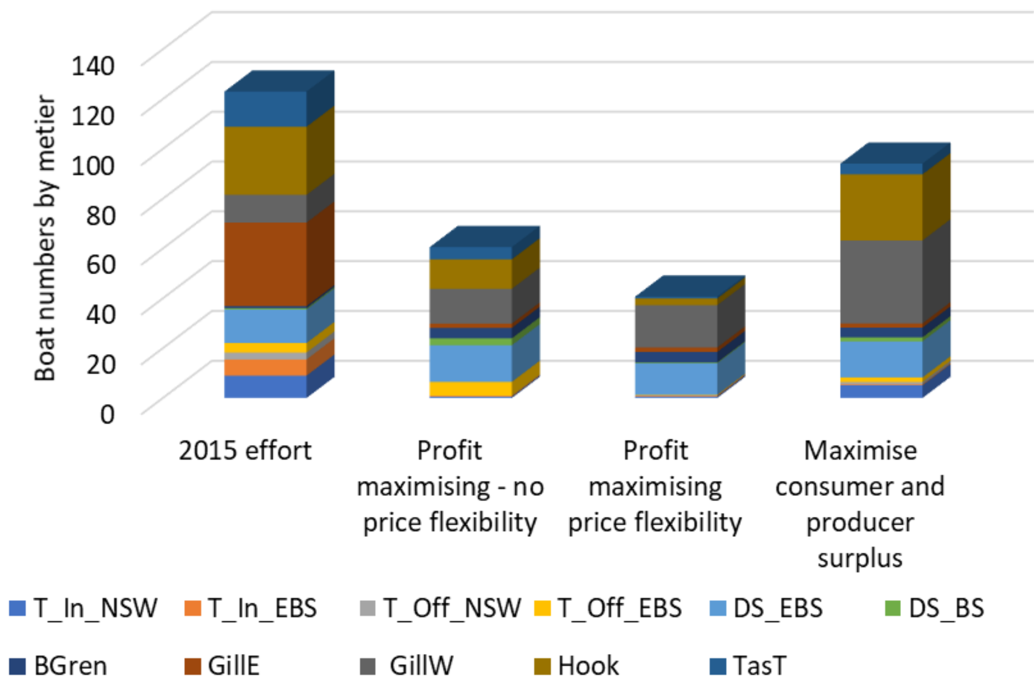


Figure 14. Relative (to 2015) catches, prices and optimal fishing mortality under different model specifications

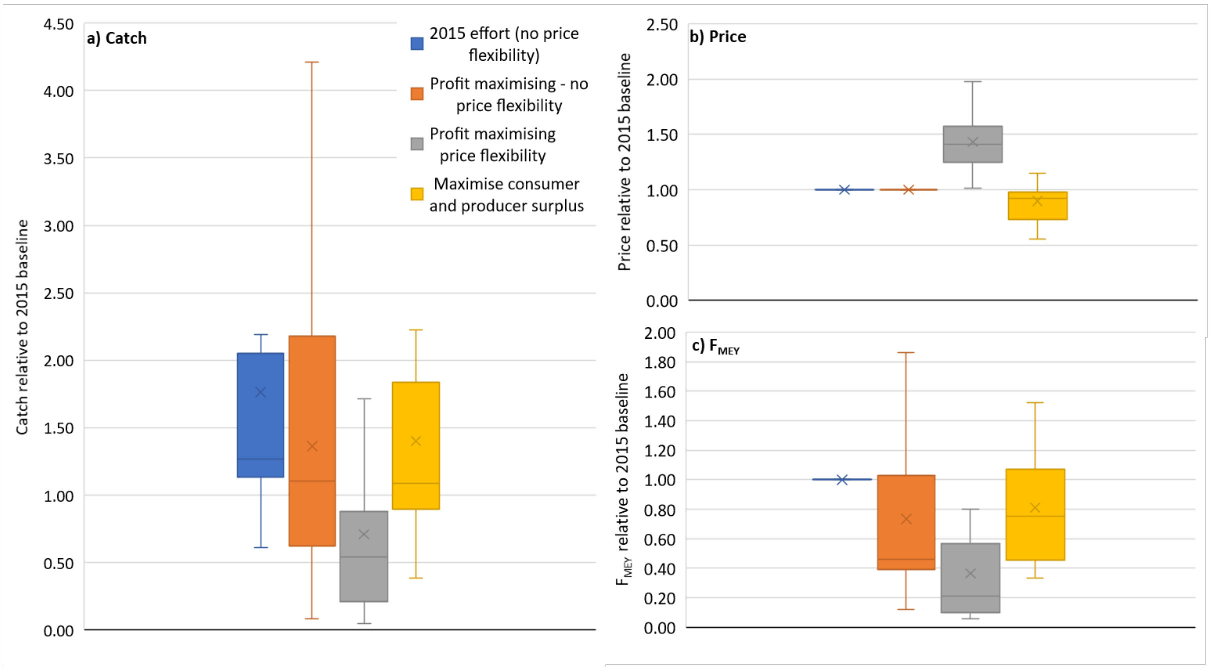
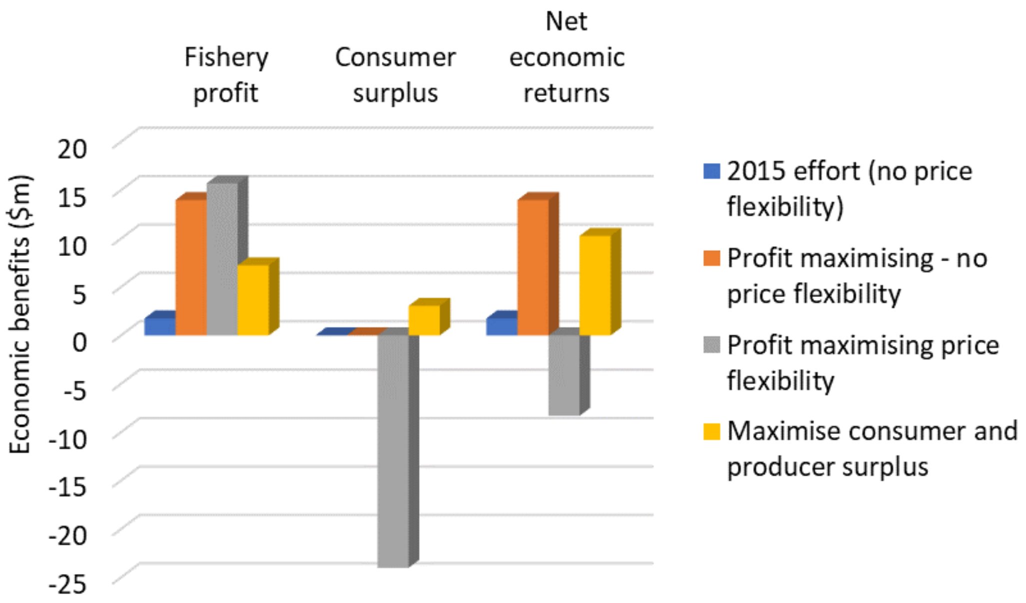


Figure 15. Economic benefits under different model specifications



Optimal fishing mortality levels (Figure 14) when maximising the sum of both producer and consumer surplus had a similar distribution to that when ignoring price changes. This is most likely an artefact of the particular set of prices, price flexibilities and costs in the model rather than a "result" that could be applied elsewhere. Prices under this scenario were generally lower than the baseline set of prices, and the catch distribution was also narrower.

From this, even though most own and cross-price flexibilities estimated in the study were relatively small in absolute terms, they can have a substantial impact on what might be considered an optimal level of fishing.

Limitations and caveats

The analyses were based on the best available data. However, as is common in fisheries economics analyses, these data were limited, and this may have implications for the interpretation of the results.

The lack of more recent Melbourne data created two issues for the study. First, the analysis comparing the two markets is based on data that is, at best, a decade old. This requires the assumption that no major changes have occurred over the last decade that may have changed these relationships. The Melbourne fish market has changed structurally since the period of the data, with one central auction market being replaced by several smaller auction and wholesale markets

The second is related to the quantity of available data. The cointegration analysis in this part of the study is based on a relatively short time series (n=67). Although we chose the ARDL bounds test which is less sensitive in its power to shorter samples, the robustness of the results could be affected.

For the demand analysis, while a longer time series of data was available (n=172), this still limited the number of species that could be included in the model. The process of seemingly unrelated regression used in the system of equations requires the estimation of a variance-covariance matrix, which requires the product of rows and columns to be less than the number of observations. In this case, even excluding lagged variables, a maximum of only 13 species could be included in the system. Once lagged variables and other variables associated with the model (e.g., the quantity index) are included, even fewer species could be considered in a single system. By splitting the species into two groups, we are able to estimate the interactions between these and the aggregated remainder, but are not able to capture the species level interactions between species in the different groups.

The Australian farmed salmon data also required a significant level of approximation due to the lack of monthly and spatially specific market data which could have affected the robustness of the results.

The treatment of imports in the analysis was also problematic. The raw data contained over 250 different import classification codes, many of which varied over time in what they contained. For example, more recent codes were more disaggregated whereas earlier codes tended to be more aggregated. The volume of potential import types was too great to include separately in the analyses, so aggregation was required. For the cointegration analysis, we used the more recent import data (from 2012) that allowed greater disaggregation. For the demand modelling, however, a higher level of aggregation was necessary as the earlier data were less disaggregated. In either case, more disaggregated information may have provided different results.

Both the market data and import data were also in product form, which in many cases involved different types of processing (e.g., fillets, gilled and gutted, head off etc). Conversion factors were used to adjust the weight of the product to a whole weight equivalent for consistency, but as some of the value of the product would have been associated with the value adding from processing, this may have distorted the average price (depending on the different combinations of processing that went into the aggregate measure). Assessing cointegration relationships at the base level product form was infeasible, as not all product forms were supplied to the market in each month. Similarly, the number of different product forms would have made a more disaggregated demand analysis infeasible.

The two selected econometric methods used for the cointegration analysis both have advantages and shortcomings. For example, a limitation of the Johansen test is the non-stationary precondition of the time series under review, and the power for the Johansen test is low for small samples (usually considered less than 80 observations) (Gonzalo and Lee 1998). Both methods are sensitive to the assumptions about constant, trends and the selected lag order. Hence, clear decision rules are required to determine under which assumptions cointegration of time series are found and under which this is not the case. This offers a substantial discretion to the analyst. Furthermore, both tests are sensitive to the assumptions that errors are independent and normally distributed. While the Johansen test has found application in a large number of studies that focus on the assessment of market relationship between multiple seafood products (e.g. Gordon *et al.* 1993; Jaffry *et al.* 2000; Bronnmann *et al.* 2016), the ARDL bounds test offers the opportunity to test for the direction of a price relationship in a bivariate case.

The demand modelling used data from the Sydney Fish Market only. While cointegration was established between the Sydney Fish Market and Melbourne market, fish landed in the SESSF also moves through other supply chains. For example, some high volume species are sold predominantly to processors, while others are also distributed through local cooperatives or sold directly to restaurants (Smith *et al.* 1998a).

Implicit in the demand analysis is that the proportion of landings sold through the Sydney Fish Market is relatively constant. That is, an increase in landings will result in a proportionate increase in supply to the Sydney Fish Market. Further, it is assumed that prices received through other supply chains move proportionally to the Sydney Fish Market (i.e., spatial equilibrium exists), and arbitrage opportunities are hence limited (i.e., limited ability to “play” the market). For those species where the Sydney Fish Market is the major market, then these assumptions are likely to be reasonably robust and the derived price flexibilities likely provide reasonable estimate. In cases where the Sydney Fish Market is only a marginal market (e.g., some other markets are supplied first which may offer higher prices or be able to accept higher volumes before the Sydney Fish Market is served), then the estimates presented in this study will only provide robust results for demand conditions within the Sydney Fish Market but may not represent demand for within SESSF as a whole (Smith *et al.* 1998a). Such concerns were also raised by Bose (2004).

For eight of the species examined in the demand modelling, Sydney Fish Market sales represented more than 50% of the total SESSF landings (Figure 3), and hence the results for these species are likely to be fairly robust. However, this concern could be valid of species such as Blue Grenadier and Orange Roughy which are predominantly sold directly by the SESSF to processors, or Gummy Shark which is sold predominantly through Melbourne markets. For these species the Sydney Fish Market sales represented a relatively small proportion of total SESSF landings (Figure 3). Hence, there could be significant variation in selling strategies which may affect the price-quantity relationship within the SESSF. Hence, a potential extension of this study could be an assessment of the supply and value chain of SESSF species. Such an analysis should specifically examine the level of competition within the wholesale segment of the supply chain as this could affect their price-quantity relationship and subsequently the representativeness of the analysis based on Sydney Fish Market data in this study.

Conclusions

The aim of this study was to investigate short term and longer term own and cross-price flexibilities of fish products traded within the Sydney Fish Market, imported fish and Australian farmed salmon. An inverse demand system framework was used to examine the price-quantity relationship of SESSF species.

Prices of the SESSF, as by proxy of Sydney Fish Market, do not develop independent of quantities supplies. Hence, catch levels/total allowable catch affect prices negatively and affect industry revenue. Prices of SESSF species were found to be primarily influenced by changes in their own quantities, but also by changes in quantities supplied by other SESSF species to a lesser extent.

The influence of imports on the price of fish caught in the SESSF has been subject to conflicting opinions in the past. For example, Ruello (2011) suggested that imports potentially complemented domestically caught fish rather than competing with them. This is through imports filling gaps in the market (seasonal gaps as well as different product forms), making consumers more aware about fish as a food choice, and thereby creating an overall increase in the demand for fish. This, in turn, leads to an increase in fish prices. In contrast, Knuckey *et al.* (2018) suggested that growth in imports may have had negative impacts on at least the lower valued species through increased competition, although there was no formal analysis undertaken at the time.

The results of our study support both apparently conflicting views when considering fresh and frozen imports separately. From the demand analysis, we found that the increases in imports of fresh fish since 2000 have had a significant negative impact on the prices of lower valued species, and may have a small negative impact on the price of high valued species in the longer term. In contrast, imports of frozen fish were found to have a positive impact on the price of the lower valued species (and no significant impact on the price of higher valued species). The combined effect of the increase in both fresh and frozen imports over the last two decades, however, has been to reduce prices (in real terms) of the lower valued SESSF species.

The impact of the growth in Australian farmed salmon production and its associated domestic consumption on the demand for wild-caught species has previously not been considered in Australia. Several studies overseas (e.g. Clayton and Gordon 1999; Jaffry *et al.* 2000; Regnier and Bayramoglu 2017) have concluded that farmed salmon (and other aquaculture species) compete with their wild-caught counterpart (e.g., wild salmon), but not generally with other fish species. From our study, we find that the increased production of farmed salmon in Australia has had a substantial negative impact on the prices received for species on the Sydney Fish Market; more so than the impact of imports. Salmon production is expected to continue to increase at around 3% a year over the next five years (Mobsby *et al.* 2020), which is likely to place further downward pressure on Sydney Fish Market prices.

The findings of this study exemplify the importance of considering market aspects in fishing management decisions as the neglect of these aspects could lead to suboptimal outcomes for the industry. We have shown that catching the full TACs (if technically feasible) may result in a loss of profits to some fishery sectors and only marginal gains to others, contributing to the understanding as to why under-caught TACs persists in the fishery. We have also shown that the optimal target reference point is sensitive to the assumptions as to how prices change in response to quantities landed. Furthermore, we have highlighted the difference between maximising fishery profits and maximising net economic returns when consumer benefits are also considered.

Implications

The results of the study have several implications for future management, not just of the SESSF but of fisheries more generally.

From the examples of application presented in the discussion section, higher total allowable catches (TACs) are not always of benefit to fishers, and under-caught TACs may be more a reflection of the market environment rather than the state of the resources. When prices decrease with quantity landing, revenues will increase less than proportionally with the increased TACs. As illustrated in the case of the Trawl sector of the SESSF, if fishers did catch their full quota (assuming that this is even technically possible), the result is a reduction in their profitability. In this case, under-caught TACs was a better outcome for this sector. Conversely, the economic impacts of a TAC reduction may be offset at least in part by higher prices and lower fishing costs. From the bioeconomic modelling example when only fishery benefits were considered, fishery profits increased with lower-than-current catches of all species. Given this, having an understanding of the price-quantity relationship is important when considering changes in TACs.

The example applications also demonstrated a need to clarify the meaning of “net economic returns”, and specifically whether changes in benefits to consumers needs to be considered when setting economic targets and/or TACs. Again, from the bioeconomic modelling application, maximising profits to the fishery resulted in a substantial loss of consumer benefits, and a net reduction in total (combined) economic benefits. Maximising benefits to both consumers and producers resulted in lower fishery profits than just considering fishers alone, but a gain to both consumers and producers from the baseline (2015) situation.

The study also highlighted the need to managers and industry to be aware of changes in the broader seafood environment in which they operate. Increasing aquaculture production globally is resulting in increased imports of fresh fish into Australia that we have shown to be directly competing with domestically produced fish, particularly lower valued species. This trend is likely to continue, resulting in ongoing downward pressure on fish prices in real terms. Similarly, increased Australian aquaculture production, particularly farmed salmon, has also negatively impacted wild-caught fish prices. Again, this production is expected to increase into the future. Lower future prices have implications for the longer-term economic sustainability of the SESSF.

Recommendations

The results of this study have demonstrated the importance of considering price-quantity interactions in TAC setting, although this is not routinely factored into such analyses. This may be, in part, due to a lack of fisheries that have well developed bioeconomic models to support decision making; a lack of understanding as to the importance of considering these interactions; a lack of information on such interactions; a lack of clear objectives or direction to include consumer impacts into the TAC setting process; or combinations of the above. Given this, managers and industry may wish to consider:

- Greater use of bioeconomic models to support TAC setting will enable these interactions to be factored directly into the determination, with implications for both industry and consumers made explicit;
- Explicit consideration of price impacts in the absence of a bioeconomic modelling framework when considering changing target catch levels;
- Explicit consideration of the future price environment given likely changes in imports and domestic salmon production when making long-term decisions for the fisheries; and
- Increased research into assessing price flexibilities in fisheries not previously assessed.

Further development

The study highlighted the importance of understanding the price-quantity relationship to fisheries management. Similar studies have been conducted at a broad scale for the Australian domestic prawn market (Schrobback *et al.* 2018; Schrobback *et al.* 2019a) and for oysters (Schrobback *et al.* 2014). However, in line with the last recommendation, there is considerable scope to gain greater information on the markets in which Australian producers operate in.

The shift in the Northern Prawn Fishery from exporting Banana Prawns to supplying these to the domestic market, and the planned expansion of prawn aquaculture in Northern Australia has potential implications for both the domestic and export markets, affecting prawn fisheries and farms around the coast. Re-examination of the prawn price-quantity relationships at a more disaggregated scale will enable industry and managers to better plan for the future.

Other fisheries are also dependent on the domestic market, but the implications of changing catch limits are not well understood. For example, the three scallop fisheries operating in Bass Strait are interlinked through the market (if not biologically), and production decisions in one fishery may have an impact on all three fisheries. A better understanding of the market dynamics for scallops would be of benefit to all three fisheries, potentially acting as a focus for more coordinated management.

The recent trade difficulties facing Rock Lobster exports has also raised challenges for the industry as to how best to trade-off reduced production against reduced prices on the domestic market. An analysis of the domestic Rock Lobster market will enable industry and managers to better navigate such problems in the future.

These are just three examples of potential further research on market dynamics that will benefit fisheries management and industry in the future. No doubt many other fisheries will benefit from similar studies relating to their key species of interest (e.g. crab fisheries). For the key export species, a better understanding of the price-quantity relationship on international markets will also be of benefit when planning future investments in the industry.

Extension and Adoption

The results of this study are largely to be disseminated through this report and journal articles that are produced from the study. The report is to be disseminated through the SESSFRAG and SEMAC to industry and management representatives.

Other activities include:

- A summary document has been produced (see Appendix G) for wider dissemination.
- A FISH magazine article is under development highlighting the importance of demand analysis for fisheries management.
- A presentation of the results is planned for SEMAC in July 2021 (delayed due to COVID-19).

Planned presentations of the results at various agricultural and fisheries economics conference (AARES and IIFET) have been thwarted by COVID19. However, presentations are being planned for future conferences (outside the time frame of the original project)

- The results of the cointegration analysis for the Sydney Fish Market will be presented at the meeting of the Queensland Branch of the Australasian Agriculture and Resource Economics Society (AARES) on 4th March 2021.
- An abstract for the presentation about the cointegration analysis for the Sydney Fish Market at the European Association of Environmental and Resource Economists Conference (23-26 June 2021, Online) has been submitted.
- An abstract has been submitted to the World Fisheries Conference (September 2021).

Project materials developed

Journal articles

- "Spatial integration of seafood prices: The case of Sydney and Melbourne, Australia", manuscript submitted to *Applied Economics*
- "Market integration of domestic and imported seafood: Insights from the Sydney Fish Market" manuscript submitted to *Australian Journal of Agricultural and Resource Economics*
- "Impact of imports and farmed salmon on domestic wild-caught fish species in Australia" manuscript in preparation
- "Price flexibilities for key species in the SESSF and their implications for management" manuscript in preparation

Appendices

Appendix A. Research staff involved with the project

The core research team consisted of

- Sean Pascoe and Eriko Hoshino, CSIRO
- Peggy Schrobback, CQUniversity
- Robert Curtotti, ABARES

Input into the project was also provided by:

- Dave Mobsby, ABARES
- Rupert Summerson, ABARES
- Gabriela Scheufele, CSIRO

Appendix B. Conversion factors product weight to live weight equivalent

Table B.1. Conversion factors, Sydney fish market

Description	Dory John	Dory Mirror	Elephant f	Flathead Tiger	Gemfish	Grenadier Blue	Ling Pink	Mowong Jack	Orange Rougy	Ocean Perch Big-eye	Perch Reef Ocean	Prawn Royal Red	Shark Gummy	Shark Saw	Shark School	Trevalla Blu Eye	Trevally Silver	Warehou Blu	Warehou Silver	Whiting E-School
BL							1													
C												1			3.35					1
CF																				2.5
CL		1.8	2.3	1.8	1.55	1.8	1.8	1.8		2.35			2	2	2	1.7		1.55	1.65	1.8
FC												1								
ff					2.15		2.5									2.25	2.1		3.9	2.5
FG												1								
FI	2.6	2.5	2.85	2.5	2.15	2.5	2.5	2.5	3.5	2.85	2.85					2.25	2.1	2	3.9	2.5
FM												2								
FN	2.6	2.5		2.5	2.15	2.5		2.5	3.5	2.85	2.85					2.25				2.5
FO	3.2	3.1	3.55		2.65		3.1	3.1	3.5		3.85						2.6			
FZ				1						1	1	1				1	1		1	1
GD	1			1			1	1			1						1			1
GG	1.2			1.2	1.2	1.2											1.2			
GH	1.5	1.5	2.3	1.5	1.5	1.5	1.45	1.5	1	1.9	1.9		2	2		1.4	1.5	1.4	1.55	1.5
GI	1.1	1.1			1.5		1.15	1.1		1.1						1.1	1.1	1.1		
GR												1								
GS												1								
GU	1.1			1.1	1.1														1.1	
HD					1.5							2				1.4				
HE					0		1									1				
IG	1.4		1.2		1.2		1.2			1.2	1.1					1.1		1.1	1.1	
IJ	1				1		1	1		1	1		1			1	1			
IS	1	1		1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1
IW	1	1		1	1	1	1	1		1	1				1	1	1	1	1	1
LC							1			2.35						2.8				
LO							1.8									2.8				
MT							3.1					2				2.8				
OL				1																
RE		1		1			1	1		1										1
RN	1				1														1	
RO	1	1		1	1	1	1		1	1						1	1	1	1	
SA								3.1								2.8	1			
SB		3.1	3.55	3.1	2.65		3.1	3.1	3.5	3.85	3.85					2.8	2.6		4.85	
SO				1.8			1.8	3.1			3.85									
ST							1													
TA												2								
WH	1			1	1	1							1		1		1	1		
WHO	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1
WI							1								1	1				
WN				1			1									1				
WO	1						1							1		1.7				

Table B.2. Conversion factors used for import data and number of applications of these factors to import categories

	Conversion factor applied																
	0	1.0	1.1	1.2	1.4	1.6	1.92	2.0	2.12	2.45	2.5	2.6	2.77	2.9	3.5	3.8	Total
Whole		*1*	*161*	*11*	*5*												*178*
• Hake (Fresh/Frozen)				5													5
• Aquaculture (Fresh/Frozen)			15														15
• Salmon (Fresh/Frozen)			17		5												22
• Fresh Other		1	57	6													64
• Frozen Other			72														72
Fillets			*3*			*1*	*4*	*20*	*1*	*1*	*5*	*10*	*1*	*2*		*1*	*49*
• Hake (Fresh/Frozen)											3			2			5
• Aquaculture (Fresh/Frozen)												10					10
• Salmon (Fresh/Frozen)								4									4
• Fresh Other			2				1	4			1						8
• Frozen Other			1			1	3	12	1	1	1		1			1	22
Meat								*12*						*3*	*5*		*20*
• Hake (Fresh/Frozen)														2			2
• Aquaculture (Fresh/Frozen)															4		4
• Salmon (Fresh/Frozen)														1			1
• Fresh Other								6									6
• Frozen Other								6							1		7
Other (e.g., roe)	*9*																*9*
• Fresh Other	5																5
• Frozen Other	4																4
Total	9	1	164	11	5	1	4	32	1	1	5	10	1	5	5	1	256

Appendix C. Cointegration test results, Sydney market

Table C.1. Results for ADF unit root test for logged nominal price data of seafood traded at the Sydney Fish Market (n=172)

Series	Assumption	Lag Selection Criterion	Lags	Level		1st difference		Result
				t-statistic	p-value	t-statistic	p-value	
John Dory	Constant	SIC	1	-3.827	0.00	-12.957	0.00	I(0)***
	Constant & trend	SIC	1	-5.998	0.00	-12.934	0.00	I(0)***
	None	SIC	3	0.244	0.76	-12.982	0.00	I(1)***
	Constant	AIC	6	-2.866	0.05	-3.047	0.03	I(0)*
	Constant & trend	AIC	5	-4.578	0.00	-6.912	0.00	I(0)***
	None	AIC	6	0.067	0.70	-6.886	0.00	I(1)***
Mirror Dory	Constant	SIC	0	-6.328	0.00	-9.420	0.00	I(0)***
	Constant & trend	SIC	10	-6.954	0.00	-9.571	0.00	I(0)***
	None	SIC	11	0.849	0.89	-9.386	0.00	I(1)***
	Constant	AIC	13	-0.773	0.82	-9.420	0.00	I(1)***
	Constant & trend	AIC	13	-1.791	0.70	-9.571	0.00	I(1)***
	None	AIC	11	0.849	0.89	-9.386	0.00	I(1)***
Tiger Flathead	Constant	SIC	4	-1.813	0.37	-12.166	0.00	I(1)***
	Constant & trend	SIC	3	-8.136	0.00	-12.128	0.00	I(0)***
	None	SIC	4	0.586	0.84	-12.163	0.00	I(1)***
	Constant	AIC	13	-1.494	0.53	-3.906	0.00	I(1)***
	Constant & trend	AIC	13	-2.943	0.15	-3.889	0.01	I(1)**
	None	AIC	13	0.958	0.91	-3.758	0.00	I(1)***
Gemfish	Constant	SIC	0	-7.265	0.00	-9.091	0.00	I(0)***
	Constant & trend	SIC	10	-8.010	0.00	-9.313	0.00	I(0)***
	None	SIC	11	-0.901	0.32	-9.056	0.00	I(1)***
	Constant	AIC	16	-0.069	0.95	-5.604	0.00	I(1)***
	Constant & trend	AIC	16	-1.526	0.82	-6.072	0.00	I(1)***
	None	AIC	16	-0.723	0.40	-5.576	0.00	I(1)***
Blue Grenadier	Constant	SIC	2	-3.487	0.01	-14.615	0.00	I(0)**
	Constant & trend	SIC	1	-7.770	0.00	-14.584	0.00	I(0)***
	None	SIC	2	-1.774	0.07	-14.660	0.00	I(0)*
	Constant	AIC	6	0.317	0.32	-8.248	0.00	I(1)***
	Constant & trend	AIC	2	-4.561	0.00	-8.231	0.00	I(0)***
	None	AIC	7	-0.853	0.34	-8.278	0.00	I(1)***
Pink Ling	Constant	SIC	11	-2.078	0.25	-10.694	0.00	I(1)***
	Constant & trend	SIC	10	-2.037	0.58	-10.725	0.00	I(1)***
	None	SIC	11	1.190	0.94	-10.592	0.00	I(1)***
	Constant	AIC	14	0.079	0.08	-4.426	0.00	I(0)**
	Constant & trend	AIC	14	-2.964	0.15	-4.520	0.00	I(1)***
	None	AIC	14	0.913	0.90	-4.301	0.00	I(1)***

Table C.1 continued

Series	Assumption	Lag Selection Criterion	Lags	Level t-statistic	Level p-value	1st difference t-statistic	1st difference p-value	Result
Jackass Morwong	Constant	SIC	0	-6.553	0.00	-10.045	0.00	I(0)***
	Constant & trend	SIC	10	-6.624	0.00	-10.514	0.00	I(0)***
	None	SIC	10	0.266	0.76	-10.043	0.00	I(1)***
	Constant	AIC	14	0.083	0.08	-4.026	0.00	I(0)**
	Constant & trend	AIC	14	-2.208	0.48	-4.438	0.00	I(1)***
	None	AIC	14	0.023	0.69	-4.044	0.00	I(1)***
Orange Roughy	Constant	SIC	2	-5.426	0.00	-11.591	0.00	I(0)***
	Constant & trend	SIC	3	-11.344	0.00	-11.552	0.00	I(0)***
	None	SIC	4	-0.258	0.59	-11.627	0.00	I(1)***
	Constant	AIC	11	0.396	0.40	-7.051	0.00	I(1)***
	Constant & trend	AIC	2	-6.894	0.00	-7.028	0.00	I(0)***
	None	AIC	11	0.181	0.74	-7.067	0.00	I(1)***
Bigeye Ocean Perch	Constant	SIC	0	-6.857	0.00	-8.919	0.00	I(0)***
	Constant & trend	SIC	9	-8.073	0.00	-8.994	0.00	I(0)***
	None	SIC	10	0.726	0.87	-8.885	0.00	I(1)***
	Constant	AIC	11	0.153	0.15	-8.308	0.00	I(1)***
	Constant & trend	AIC	10	-2.423	0.37	-8.427	0.00	I(1)***
	None	AIC	11	0.181	0.74	-7.067	0.00	I(1)***
Reef Ocean Perch	Constant	SIC	0	-8.756	0.00	-14.719	0.00	I(0)***
	Constant & trend	SIC	1	-8.729	0.00	-14.676	0.00	I(0)***
	None	SIC	2	-0.747	0.39	-14.763	0.00	I(1)***
	Constant	AIC	2	0.000	0.00	-9.903	0.00	I(0)***
	Constant & trend	AIC	2	-4.648	0.00	-9.873	0.00	I(0)***
	None	AIC	4	-0.628	0.44	-9.934	0.00	I(1)***
Royal Red Prawn	Constant	SIC	3	-3.011	0.04	-12.615	0.00	I(0)**
	Constant & trend	SIC	2	-3.968	0.01	-12.574	0.00	I(0)**
	None	SIC	3	0.138	0.72	-12.610	0.00	I(1)***
	Constant	AIC	3	0.036	0.04	-12.615	0.00	I(0)**
	Constant & trend	AIC	3	-3.339	0.06	-12.574	0.00	I(0)**
	None	AIC	3	0.138	0.72	-12.610	0.00	I(1)***
Gummy Shark	Constant	SIC	5	-2.153	0.22	-10.294	0.00	I(1)***
	Constant & trend	SIC	4	-8.456	0.00	-10.307	0.00	I(0)***
	None	SIC	5	0.494	0.82	-10.271	0.00	I(1)***
	Constant	AIC	17	0.298	0.30	-4.967	0.00	I(1)***
	Constant & trend	AIC	13	-2.694	0.24	-5.178	0.00	I(1)***
	None	AIC	3	0.138	0.72	-12.610	0.00	I(1)***

Table C.1 continued

Series	Assumption	Lag Selection Criterion	Lags	Level t-statistic	Level p-value	1st difference t-statistic	1st difference p-value	Result
Common Shark Saw	Constant	SIC	0	-5.538	0.00	-10.010	0.00	I(0)***
	Constant & trend	SIC	9	-6.546	0.00	-9.493	0.00	I(0)***
	None	SIC	10	-0.843	0.35	-9.997	0.00	I(1)***
	Constant	AIC	14	0.789	0.79	-3.949	0.00	I(1)***
	Constant & trend	AIC	14	-2.757	0.22	-4.187	0.01	I(1)***
	None	AIC	14	-0.729	0.40	-3.933	0.00	I(1)***
School Shark	Constant	SIC	0	-11.612	0.00	-9.254	0.00	I(0)***
	Constant & trend	SIC	7	-11.609	0.00	-9.218	0.00	I(0)***
	None	SIC	8	-0.292	0.58	-9.286	0.00	I(1)***
	Constant	AIC	1	0.000	0.00	-9.254	0.00	I(0)***
	Constant & trend	AIC	1	-10.104	0.00	-9.218	0.00	I(0)***
	None	AIC	8	-0.292	0.58	-9.286	0.00	I(1)***
Blue-eye Trevalla	Constant	SIC	2	-2.638	0.09	-15.195	0.00	I(0)*
	Constant & trend	SIC	1	-10.220	0.00	-15.165	0.00	I(0)***
	None	SIC	2	0.227	0.75	-15.226	0.00	I(1)***
	Constant	AIC	11	0.888	0.89	-7.896	0.00	I(1)***
	Constant & trend	AIC	0	-10.220	0.00	-7.876	0.00	I(0)***
	None	AIC	11	1.809	0.98	-7.617	0.00	I(1)***
Silver Trevally	Constant	SIC	11	-1.687	0.44	-9.698	0.00	I(1)***
	Constant & trend	SIC	10	-2.474	0.34	-9.712	0.00	I(1)***
	None	SIC	11	1.826	0.98	-11.109	0.00	I(1)***
	Constant	AIC	16	0.537	0.54	-3.002	0.04	I(1)**
	Constant & trend	AIC	16	-2.902	0.16	-2.986	0.14	I(2)***
	None	AIC	16	0.672	0.86	-2.880	0.00	I(1)***
Blue Warehou	Constant	SIC	0	-9.812	0.00	-10.746	0.00	I(0)***
	Constant & trend	SIC	4	-9.858	0.00	-10.776	0.00	I(0)***
	None	SIC	5	-0.808	0.36	-10.773	0.00	I(1)***
	Constant	AIC	16	0.537	0.54	-3.002	0.04	I(1)**
	Constant & trend	AIC	5	-2.971	0.14	-7.703	0.00	I(2)***
	None	AIC	9	-0.795	0.37	-7.607	0.00	I(1)***
Silver Warehou	Constant	SIC	4	-2.709	0.07	-11.935	0.00	I(0)*
	Constant & trend	SIC	3	-9.880	0.00	-11.910	0.00	I(0)***
	None	SIC	4	-1.040	0.27	-11.971	0.00	I(1)***
	Constant	AIC	5	0.050	0.05	-6.880	0.00	I(0)**
	Constant & trend	AIC	5	-4.889	0.00	-6.881	0.00	I(0)***
	None	AIC	11	-0.796	0.37	-7.174	0.00	I(1)***

Table C.1 continued

Series	Assumption	Lag Selection Criterion	Lags	Level		1st difference		Result
				t-statistic	p-value	t-statistic	p-value	
Eastern School Whiting	Constant	SIC	0	-4.859	0.00	-18.624	0.00	I(0)***
	Constant & trend	SIC	0	-5.883	0.00	-18.591	0.00	I(0)***
	None	SIC	1	-0.128	0.64	-18.651	0.00	I(1)***
	Constant	AIC	9	0.074	0.07	-7.224	0.00	I(0)**
	Constant & trend	AIC	9	-2.748	0.22	-7.295	0.00	I(1)***
	None	AIC	9	0.755	0.88	-7.120	0.00	I(1)***

Table C.2. Results for ADF unit root test for logged nominal price data of seafood traded at the Sydney Fish Market, seafood imports to New South Wales and Australian farmed salmon (n=93)

Series	Assumption	Lag Selection Criterion	Lags	Level		1st difference		Result
				t-statistic	p-value	t-statistic	p-value	
John Dory	Constant	SIC	0	-3.9021	0.00	-10.499	0.00	I(0)***
	Constant & trend	SIC	0	-6.0329	0.00	-10.484	0.00	I(0)***
	None	SIC	2	0.5584	0.84	-10.514	0.00	I(1)***
	Constant	AIC	2	-1.6326	0.46	-10.499	0.00	I(1)***
	Constant & trend	AIC	5	-3.7370	0.03	-10.484	0.00	I(0)**
	None	AIC	2	0.5584	0.84	-10.514	0.00	I(1)***
Mirror Dory	Constant	SIC	0	-4.5520	0.00	-8.024	0.00	I(0)**
	Constant & trend	SIC	0	-5.5994	0.00	-7.999	0.00	I(0)***
	None	SIC	3	-0.2645	0.59	-8.070	0.00	I(1)***
	Constant	AIC	0	-4.5520	0.00	-5.981	0.00	I(0)**
	Constant & trend	AIC	0	-5.5994	0.00	-5.954	0.00	I(0)***
	None	AIC	10	1.0116	0.92	-5.875	0.00	I(1)***
Tiger Flathead	Constant	SIC	0	-4.5568	0.00	-8.747	0.00	I(0)***
	Constant & trend	SIC	0	-5.6971	0.00	-8.695	0.00	I(0)***
	None	SIC	4	0.5713	0.84	-8.752	0.00	I(1)***
	Constant	AIC	12	-1.2455	0.65	-2.496	0.12	I(2)***
	Constant & trend	AIC	12	-1.9313	0.63	-2.521	0.32	I(2)***
	None	AIC	12	0.4962	0.82	-2.597	0.01	I(1)**
Gemfish	Constant	SIC	0	-4.9165	0.00	-8.311	0.00	I(0)***
	Constant & trend	SIC	2	-6.3647	0.00	-8.262	0.00	I(0)***
	None	SIC	4	-0.6512	0.43	-8.359	0.00	I(1)***
	Constant	AIC	9	-1.0863	0.72	-3.953	0.00	I(1)***
	Constant & trend	AIC	2	-6.3647	0.00	-5.704	0.00	I(0)***
	None	AIC	12	-1.3036	0.18	-3.761	0.00	I(1)***
Blue Grenadier	Constant	SIC	0	-8.0765	0.00	-8.679	0.00	I(0)***
	Constant & trend	SIC	0	-8.1750	0.00	-8.667	0.00	I(0)***
	None	SIC	2	-2.4905	0.01	-8.722	0.00	I(0)**
	Constant	AIC	0	-8.0765	0.00	-6.605	0.00	I(0)***
	Constant & trend	AIC	0	-8.1750	0.00	-4.911	0.00	I(0)***
	None	AIC	8	-1.3744	0.16	-4.893	0.00	I(1)***
Pink Ling	Constant	SIC	11	-2.5580	0.11	-7.876	0.00	I(1)***
	Constant & trend	SIC	7	-7.1172	0.00	-7.863	0.00	I(0)***
	None	SIC	11	0.4838	0.82	-7.913	0.00	I(1)***
	Constant	AIC	11	-2.5580	0.11	-7.876	0.00	I(1)***
	Constant & trend	AIC	11	-2.9992	0.14	-7.863	0.00	I(1)***
	None	AIC	11	0.4838	0.82	-7.913	0.00	I(1)***

Table C.2 *continued*

Series	Assumption	Lag Selection Criterion	Lags	Level		1st difference		Result
				t-statistic	p-value	t-statistic	p-value	
Jackass Morwong	Constant	SIC	0	-4.7042	0.00	-8.528	0.00	I(0)***
	Constant & trend	SIC	2	-5.9564	0.00	-8.054	0.00	I(0)***
	None	SIC	11	-0.8800	0.33	-8.487	0.00	I(1)***
	Constant	AIC	11	-0.1961	0.93	-7.904	0.00	I(1)***
	Constant & trend	AIC	11	-2.2758	0.44	-8.054	0.00	I(1)***
	None	AIC	11	-0.8800	0.33	-7.873	0.00	I(1)***
Orange Roughy	Constant	SIC	1	-9.6130	0.00	-9.095	0.00	I(0)***
	Constant & trend	SIC	1	-9.5635	0.00	-9.047	0.00	I(0)***
	None	SIC	4	-0.2330	0.60	-9.149	0.00	I(1)***
	Constant	AIC	1	-9.6130	0.00	-6.110	0.00	I(0)***
	Constant & trend	AIC	1	-9.5635	0.00	-6.071	0.00	I(0)***
	None	AIC	8	-0.2232	0.60	-6.151	0.00	I(1)***
Bigeye Ocean Perch	Constant	SIC	0	-6.2858	0.00	-12.452	0.00	I(0)***
	Constant & trend	SIC	0	-6.2796	0.00	-12.383	0.00	I(0)***
	None	SIC	1	-0.2047	0.61	-12.521	0.00	I(1)***
	Constant	AIC	0	-6.2858	0.00	-6.209	0.00	I(0)***
	Constant & trend	AIC	7	-5.5490	0.00	-6.234	0.00	I(0)***
	None	AIC	12	-0.1956	0.61	-6.256	0.00	I(1)***
Reef Ocean Perch	Constant	SIC	0	-6.1618	0.00	-7.582	0.00	I(0)***
	Constant & trend	SIC	0	-6.2715	0.00	-7.539	0.00	I(0)***
	None	SIC	4	-0.7157	0.40	-7.619	0.00	I(1)***
	Constant	AIC	5	-3.6247	0.01	-7.582	0.00	I(0)***
	Constant & trend	AIC	5	-3.7086	0.03	-7.539	0.00	I(0)**
	None	AIC	4	-0.7157	0.40	-7.619	0.00	I(1)***
Royal Red Prawn	Constant	SIC	0	-6.1621	0.00	-10.172	0.00	I(0)***
	Constant & trend	SIC	0	-8.2755	0.00	-10.094	0.00	I(0)***
	None	SIC	3	0.3114	0.77	-10.196	0.00	I(1)***
	Constant	AIC	3	-2.0604	0.26	-10.172	0.00	I(1)***
	Constant & trend	AIC	0	-8.2755	0.00	-10.094	0.00	I(0)***
	None	AIC	3	0.3114	0.77	-10.196	0.00	I(1)***
Gummy Shark	Constant	SIC	0	-6.7851	0.00	-8.174	0.00	I(0)***
	Constant & trend	SIC	0	-6.8108	0.00	-7.404	0.00	I(0)***
	None	SIC	4	-0.0608	0.66	-7.464	0.00	I(1)***
	Constant	AIC	0	-6.7851	0.00	-4.281	0.00	I(0)***
	Constant & trend	AIC	0	-6.8108	0.00	-4.271	0.01	I(0)***
	None	AIC	11	-0.1214	0.64	-4.319	0.00	I(1)***

Table C.2 *continued*

Series	Assumption	Lag Selection Criterion	Lags	Level t-statistic	Level p-value	1st difference t-statistic	1st difference p-value	Result
Common Shark Saw	Constant	SIC	0	-4.4774	0.00	-11.174	0.00	I(0)***
	Constant & trend	SIC	0	-5.6027	0.00	-11.113	0.00	I(0)***
	None	SIC	0	-2.5119	0.01	-11.231	0.00	I(0)***
	Constant	AIC	11	-0.4245	0.90	-6.712	0.00	I(1)***
	Constant & trend	AIC	0	-5.6027	0.00	-6.667	0.00	I(0)***
	None	AIC	11	-1.7227	0.08	-6.417	0.00	I(0)*
School Shark	Constant	SIC	0	-8.3228	0.00	-8.310	0.00	I(0)***
	Constant & trend	SIC	0	-8.3805	0.00	-8.257	0.00	I(0)***
	None	SIC	4	-0.6428	0.44	-8.364	0.00	I(1)***
	Constant	AIC	1	-7.3048	0.00	-6.238	0.00	I(0)***
	Constant & trend	AIC	1	-7.4262	0.00	-6.195	0.00	I(0)***
	None	AIC	8	-0.2609	0.59	-6.279	0.00	I(1)***
Blue-eye Trevalla	Constant	SIC	0	-6.0845	0.00	-11.037	0.00	I(0)***
	Constant & trend	SIC	0	-8.0324	0.00	-10.985	0.00	I(0)***
	None	SIC	2	0.2570	0.76	-11.083	0.00	I(1)***
	Constant	AIC	0	-6.0845	0.00	-5.548	0.00	I(0)***
	Constant & trend	AIC	6	-5.2718	0.00	-5.519	0.00	I(0)***
	None	AIC	11	1.5007	0.97	-5.285	0.00	I(1)***
Silver Trevally	Constant	SIC	2	-5.1605	0.00	-7.997	0.00	I(0)***
	Constant & trend	SIC	7	-7.2862	0.00	-7.942	0.00	I(0)***
	None	SIC	11	1.2918	0.95	-7.838	0.00	I(1)***
	Constant	AIC	11	-0.7919	0.82	-7.997	0.00	I(1)***
	Constant & trend	AIC	7	-7.2862	0.00	-7.942	0.00	I(0)***
	None	AIC	11	1.2918	0.95	-7.838	0.00	I(1)***
Blue Warehou	Constant	SIC	0	-6.9741	0.00	-7.948	0.00	I(0)***
	Constant & trend	SIC	0	-7.3115	0.00	-8.007	0.00	I(0)***
	None	SIC	5	-0.8082	0.36	-7.975	0.00	I(1)***
	Constant	AIC	6	-2.2116	0.20	-4.763	0.00	I(1)***
	Constant & trend	AIC	0	-7.3115	0.00	-5.089	0.00	I(0)***
	None	AIC	11	-0.8849	0.33	-4.693	0.00	I(1)***
Silver Warehou	Constant	SIC	0	-6.9507	0.00	-8.671	0.00	I(0)***
	Constant & trend	SIC	0	-7.7239	0.00	-8.618	0.00	I(0)***
	None	SIC	1	-1.9097	0.054	-8.718	0.00	I(0)**
	Constant	AIC	5	-3.0654	0.03	-5.601	0.00	I(0)**
	Constant & trend	AIC	5	-3.9944	0.01	-5.570	0.00	I(0)***
	None	AIC	10	-0.8958	0.33	-5.612	0.00	I(1)***

Table C.2 *continued*

Series	Assumption	Lag Selection Criterion	Lags	Level t-statistic	Level p-value	1st difference t-statistic	1st difference p-value	Result
Eastern School Whiting	Constant	SIC	0	-4.1322	0.00	-11.665	0.00	I(0)***
	Constant & trend	SIC	0	-4.1094	0.01	-11.600	0.00	I(0)***
	None	SIC	0	-0.2959	0.58	-11.727	0.00	I(1)***
	Constant	AIC	0	-4.1322	0.00	-5.988	0.00	I(0)***
	Constant & trend	AIC	0	-4.1094	0.01	-5.943	0.00	I(0)***
	None	AIC	7	0.0151	0.68	-6.023	0.00	I(1)***
Imported Aquaculture	Constant	SIC	1	-1.7593	0.40	-16.465	0.00	I(1)***
	Constant & trend	SIC	1	-3.8985	0.02	-16.414	0.00	I(0)**
	None	SIC	1	-0.3162	0.57	-16.541	0.00	I(1)***
	Constant	AIC	10	-0.7817	0.82	-4.240	0.00	I(1)***
	Constant & trend	AIC	1	-3.8985	0.02	-4.160	0.01	I(0)**
	None	AIC	10	0.9814	0.37	-4.012	0.00	I(1)***
Imported Hake	Constant	SIC	2	-2.9974	0.04	-12.408	0.00	I(0)**
	Constant & trend	SIC	0	-9.4872	0.00	-12.355	0.00	I(0)***
	None	SIC	2	-0.7107	0.41	-12.474	0.00	I(1)***
	Constant	AIC	2	-2.9974	0.04	-6.736	0.00	I(0)**
	Constant & trend	AIC	0	-9.4872	0.00	-6.688	0.00	I(0)***
	None	AIC	7	0.6421	0.85	-6.657	0.00	I(1)***
Imported Other Fresh Fish	Constant	SIC	1	-1.8091	0.37	-15.432	0.00	I(1)***
	Constant & trend	SIC	0	-6.2305	0.00	-15.360	0.00	I(0)***
	None	SIC	1	0.4687	0.81	-15.484	0.00	I(1)***
	Constant	AIC	1	-1.8091	0.37	-8.057	0.00	I(1)***
	Constant & trend	AIC	1	-4.2386	0.01	-8.018	0.00	I(0)**
	None	AIC	3	0.8706	0.90	-8.012	0.00	I(1)***
Imported Other Frozen Fish	Constant	SIC	1	-3.0875	0.03	-8.775	0.00	I(0)**
	Constant & trend	SIC	1	-4.2054	0.01	-8.721	0.00	I(0)*
	None	SIC	3	0.6528	0.86	-8.760	0.00	I(1)***
	Constant	AIC	1	-3.0875	0.03	-8.775	0.00	I(0)**
	Constant & trend	AIC	1	-4.2054	0.01	-8.721	0.00	I(0)*
	None	AIC	3	0.6528	0.86	-8.760	0.00	I(1)***
Imported Salmon	Constant	SIC	1	-2.6223	0.09	-11.792	0.00	I(1)***
	Constant & trend	SIC	1	-3.6256	0.03	-11.763	0.00	I(0)**
	None	SIC	2	0.8214	0.89	-11.759	0.00	I(1)***
	Constant	AIC	4	-2.4652	0.13	-6.798	0.00	I(1)***
	Constant & trend	AIC	7	-2.7488	0.22	-6.899	0.00	I(1)***
	None	AIC	4	1.1456	0.93	-6.642	0.00	I(1)***

Table C.3. Johansen test results for seafood traded at the Sydney Fish Market (n=172)

Variables	Assumption	Criterion	Lag	Rank	Trace Test Statistic	10%	5%	1%	Cointegration	Law of One Price			LM Test		
										Chi-squared	p-value	Substitutes	Chi-squared	p-value	Serial correlation
John Dory & Mirror Dory	None	AIC(n)	11	r<=1	0.87	7.52	9.24	12.97					69.38	0.15	No
				r=0	15.56	17.85	19.96	24.6	No						
John Dory & Flathead Tiger	None	AIC(n)	5	r<=1	2.87	6.5	8.18	11.65					59.80	0.08	Yes
				r=0	21.76	15.66	17.95	23.52	No						
John Dory & Gemfish	Constant	AIC(n)	12	r<=1	1.34	7.52	9.24	12.97		20.5	0.00	No	28.66	0.05	Yes
				r=0	23.42	17.85	19.96	24.6	No						
John Dory & Blue Grenadier	None	AIC(n)	3	r<=1	7.4	6.5	8.18	11.65					56.78	0.37	Yes
				r=0	26.61	15.66	17.95	23.52	No - Full rank						
John Dory & Pink Ling	None	AIC(n)	3	r<=1	8.85	6.5	8.18	11.65					92.98	0.00	Yes
				r=0	41.88	15.66	17.95	23.52	No - Full rank						
John Dory & Morwong Jackass	None	AIC(n)	12	r<=1	1.82	6.5	8.18	11.65					27.83	0.06	Yes
				r=0	22.73	15.66	17.95	23.52	No - Full rank						
John Dory & Orange Roughy	None	AIC(n)	9	r<=1	3.48	6.5	8.18	11.65					42.55	0.06	Yes
				r=0	13.49	15.66	17.95	23.52	No						
John Dory & Bigeye Ocean	None	AIC(n)	11	r<=1	4.94	6.5	8.18	11.65					17.38	0.74	No
Perch				r=0	13.59	15.66	17.95	23.52	No						
John Dory & Reef Ocean Perch	None	AIC(n)	4	r<=1	8.95	6.5	8.18	11.65					51.33	0.42	No
				r=0	32.41	15.66	17.95	23.52	No - Full rank						
John Dory & Royal Red Prawn	None	SC(n)	3	r<=1	8.34	6.5	8.18	11.65					62.91	0.19	No
				r=0	23.51	15.66	17.95	23.52	No						
John Dory & Gummy Shark	None	AIC(n)	4	r<=1	8.31	6.5	8.18	11.65					77.53	0.01	Yes
				r=0	22.02	15.66	17.95	23.52	No						
John Dory & Common Saw	None	AIC(n)	12	r<=1	0.03	6.5	8.18	11.65					32.30	0.02	Yes
Shark				r=0	14.06	15.66	17.95	23.52	No						
John Dory & School Shark	None	AIC(n)	3	r<=1	9.27	6.5	8.18	11.65					53.15	0.51	No
				r=0	76.17	15.66	17.95	23.52	No - Full rank						
John Dory & Blue-eye Trevalla	None	SC(n)	3	r<=1	5.69	6.5	8.18	11.65		0.9	0.34	Yes	60.62	0.25	No
				r=0	25.6	15.66	17.95	23.52	Yes						
John Dory & Trevally Silver	None	AIC(n)	12	r<=1	1.25	6.5	8.18	11.65					32.43	0.02	Yes
				r=0	11.49	15.66	17.95	23.52	No						
John Dory & Blue Warehou	None	AIC(n)	7	r<=1	4.83	6.5	8.18	11.65					33.40	0.68	No
				r=0	23.86	15.66	17.95	23.52	No						
John Dory & Silver Warehou	Constant	AIC(n)	6	r<=1	6.29	7.52	9.24	12.97		20.99	0.00	No	48.99	0.21	No
				r=0	33.58	17.85	19.96	24.6	Yes						
John Dory & Eastern School	None	AIC(n)	8	r<=1	4.42	6.5	8.18	11.65					34.06	0.47	No
Whiting				r=0	14.77	15.66	17.95	23.52	No						
Mirror Dory & Flathead Tiger	None	AIC(n)	12	r<=1	0.02	6.5	8.18	11.65					25.92	0.10	No
				r=0	9.09	15.66	17.95	23.52	No						
Mirror Dory & Gemfish	None	AIC(n)	12	r<=1	0.28	6.5	8.18	11.65					29.13	0.05	Yes
				r=0	7.23	15.66	17.95	23.52	No						
Mirror Dory & Blue Grenadier	None	AIC(n)	11	r<=1	0.41	6.5	8.18	11.65					32.99	0.06	Yes
				r=0	5.36	15.66	17.95	23.52	No						

Table C.3 continued (1)

Variables	Assumption	Criterion	Lag	Rank	Trace Test Statistic	10%	5%	1%	Cointegration	Law of One Price			LM Test		
										Chi-squared	p-value	Substitutes	Chi-squared	p-value	Serial correlation
Mirror Dory & Pink Ling	Constant	AIC(n)	12	r<=1	0.99	7.52	9.24	12.97					21.12	0.27	Yes
				r=0	11.57	17.85	19.96	24.6	No						
Mirror Dory & Morwong Jackass	None	AIC(n)	12	r<=1	0	6.5	8.18	11.65					26.42	0.09	Yes
				r=0	8.91	15.66	17.95	23.52	No						
Mirror Dory & Orange Roughy	None	AIC(n)	12	r<=1	0.53	6.5	8.18	11.65					22.47	0.21	No
				r=0	7.4	15.66	17.95	23.52	No						
Mirror Dory & Bigeye Ocean Perch	None	AIC(n)	12	r<=1	0.08	6.5	8.18	11.65					30.75	0.03	Yes
				r=0	8.25	15.66	17.95	23.52	No						
Mirror Dory & Reef Ocean Perch	None	AIC(n)	12	r<=1	0	6.5	8.18	11.65					17.61	0.48	Yes
				r=0	14.98	15.66	17.95	23.52	No						
Mirror Dory & Royal Red Prawn	None	AIC(n)	12	r<=1	0.17	6.5	8.18	11.65					26.29	0.09	Yes
				r=0	11.33	15.66	17.95	23.52	No						
Mirror Dory & Gummy Shark	None	HQ(n)	6	r<=1	4.55	6.5	8.18	11.65		1.49	0.22	Yes	52.23	0.13	No
				r=0	28.64	15.66	17.95	23.52	Yes						
Mirror Dory & Common Saw Shark	Constant	AIC(n)	11	r<=1	0.67	7.52	9.24	12.97					38.51	0.02	Yes
				r=0	14.97	17.85	19.96	24.6	No						
Mirror Dory & School Shark	None	AIC(n)	11	r<=1	0.4	6.5	8.18	11.65					28.75	0.15	No
				r=0	13.19	15.66	17.95	23.52	No						
Mirror Dory & Blue-eye Trevalla	None	HQ(n)	5	r<=1	1.95	6.5	8.18	11.65		0.03	0.87	Yes	37.29	0.79	No
				r=0	40.79	15.66	17.95	23.52	Yes						
Mirror Dory & Trevally Silver	None	HQ(n)	11	r<=1	0.06	6.5	8.18	11.65					39.85	0.01	Yes
				r=0	16.95	15.66	17.95	23.52	No						
Mirror Dory & Warehou Blue	None	AIC(n)	12	r<=1	0.12	6.5	8.18	11.65					19.89	0.34	No
				r=0	4.13	15.66	17.95	23.52	No						
Mirror Dory & Warehou Silver	None	AIC(n)	11	r<=1	0.44	6.5	8.18	11.65					22.28	0.44	No
				r=0	10.07	15.66	17.95	23.52	No						
Mirror Dory & Eastern School Whiting	None	AIC(n)	12	r<=1	0.16	6.5	8.18	11.65					31.74	0.02	Yes
				r=0	11.06	15.66	17.95	23.52	No						
Tiger Flathead & Gemfish	None	SC(n)	5	r<=1	2.96	6.5	8.18	11.65					66.49	0.03	Yes
				r=0	17.69	15.66	17.95	23.52	No						
Tiger Flathead & Grenadier Blue	None	HQ(n)	6	r<=1	1.46	6.5	8.18	11.65					46.03	0.31	No
				r=0	14.64	15.66	17.95	23.52	No						
Tiger Flathead & Pink Ling	None	HQ(n)	11	r<=1	1.37	6.5	8.18	11.65					36.12	0.03	Yes
				r=0	7.55	15.66	17.95	23.52	No						
Tiger Flathead & Morwong Jackass	None	HQ(n)	11	r<=1	0.09	6.5	8.18	11.65					43.28	0.00	Yes
				r=0	10.19	15.66	17.95	23.52	No						
Tiger Flathead & Orange Roughy	None	AIC(n)	5	r<=1	3.25	6.5	8.18	11.65					59.81	0.08	Yes
				r=0	21.65	15.66	17.95	23.52	No						
Tiger Flathead & Bigeye Ocean Perch	None	HQ(n)	5	r<=1	3.23	6.5	8.18	11.65					56.04	0.15	No
				r=0	20.35	15.66	17.95	23.52	No						

Table C.3 continued (2)

Variables	Assumption	Criterion	Lag	Rank	Trace Test Statistic	10%	5%	1%	Cointegration	Law of One Price			LM Test		
										Chi-squared	p-value	Substitutes	Chi-squared	p-value	Serial correlation
Tiger Flathead & Reef Ocean Perch	None	AIC(n)	5	r<=1	3.21	6.5	8.18	11.65					47.93	0.39	No
				r=0	17.01	15.66	17.95	23.52	No						
Tiger Flathead & Royal Red Prawn	None	HQ(n)	5	r<=1	3.09	6.5	8.18	11.65					56.19	0.14	No
				r=0	16.08	15.66	17.95	23.52	No						
Tiger Flathead & Gummy Shark	None	HQ(n)	5	r<=1	3.89	6.5	8.18	11.65					77.40	0.00	Yes
				r=0	18.8	15.66	17.95	23.52	No						
Tiger Flathead & Common Saw Shark	None	HQ(n)	5	r<=1	1.16	6.5	8.18	11.65		20.25	0.00	No	58.21	0.11	Yes
				r=0	25.46	15.66	17.95	23.52	Yes						
Tiger Flathead & School Shark	None	AIC(n)	5	r<=1	3.22	6.5	8.18	11.65		27.71	0.00	No	45.01	0.51	Yes
				r=0	51.31	15.66	17.95	23.52	Yes						
Tiger Flathead & Blue-eye Trevalla	None	AIC(n)	12	r<=1	0.35	6.5	8.18	11.65					32.10	0.02	Yes
				r=0	5.58	15.66	17.95	23.52	No						
Tiger Flathead & Silver Trevally	None	HQ(n)	11	r<=1	3.26	6.5	8.18	11.65					41.31	0.01	Yes
				r=0	10.54	15.66	17.95	23.52	No						
Tiger Flathead & Warehou Blue	None	AIC(n)	6	r<=1	2.4	6.5	8.18	11.65					44.15	0.38	No
				r=0	12.54	15.66	17.95	23.52	No						
Tiger Flathead & Silver Warehou	None	HQ(n)	5	r<=1	1.97	6.5	8.18	11.65					77.58	0.00	Yes
				r=0	14.65	15.66	17.95	23.52	No						
Tiger Flathead & Eastern School	None	HQ(n)	5	r<=1	3.26	6.5	8.18	11.65		0.06	0.81	Yes	53.03	0.22	Yes
Whiting				r=0	28.61	15.66	17.95	23.52	Yes						
Gemfish & Blue Grenadier	None	HQ(n)	5	r<=1	6.44	6.5	8.18	11.65					74.58	0.00	Yes
				r=0	22	15.66	17.95	23.52	No						
Gemfish & Pink Link	None	HQ(n)	11	r<=1	0.71	6.5	8.18	11.65					33.56	0.05	Yes
				r=0	7.51	15.66	17.95	23.52	No						
Gemfish & Morwong Jackass	None	HQ(n)	12	r<=1	0.12	6.5	8.18	11.65					38.24	0.00	Yes
				r=0	16.18	15.66	17.95	23.52	No						
Gemfish & Orange Roughy	None	AIC(n)	12	r<=1	0.13	6.5	8.18	11.65					33.44	0.01	Yes
				r=0	5.02	15.66	17.95	23.52	No						
Gemfish & Bigeye Ocean Perch	None	AIC(n)	12	r<=1	0.34	6.5	8.18	11.65					31.48	0.03	Yes
				r=0	8.69	15.66	17.95	23.52	No						
Gemfish & Reef Ocean Perch	None	AIC(n)	12	r<=1	0	6.5	8.18	11.65					42.51	0.00	Yes
				r=0	15.65	15.66	17.95	23.52	No						
Gemfish & Royal Red Prawn	None	AIC(n)	12	r<=1	0.27	6.5	8.18	11.65					18.09	0.45	No
				r=0	9.84	15.66	17.95	23.52	No						
Gemfish & Gummy Shark	None	SC(n)	5	r<=1	5.36	6.5	8.18	11.65					58.74	0.10	Yes
				r=0	17.83	15.66	17.95	23.52	No						
Gemfish & Common Saw Shark	None	AIC(n)	12	r<=1	0.28	6.5	8.18	11.65					38.89	0.00	Yes
				r=0	5.45	15.66	17.95	23.52	No						
Gemfish & Blue-eye Trevalla	None	AIC(n)	12	r<=1	0	6.5	8.18	11.65					22.40	0.21	No
				r=0	13.71	15.66	17.95	23.52	No						

Table C.3 continued (3)

Variables	Assumption	Criterion	Lag	Rank	Trace Test Statistic	10%	5%	1%	Cointegration	Law of One Price			LM Test		
										Chi-squared	p-value	Substitutes	Chi-squared	p-value	Serial correlation
Gemfish & Blue-eye Trevalla	None	SC(n)	3	r<=1	4.08	6.5	8.18	11.65		93.81	0.01	No	45.64	0.45	No
				r=0	53.91	15.66	17.95	23.52	Yes						
Gemfish & Silver Trevally	Constant	HQ(n)	10	r<=1	2.79	7.52	9.24	12.97					47.67	0.01	Yes
				r=0	13.21	17.85	19.96	24.6	No						
Gemfish & Blue Warehou	None	HQ(n)	6	r<=1	7.51	6.5	8.18	11.65					64.71	0.01	Yes
				r=0	20.11	15.66	17.95	23.52	No						
Gemfish & Silver Warehou	None	AIC(n)	12	r<=1	1.36	6.5	8.18	11.65					31.71	0.02	Yes
				r=0	12.24	15.66	17.95	23.52	No						
Gemfish & Eastern School Whiting	None	HQ(n)	6	r<=1	5.14	6.5	8.18	11.65					61.07	0.03	Yes
				r=0	14.47	15.66	17.95	23.52	No						
Blue Grenadier & Pink Ling	None	HQ(n)	11	r<=1	1.72	6.5	8.18	11.65					40.00	0.01	Yes
				r=0	14.05	15.66	17.95	23.52	No						
Blue Grenadier & Morwong Jackass	None	HQ(n)	11	r<=1	2.66	6.5	8.18	11.65					33.54	0.05	Yes
				r=0	10.03	15.66	17.95	23.52	No						
Blue Grenadier & Orange Roughy	None	AIC(n)	7	r<=1	3.15	6.5	8.18	11.65					58.98	0.02	Yes
				r=0	23.37	15.66	17.95	23.52	No						
Blue Grenadier & Bigeye Ocean Perch	None	AIC(n)	11	r<=1	2.09	6.5	8.18	11.65					23.80	0.36	No
				r=0	15.29	15.66	17.95	23.52	No						
Blue Grenadier & Ocean Reef Perch	None	AIC(n)	3	r<=1	11.39	7.52	9.24	12.97					62.79	0.19	No
				r=0	33.1	17.85	19.96	24.6	No - Full rank						
Blue Grenadier & Royal Red Prawn	None	SC(n)	3	r<=1	8.99	7.52	9.24	12.97					70.63	0.06	Yes
				r=0	25.05	17.85	19.96	24.6	No						
Blue Grenadier & Gummy Shark	None	AIC(n)	7	r<=1	1.97	6.5	8.18	11.65					41.82	0.31	No
				r=0	18.56	15.66	17.95	23.52	No						
Blue Grenadier & Common Saw Shark	None	AIC(n)	11	r<=1	0.32	6.5	8.18	11.65					35.93	0.03	Yes
				r=0	5.22	15.66	17.95	23.52	No						
Blue Grenadier & School Shark	None	HQ(n)	6	r<=1	4.65	6.5	8.18	11.65		27.99	0.00	No	48.48	0.23	Yes
				r=0	37.7	15.66	17.95	23.52	Yes						
Blue Grenadier & Blue-eye Trevalla	None	AIC(n)	11	r<=1	0.14	6.5	8.18	11.65					34.14	0.05	Yes
				r=0	9.09	15.66	17.95	23.52	No						
Blue Grenadier & Silver Trevally	None	HQ(n)	11	r<=1	1.2	6.5	8.18	11.65					26.84	0.22	No
				r=0	12.36	15.66	17.95	23.52	No						
Blue Grenadier & Blue Warehou	None	AIC(n)	7	r<=1	4.2	6.5	8.18	11.65					44.39	0.22	No
				r=0	17.82	15.66	17.95	23.52	No						
Blue Grenadier & Silver Warehou	None	AIC(n)	5	r<=1	5.41	6.5	8.18	11.65					52.82	0.23	No
				r=0	22.04	15.66	17.95	23.52	No						
Blue Grenadier & Eastern School Whiting	None	AIC(n)	10	r<=1	2.27	6.5	8.18	11.65					27.52	0.38	No
				r=0	12.45	15.66	17.95	23.52	No						
Pink Ling & Morwong Jackass	None	AIC(n)	12	r<=1	1.45	6.5	8.18	11.65					32.07	0.02	Yes
				r=0	13.91	15.66	17.95	23.52	No						

Table C.3 continued (4)

Variables	Assumption	Criterion	Lag	Rank	Trace Test Statistic	10%	5%	1%	Cointegration	Law of One Price			LM Test		
										Chi-squared	p-value	Substitutes	Chi-squared	p-value	Serial correlation
Pink Ling & Orange Roughy	None	AIC(n)	12	r<=1	3.55	6.5	8.18	11.65					35.47	0.01	Yes
				r=0	15.41	15.66	17.95	23.52	No						
Pink Ling & Bigeye Ocean Perch	None	HQ(n)	11	r<=1	5.67	6.5	8.18	11.65		2.9	0.09	No	30.95	0.10	Yes
				r=0	23.55	15.66	17.95	23.52	No*						
Pink Ling & Reef Ocean Perch	None	AIC(n)	12	r<=1	4.66	6.5	8.18	11.65					21.59	0.25	No
				r=0	20.56	15.66	17.95	23.52	No						
Pink Ling & Royal Red Prawn	None	AIC(n)	12	r<=1	4.39	6.5	8.18	11.65					32.28	0.02	Yes
				r=0	12.86	15.66	17.95	23.52	No						
Pink Ling & Gummy Shark	None	AIC(n)	12	r<=1	3.93	7.52	9.24	12.97					29.79	0.04	Yes
				r=0	12.64	17.85	19.96	24.6	No						
Pink Ling & Common Saw Shark	None	HQ(n)	11	r<=1	0.11	6.5	8.18	11.65					26.85	0.22	No
				r=0	9.93	15.66	17.95	23.52	No						
Pink Ling & School Shark	None	AIC(n)	12	r<=1	6.85	7.52	9.24	12.97					32.20	0.02	Yes
				r=0	22.1	17.85	19.96	24.6	No						
Pink Ling & Blue-eye Trevalla	None	HQ(n)	11	r<=1	0.51	6.5	8.18	11.65					25.30	0.28	No
				r=0	11.15	15.66	17.95	23.52	No						
Pink Ling & Silver Trevally	None	HQ(n)	12	r<=1	5.72	6.5	8.18	11.65					31.06	0.03	Yes
				r=0	13.31	15.66	17.95	23.52	No						
Pink Ling & Blue Warehou	None	HQ(n)	11	r<=1	2.57	6.5	8.18	11.65					20.81	0.53	No
				r=0	8.76	15.66	17.95	23.52	No						
Pink Ling & Silver Warehou	None	HQ(n)	12	r<=1	2.07	6.5	8.18	11.65					20.37	0.31	Yes
				r=0	11.51	15.66	17.95	23.52	No						
Pink Ling & Eastern School Whiting	None	HQ(n)	12	r<=1	6.77	6.5	8.18	11.65					32.12	0.02	Yes
				r=0	16.54	15.66	17.95	23.52	No						
Morwong Jackass & Orange Roughy	None	AIC(n)	12	r<=1	4.74	6.5	8.18	11.65					31.20	0.03	Yes
				r=0	13.31	15.66	17.95	23.52	No						
Morwong Jackass & Bigeye Ocean Perch	None	AIC(n)	11	r<=1	3.76	6.5	8.18	11.65					28.57	0.16	No
				r=0	13.83	15.66	17.95	23.52	No						
Morwong Jackass & Reef Ocean Perch	None	AIC(n)	12	r<=1	7.98	6.5	8.18	11.65					20.30	0.32	No
				r=0	29.17	15.66	17.95	23.52	No - Full rank						
Morwong Jackass & Royal Red Prawn	None	HQ(n)	11	r<=1	1.35	6.5	8.18	11.65					45.10	0.00	Yes
				r=0	13.33	15.66	17.95	23.52	No						
Morwong Jackass & Gummy Shark	None	AIC(n)	12	r<=1	3.11	6.5	8.18	11.65					48.59	0.00	Yes
				r=0	12.81	15.66	17.95	23.52	No						
Morwong Jackass & Common Saw Shark	None	HQ(n)	11	r<=1	0.8	6.5	8.18	11.65					41.74	0.01	Yes
				r=0	10.4	15.66	17.95	23.52	No						
Morwong Jackass & School Shark	None	AIC(n)	12	r<=1	7.54	6.5	8.18	11.65					28.88	0.05	Yes
				r=0	24.96	15.66	17.95	23.52	No - Full rank						
Morwong Jackass & Blue-eye Trevalla	None	HQ(n)	12	r<=1	0.05	6.5	9.24	12.97					38.10	0.00	Yes
				r=0	11.96	8.18	11.65	23.52	No						
Morwong Jackass & Silver Trevally	None	HQ(n)	12	r<=1	0.14	6.5	8.18	11.65					27.62	0.07	Yes
				r=0	12.47	15.66	17.95	23.52	No						

Table C.3 continued (5)

Variables	Assumption	Criterion	Lag	Rank	Trace Test Statistic	10%	5%	1%	Cointegration	Law of One Price			LM Test		
										Chi-squared	p-value	Substitutes	Chi-squared	p-value	Serial correlation
Morwong Jackass & Eastern School Whiting	None	HQ(n)	12	r<=1	1.12	6.5	8.18	11.65					27.20	0.08	Yes
				r=0	12.82	15.66	17.95	23.52	No						
Orange Roughy & Bigeye Ocean Perch	None	AIC(n)	11	r<=1	4.25	6.5	8.18	11.65					24.90	0.30	No
				r=0	21.91	15.66	17.95	23.52	No						
Orange Roughy & Reef Ocean Perch	None	AIC(n)	5	r<=1	10.13	6.5	8.18	11.65					46.10	0.47	No
				r=0	30.95	15.66	17.95	23.52	No - Full rank						
Orange Roughy & Royal Red Prawn	Constant	AIC(n)	5	r<=1	8.6	7.52	9.24	12.97					47.42	0.41	No
				r=0	23.56	17.85	19.96	24.6	No						
Orange Roughy & Gummy Shark	None	AIC(n)	12	r<=1	2.75	6.5	8.18	11.65					32.97	0.02	Yes
				r=0	19.54	15.66	17.95	23.52	No						
Orange Roughy & Common Saw Shark	None	AIC(n)	12	r<=1	0.19	6.5	8.18	11.65					37.27	0.00	Yes
				r=0	7.55	15.66	17.95	23.52	No						
Orange Roughy & School Shark	None	AIC(n)	9	r<=1	4.95	6.5	8.18	11.65		7.22	0.01	No	40.78	0.09	Yes
				r=0	25.17	15.66	17.95	23.52	No*						
Orange Roughy & Blue-eye Trevalla	None	AIC(n)	10	r<=1	0.87	6.5	8.18	11.65					27.41	0.39	No
				r=0	19.52	15.66	17.95	23.52	No						
Orange Roughy & Silver Trevally	None	AIC(n)	12	r<=1	1.94	6.5	8.18	11.65					28.69	0.05	Yes
				r=0	15.52	15.66	17.95	23.52	No						
Orange Roughy & Blue Warehou	None	AIC(n)	12	r<=1	0.96	6.5	8.18	11.65					35.47	0.01	Yes
				r=0	4.08	15.66	17.95	23.52	No						
Orange Roughy & Silver Warehou	Constant	AIC(n)	8	r<=1	1.6	7.52	9.24	12.97		22.5	0.00	No	37.44	0.31	No
				r=0	25.74	17.85	19.96	24.6	Yes						
Orange Roughy & Eastern School Whiting	None	AIC(n)	6	r<=1	7.05	7.52	9.24	12.97		3.11	0.08	No	45.13	0.34	No
				r=0	31.57	17.85	19.96	24.6	Yes						
Bigeye Ocean Perch & Reef Ocean Perch	None	AIC(n)	12	r<=1	6.09	6.5	8.18	11.65		1.22	0.27	Yes	22.65	0.20	No
				r=0	24.37	15.66	17.95	23.52	Yes						
Bigeye Ocean Perch & Royal Red Prawn	None	AIC(n)	11	r<=1	5.9	6.5	8.18	11.65					19.57	0.61	No
				r=0	16.17	15.66	17.95	23.52	No						
Bigeye Ocean Perch & Gummy Shark	None	HQ(n)	6	r<=1	4.77	6.5	8.18	11.65		16.75	0.00	No	40.75	0.53	No
				r=0	41.99	15.66	17.95	23.52	Yes						
Bigeye Ocean Perch & Common Saw Shark	None	AIC(n)	12	r<=1	0.12	6.5	8.18	11.65					29.95	0.04	Yes
				r=0	9.53	15.66	17.95	23.52	No						
Bigeye Ocean Perch & School Shark	None	AIC(n)	12	r<=1	6.13	6.5	8.18	11.65		4.52	0.03	No	22.93	0.19	No
				r=0	29.08	15.66	17.95	23.52	Yes						
Bigeye Ocean Perch & Blue-eye Trevalla	None	HQ(n)	5	r<=1	2.8	6.5	8.18	11.65		8.75	0.00	No	52.72	0.23	No
				r=0	38.51	15.66	17.95	23.52	Yes						
Bigeye Ocean Perch & Silver Trevally	None	AIC(n)	11	r<=1	4.94	6.5	8.18	11.65					26.96	0.21	No
				r=0	13.01	15.66	17.95	23.52	No						
Bigeye Ocean Perch & Blue Warehou	None	AIC(n)	11	r<=1	4.37	6.5	8.18	11.65					16.47	0.79	No
				r=0	12.26	15.66	17.95	23.52	No						
Bigeye Ocean Perch & Eastern School Whiting	None	AIC(n)	12	r<=1	8.01	6.5	8.18	11.65					23.48	0.17	No
				r=0	16.36	15.66	17.95	23.52	No						

Table C.3 continued (6)

Variables	Assumption	Criterion	Lag	Rank	Trace Test Statistic	10%	5%	1%	Cointegration	Law of One Price			LM Test		
										Chi-squared	p-value	Substitutes	Chi-squared	p-value	Serial correlation
Reef Ocean Perch & Royal Red Prawn	None	AIC(n)	5	r<=1	9.82	6.5	8.18	11.65					41.06	0.68	No
				r=0	26.59	15.66	17.95	23.52	No - Full rank						
Reef Ocean Perch & Gummy Shark	None	AIC(n)	12	r<=1	3.46	6.5	8.18	11.65					18.73	0.41	No
				r=0	18.86	15.66	17.95	23.52	No						
Reef Ocean Perch & Common Saw Shark	None	AIC(n)	11	r<=1	0.2	6.5	8.18	11.65					28.36	0.16	No
				r=0	13.55	15.66	17.95	23.52	No						
Reef Ocean Perch & School Shark	None	SC(n)	3	r<=1	21.45	6.5	8.18	11.65					50.94	0.59	No
				r=0	92.19	15.66	17.95	23.52	No - Full rank						
Reef Ocean Perch & Blue-eye Trevalla	None	AIC(n)	12	r<=1	0.54	6.5	8.18	11.65					21.75	0.24	No
				r=0	17.47	15.66	17.95	23.52	No						
Reef Ocean Perch & Silver Trevally	None	AIC(n)	12	r<=1	4	6.5	8.18	11.65		14.66	0.00	No	25.68	0.11	No
				r=0	27.88	15.66	17.95	23.52	Yes						
Reef Ocean Perch & Blue Warehou	None	AIC(n)	3	r<=1	20.63	6.5	8.18	11.65					69.71	0.07	Yes
				r=0	54.45	15.66	17.95	23.52	No - Full rank						
Reef Ocean Perch & Silver Warehou	None	AIC(n)	5	r<=1	7.85	6.5	8.18	11.65					53.73	0.20	No
				r=0	22.66	15.66	17.95	23.52	No - Full rank						
Reef Ocean Perch & Eastern School Whiting	None	AIC(n)	3	r<=1	10.53	6.5	8.18	11.65					69.99	0.07	Yes
				r=0	36.99	15.66	17.95	23.52	No - Full rank						
Royal Red Prawn & Gummy Shark	None	AIC(n)	6	r<=1	4.97	6.5	8.18	11.65					37.43	0.67	No
				r=0	15.66	15.66	17.95	23.52	No						
Royal Red Prawn & Common Saw Shark	None	AIC(n)	12	r<=1	0.19	6.5	8.18	11.65					24.89	0.13	No
				r=0	7.97	15.66	17.95	23.52	No						
Royal Red Prawn & School Shark	None	AIC(n)	11	r<=1	6.61	6.5	8.18	11.65					21.66	0.48	No
				r=0	20.05	15.66	17.95	23.52	No						
Royal Red Prawn & Blue-eye Trevalla	None	SC(n)	3	r<=1	5.74	6.5	8.18	11.65		0.13	0.72	Yes	52.82	0.20	No
				r=0	23.7	15.66	17.95	23.52	Yes						
Royal Red Prawn & Silver Trevally	None	HQ(n)	11	r<=1	3.64	6.5	8.18	11.65					35.30	0.04	Yes
				r=0	17.65	15.66	17.95	23.52	No						
Royal Red Prawn & Blue Warehou	Constant	AIC(n)	10	r<=1	1.59	7.52	9.24	12.97					33.31	0.15	No
				r=0	8.75	17.85	19.96	24.6	No						
Royal Red Prawn & Silver Warehou	None	AIC(n)	5	r<=1	3.94	6.5	8.18	11.65					40.14	0.72	No
				r=0	18.05	15.66	17.95	23.52	No						
Royal Red Prawn & Eastern School Whiting	None	SC(n)	3	r<=1	10.36	6.5	8.18	11.65					62.70	0.20	No
				r=0	26.81	15.66	17.95	23.52	No - Full rank						
Gummy Shark & Common Saw Shark	None	AIC(n)	12	r<=1	2.29	6.5	8.18	11.65					49.51	0.00	Yes
				r=0	12.27	15.66	17.95	23.52	No						
Gummy Shark & School Shark	None	AIC(n)	12	r<=1	2.89	6.5	8.18	11.65					21.88	0.24	No
				r=0	22.38	15.66	17.95	23.52	No						
Gummy Shark & Blue-eye Trevalla	None	SC(n)	3	r<=1	5.75	6.5	8.18	11.65		0.13	0.72	Yes	26.45	0.99	No
				r=0	41.17	15.66	17.95	23.52	Yes						

Table C.3 continued (7)

Variables	Assumption	Criterion	Lag	Rank	Trace Test Statistic	10%	5%	1%	Cointegration	Law of One Price			LM Test		
										Chi-squared	p-value	Substitutes	Chi-squared	p-value	Serial correlation
Gummy Shark & Silver Trevally	None	AIC(n)	12	r<=1	3.02	6.5	8.18	11.65					35.87	0.01	Yes
				r=0	10.33	15.66	17.95	23.52	No						
Gummy Shark & Blue Warehou	None	AIC(n)	6	r<=1	5.1	6.5	8.18	11.65					34.76	0.78	No
				r=0	16.49	15.66	17.95	23.52	No						
Gummy Shark & Silver Warehou	None	HQ(n)	5	r<=1	3.45	6.5	8.18	11.65					72.89	0.01	Yes
				r=0	22.32	15.66	17.95	23.52	No						
Gummy Shark & Eastern School Whiting	None	AIC(n)	12	r<=1	2.68	6.5	8.18	11.65					36.87	0.01	Yes
				r=0	15.84	15.66	17.95	23.52	No						
Common Saw Shark & School Shark	None	HQ(n)	11	r<=1	0.18	6.5	8.18	11.65					32.27	0.07	Yes
				r=0	11.61	15.66	17.95	23.52	No						
Common Saw Shark & Blue-eye Trevalla	None	AIC(n)	11	r<=1	0.03	6.5	8.18	11.65					36.44	0.03	Yes
				r=0	7.97	15.66	17.95	23.52	No						
Common Saw Shark & Silver Trevally	None	SC(n)	6	r<=1	3.57	6.5	8.18	11.65					56.00	0.07	Yes
				r=0	18.78	15.66	17.95	23.52	No						
Common Saw Shark & Blue Warehou	None	AIC(n)	11	r<=1	1.22	6.5	8.18	11.65					28.44	0.16	No
				r=0	8.47	15.66	17.95	23.52	No						
Common Saw Shark & Silver Warehou	None	AIC(n)	12	r<=1	0.41	6.5	8.18	11.65					43.36	0.00	Yes
				r=0	12.96	15.66	17.95	23.52	No						
Common Saw Shark & Eastern School	None	AIC(n)	11	r<=1	0.27	6.5	8.18	11.65					43.59	0.00	Yes
Whiting				r=0	7.98	15.66	17.95	23.52	No						
School Shark & Blue-eye Trevalla	None	AIC(n)	3	r<=1	7	6.5	8.18	11.65					47.60	0.72	No
				r=0	74.53	15.66	17.95	23.52	No - Full rank						
School Shark & Silver Trevally	None	HQ(n)	11	r<=1	3.4	6.5	8.18	11.65					37.22	0.02	Yes
				r=0	16.34	15.66	17.95	23.52	No						
School Shark & Blue Warehou	None	HQ(n)	7	r<=1	11.75	6.5	8.18	11.65					39.88	0.39	No
				r=0	41.9	15.66	17.95	23.52	No - Full rank						
School Shark & Silver Warehou	None	AIC(n)	9	r<=1	8.03	6.5	8.18	11.65					34.86	0.25	No
				r=0	27.51	15.66	17.95	23.52	No - Full rank						
School Shark & Eastern School Whiting	None	HQ(n)	2	r<=1	13.63	6.5	8.18	11.65					67.71	0.18	No
				r=0	97.61	15.66	17.95	23.52	No - Full rank						
Blue-eye Trevalla & Silver Trevally	Constant	HQ(n)	5	r<=1	3.66	7.52	9.24	12.97		4.85	0.03	No	55.09	0.17	No
				r=0	56.54	17.85	19.96	24.6	Yes						
Blue-eye Trevalla & Blue Warehou	None	AIC(n)	9	r<=1	0.65	6.5	8.18	11.65					37.02	0.18	No
				r=0	7.1	15.66	17.95	23.52	No						

Table C.3 continued (8)

Variables	Assumption	Criterion	Lag	Rank	Trace Test Statistic	10%	5%	1%	Cointegration	Law of One Price			LM Test		
										Chi-squared	p-value	Substitutes	Chi-squared	p-value	Serial correlation
Blue-eye Trevally & Silver Warehou	None	AIC(n)	9	r<=1	0.36	6.5	8.18	11.65		19.7	0.00	No	30.75	0.43	No
				r=0	20.79	15.66	17.95	23.52	Yes						
Blue-eye Trevally & Eastern School Whiting	None	AIC(n)	10	r<=1	4.23	7.52	9.24	12.97					41.02	0.03	Yes
				r=0	14.68	17.85	19.96	24.6	No						
Silver Trevally & Blue Warehou	None	HQ(n)	11	r<=1	3.08	6.5	8.18	11.65					34.36	0.05	Yes
				r=0	8.12	15.66	17.95	23.52	No						
Silver Trevally & Silver Warehou	None	HQ(n)	11	r<=1	1.54	6.5	8.18	11.65					44.99	0.00	Yes
				r=0	10.05	15.66	17.95	23.52	No						
Silver Trevally & Eastern School Whiting	None	HQ(n)	11	r<=1	5.42	6.5	8.18	11.65					28.40	0.16	No
				r=0	13.99	15.66	17.95	23.52	No						
Blue Warehou & Silver Warehou	None	AIC(n)	6	r<=1	7.2	6.5	8.18	11.65					51.64	0.15	No
				r=0	19.73	15.66	17.95	23.52	No						
Blue Warehou & Eastern School Whiting	None	HQ(n)	2	r<=1	14.45	6.5	8.18	11.65					71.90	0.10	No
				r=0	57.79	15.66	17.95	23.52	No - Full rank						
Silver Warehou & Eastern School Whiting	None	AIC(n)	12	r<=1	1.07	6.5	8.18	11.65					26.93	0.08	Yes
				r=0	10.77	15.66	17.95	23.52	No						

Note: “No*” indicates a cointegrated pair but estimate is serial correlated. The lag selection criterion that returned the smallest lag order was selected unless the estimated model had serial correlation, or a full rank result was found. In these cases, the next highest lag order selected the remaining criteria was used for the estimation. Serial correlation was detected for a large number of pairs. Other assumptions and the highest selected lag order were used for the estimation in an attempt to remove the serial correlation which was unsuccessful in most cases. In many cases there was only one lag order selected by all criteria which was also as reason why the full rank result or serial correlation could not be removed.

Table C.4. Johansen test results for the relationship between seafood traded at the Sydney Fish Market and imported seafood (n=93)

Variables	Assumption	Criterion	Lag	Rank	Trace Test Statistic	10%	5%	1%	Cointegration	Law of One Price			LM Test		
										Chi-squared	p-value	Substitutes	Chi-squared	p-value	Serial correlation
John Dory & Imported Aquaculture	None	SC(n)	2	r<=1	1.62	6.5	8.18	11.65					64.15	0.05	Yes
				r=0	15.46	15.66	17.95	23.52	No						
John Dory & Imported Hake	Const	AIC(n)	3	r<=1	3.23	7.52	9.24	12.97					62.61	0.20	No
				r=0	16.72	17.85	19.96	24.6	No						
John Dory & Imported Other Fish	None	SC(n)	2	r<=1	1.38	6.5	8.18	11.65					69.26	0.15	No
				r=0	16.74	15.66	17.95	23.52	No						
John Dory & Imported Other Frozen Fish	None	SC(n)	2	r<=1	4.47	6.5	8.18	11.65					55.71	0.56	No
				r=0	19.58	15.66	17.95	23.52	No						
John Dory & Imported Salmon	None	SC(n)	2	r<=1	4.02	6.5	8.18	11.65					68.42	0.16	No
				r=0	20.78	15.66	17.95	23.52	No						
Mirror Dory & Imported Aquaculture	None	SC(n)	2	r<=1	2.98	6.5	8.18	11.65		0.38	0.54	Yes	40.66	0.69	No
				r=0	25.92	15.66	17.95	23.52	Yes						
Mirror Dory & Imported Hake	None	SC(n)	2	r<=1	12.17	6.5	8.18	11.65					71.39	0.11	No
				r=0	50.89	15.66	17.95	23.52	No - Full rank						
Mirror Dory & Imported Other Fresh Fish	None	SC(n)	2	r<=1	2.5	6.5	8.18	11.65		3	0.08	No	60.65	0.38	No
				r=0	30.44	15.66	17.95	23.52	Yes						
Mirror Dory & Imported Other Frozen Fish	None	SC(n)	2	r<=1	6.42	6.5	8.18	11.65		1.15	0.28	Yes	67.40	0.19	No
				r=0	32.48	15.66	17.95	23.52	Yes						
Mirror Dory & Imported Salmon	None	SC(n)	2	r<=1	6.13	6.5	8.18	11.65		0.18	0.67	Yes	61.33	0.36	No
				r=0	34.73	15.66	17.95	23.52	Yes						
Tiger Flathead & Imported Aquaculture	None	AIC(n)	5	r<=1	0.96	6.5	8.18	11.65					38.50	0.78	No
				r=0	5.99	15.66	17.95	23.52	No						
Tiger Flathead & Imported Hake	None	AIC(n)	5	r<=1	2.13	6.5	8.18	11.65					43.85	0.56	No
				r=0	15.41	15.66	17.95	23.52	No						
Tiger Flathead & Imported Other Fresh Fish	None	SC(n)	2	r<=1	1.89	6.5	8.18	11.65		0.82	0.36	Yes	58.71	0.45	No
				r=0	23.86	15.66	17.95	23.52	Yes						
Tiger Flathead & Imported Other Frozen Fish	None	AIC(n)	5	r<=1	1.8	6.5	8.18	11.65					36.70	0.83	No
				r=0	5.01	15.66	17.95	23.52	No						
Tiger Flathead & Imported Salmon	None	AIC(n)	5	r<=1	2.61	6.5	8.18	11.65					44.80	0.52	No
				r=0	13.59	15.66	17.95	23.52	No						
Gemfish & Imported Aquaculture	None	AIC(n)	11	r<=1	0.12	6.5	8.18	11.65					36.24	0.03	Yes
				r=0	7.6	15.66	17.95	23.52	No						
Gemfish & Imported Hake	None	AIC(n)	10	r<=1	0.66	6.5	8.18	11.65					30.36	0.25	No
				r=0	6.62	15.66	17.95	23.52	No						
Gemfish & Imported Other Fresh Fish	None	AIC(n)	6	r<=1	0.37	6.5	8.18	11.65					46.47	0.29	No
				r=0	15.4	15.66	17.95	23.52	No						
Gemfish & Imported Salmon	None	SC(n)	2	r<=1	5.81	6.5	8.18	11.65		15.37	0	No	68.03	0.17	No
				r=0	30.57	15.66	17.95	23.52	Yes						
Blue Grenadier & Imported Aquaculture	None	SC(n)	2	r<=1	3.11	6.5	8.18	11.65		10.52	0	No	71.16	0.12	No
				r=0	34.64	15.66	17.95	23.52	Yes						

Table C.4 continued (1)

Variables	Assumption	Criterion	Lag	Rank	Trace Test Statistic	10%	5%	1%	Cointegration	Law of One Price			LM Test		
										Chi-squared	p-value	Substitutes	Chi-squared	p-value	Serial correlation
Blue Grenadier & Imported Hake	None	AIC(n)	3	r<=1	9.07	6.5	8.18	11.65					48.97	0.67	No
				r=0	28.02	15.66	17.95	23.52	No - Full rank						
Blue Grenadier & Imported Other Fresh	None	SC(n)	2	r<=1	3.57	6.5	8.18	11.65		3.31	0.07	No	48.23	0.82	No
Fish				r=0	35.15	15.66	17.95	23.52	Yes						
Blue Grenadier & Imported Other	None	SC(n)	2	r<=1	9.29	6.5	8.18	11.65					52.09	0.69	No
Frozen fish				r=0	39.84	15.66	17.95	23.52	No - Full rank						
Blue Grenadier & Imported Salmon	None	SC(n)	2	r<=1	8.23	6.5	8.18	11.65					52.45	0.68	No
				r=0	44.03	15.66	17.95	23.52	No - Full rank						
Pink Ling & Imported Aquaculture	Constant	AIC(n)	8	r<=1	1.58	7.52	9.24	12.97		43.11	0	No	44.24	0.11	No
				r=0	47.75	17.85	19.96	24.6	Yes						
Pink Ling & Imported Hake	Constant	AIC(n)	8	r<=1	2.86	7.52	9.24	12.97		40.24	0	No	29.33	0.70	No
				r=0	48.45	17.85	19.96	24.6	Yes						
Pink Ling & Imported Other Fresh Fish	Constant	AIC(n)	10	r<=1	2.52	7.52	9.24	12.97		21.04	0	No	28.71	0.32	No
				r=0	26.17	17.85	19.96	24.6	Yes						
Pink Ling & Imported Other Frozen Fish	Constant	AIC(n)	8	r<=1	4.17	7.52	9.24	12.97		36.03	0	No	40.58	0.20	No
				r=0	50.03	17.85	19.96	24.6	Yes						
Pink Ling & Imported Salmon	Constant	AIC(n)	8	r<=1	5.16	7.52	9.24	12.97		42.61	0	No	27.60	0.77	No
				r=0	53.43	17.85	19.96	24.6	Yes						
Jackass Morwong & Imported	None	AIC(n)	12	r<=1	0.04	6.5	8.18	11.65					29.90	0.04	Yes
Aquaculture				r=0	12.49	15.66	17.95	23.52	No						
Jackass Morwong & Imported Hake	None	AIC(n)	12	r<=1	0.42	6.5	8.18	11.65					22.99	0.19	No
				r=0	6.41	15.66	17.95	23.52	No						
Jackass Morwong & Imported Other	Constant	AIC(n)	8	r<=1	1.48	7.52	9.24	12.97		32.59	0	No	33.37	0.50	No
Fresh Fish				r=0	42.04	17.85	19.96	24.6	Yes						
Jackass Morwong & Imported Other	None	AIC(n)	12	r<=1	1.05	6.5	8.18	11.65					31.18	0.03	Yes
Frozen Fish				r=0	18.65	15.66	17.95	23.52	No						
Jackass Morwong & Imported Salmon	None	AIC(n)	3	r<=1	3.94	6.5	8.18	11.65		16.53	0	No	59.61	0.28	No
				r=0	33.31	15.66	17.95	23.52	Yes						
Orange Roughy & Imported Aquaculture	None	SC(n)	3	r<=1	2.8	6.5	8.18	11.65		15.6	0	No	54.41	0.46	No
				r=0	32.59	15.66	17.95	23.52	Yes						
Orange Roughy & Imported Hake	None	AIC(n)	4	r<=1	7.41	6.5	8.18	11.65					44.39	0.70	No
				r=0	26.15	15.66	17.95	23.52	No - Full rank						
Orange Roughy & Imported Other Fresh	None	SC(n)	2	r<=1	3.22	6.5	8.18	11.65		9.71	0	No	45.76	0.88	No
Fish				r=0	68.28	15.66	17.95	23.52	Yes						
Orange Roughy & Imported Other	None	SC(n)	3	r<=1	6.47	6.5	8.18	11.65		7.16	0.01	No	62.26	0.21	No
Frozen Fish				r=0	39.3	15.66	17.95	23.52	Yes						
Orange Roughy & Imported Salmon	None	HQ(n)	3	r<=1	4.08	6.5	8.18	11.65		16.09	0	No	53.67	0.49	No
				r=0	35.65	15.66	17.95	23.52	Yes						
Bigeye Ocean Perch & Imported	Constant	AIC(n)	9	r<=1	2.77	7.52	9.24	12.97		23.11	0	No	23.05	0.81	No
Aquaculture				r=0	28.95	17.85	19.96	24.6	Yes						
Bigeye Ocean Perch & Imported Hake	Constant	AIC(n)	8	r<=1	2.42	7.52	9.24	12.97		34.21	0	No	28.74	0.72	No
				r=0	40.8	17.85	19.96	24.6	Yes						

Table C.4 continued (2)

Variables	Assumption	Criterion	Lag	Rank	Trace Test Statistic	10%	5%	1%	Cointegration	Law of One Price			LM Test		
										Chi-squared	**p-value**	**Substitutes**	**Chi-squared**	**p-value**	**Serial correlation**
Bigeye Ocean Perch & Imported Other	None	SC(n)	2	r<=1	3.32	6.5	8.18	11.65		11.16	0	No	69.41	0.15	No
Fresh Fish				r=0	31	15.66	17.95	23.52	Yes						
Bigeye Ocean Perch & Imported Other	None	SC(n)	2	r<=1	9.38	6.5	8.18	11.65					63.60	0.29	No
Frozen Fish				r=0	36.43	15.66	17.95	23.52	No - Full rank						
Bigeye Ocean Perch & Imported Salmon	None	SC(n)	2	r<=1	7.27	6.5	8.18	11.65					68.93	0.15	No
				r=0	36.33	15.66	17.95	23.52	No - Full rank						
Reef Ocean Perch & Imported	None	SC(n)	2	r<=1	3.07	6.5	8.18	11.65		9.23	0	No	68.87	0.16	No
Aquaculture				r=0	26.37	15.66	17.95	23.52	Yes						
Reef Ocean Perch & Imported Hake	Constant	AIC(n)	3	r<=1	7.32	7.52	9.24	12.97		9.76	0	No	52.79	0.52	No
				r=0	26.22	17.85	19.96	24.6	Yes						
Reef Ocean Perch & Imported Other	None	SC(n)	2	r<=1	3.32	6.5	8.18	11.65		3.37	0.07	No	69.79	0.14	No
Fresh Fish				r=0	26.07	15.66	17.95	23.52	Yes						
Reef Ocean Perch & Imported Other	None	AIC(n)	4	r<=1	3.64	6.5	8.18	11.65					47.18	0.59	No
Frozen Fish				r=0	22.18	15.66	17.95	23.52	No						
Reef Ocean Perch & Imported Salmon	Constant	SC(n)	2	r<=1	7.43	7.52	9.24	12.97		5.61	0.02	No	57.83	0.48	No
				r=0	30.59	17.85	19.96	24.6	Yes						
Royal Red Prawn & Imported	None	SC(n)	2	r<=1	2.67	6.5	8.18	11.65		0.71	0.4	Yes	59.81	0.41	No
Aquaculture				r=0	35.6	15.66	17.95	23.52	Yes						
Royal Red Prawn & Imported Hake	None	HQ(n)	4	r<=1	2.72	6.5	8.18	11.65		34.203	0.01	No	33.21	0.90	No
				r=0	25.71	15.66	17.95	23.52	Yes						
Royal Red Prawn & Imported Other	None	SC(n)	2	r<=1	1.88	6.5	8.18	11.65		7.94	0	No	50.13	0.76	No
Fresh Fish				r=0	35.6	15.66	17.95	23.52	Yes						
Royal Red Prawn & Imported Other	None	SC(n)	2	r<=1	5.46	6.5	8.18	11.65		2.71	0.1	No	46.24	0.87	No
Frozen Fish				r=0	32.52	15.66	17.95	23.52	Yes						
Royal Red Prawn & Imported Salmon	None	SC(n)	2	r<=1	5.63	6.5	8.18	11.65		0.6	0.44	Yes	58.30	0.46	No
				r=0	34.22	15.66	17.95	23.52	Yes						
Gummy Shark & Imported Aquaculture	None	SC(n)	2	r<=1	3.08	6.5	8.18	11.65		24.86	0	No	63.87	0.28	No
				r=0	38.05	15.66	17.95	23.52	Yes						
Gummy Shark & Imported Hake	None	AIC(n)	12	r<=1	0.5	6.5	8.18	11.65					29.38	0.04	Yes
				r=0	13.11	15.66	17.95	23.52	No						
Gummy Shark & Imported Other Fresh	None	SC(n)	2	r<=1	2.9	6.5	8.18	11.65		9.77	0	No	65.31	0.24	No
Fish				r=0	36.71	15.66	17.95	23.52	Yes						
Gummy Shark & Imported Other Frozen	None	SC(n)	3	r<=1	5.82	6.5	8.18	11.65		5.15	0.02	No	58.16	0.32	No
Fish				r=0	26.45	15.66	17.95	23.52	Yes						
Gummy Shark & Imported Salmon	None	AIC(n)	3	r<=1	3.76	6.5	8.18	11.65					54.01	0.47	No
				r=0	23.28	15.66	17.95	23.52	No						
Common Saw Shark & Imported	None	AIC(n)	5	r<=1	0.32	6.5	8.18	11.65					40.13	0.72	No
Aquaculture				r=0	15.11	15.66	17.95	23.52	No						
Common Saw Shark & Imported Hake	None	AIC(n)	3	r<=1	6.77	6.5	8.18	11.65					57.89	0.33	No
				r=0	30.05	15.66	17.95	23.52	No - Full rank						
Common Saw Shark & Imported Other	None	SC(n)	2	r<=1	2.98	6.5	8.18	11.65		10.22	0	No	65.02	0.25	No
Fresh Fish				r=0	24.09	15.66	17.95	23.52	Yes						

Table C.4 continued (3)

Variables	Assumption	Criterion	Lag	Rank	Trace Test Statistic	10%	5%	1%	Cointegration	Law of One Price			LM Test		
										Chi-squared	**p-value**	**Substitutes**	**Chi-squared**	**p-value**	**Serial correlation**
Common Saw Shark & Imported Other	None	AIC(n)	5	r<=1	1.49	6.5	8.18	11.65					48.10	0.39	No
Frozen Fish				r=0	12.2	15.66	17.95	23.52	No						
Common Saw Shark & Imported Salmon	Constant	SC(n)	2	r<=1	7.3	7.52	9.24	12.97		13.22	0	No	56.29	0.54	No
				r=0	31.35	17.85	19.96	24.6	Yes						
School Shark & Imported Aquaculture	None	SC(n)	2	r<=1	3.34	6.5	8.18	11.65		19.85	0	No	65.80	0.22	No
				r=0	54.24	15.66	17.95	23.52	Yes						
School Shark & Imported Hake	None	SC(n)	3	r<=1	8.67	6.5	8.18	11.65					37.49	0.96	No
				r=0	40.32	15.66	17.95	23.52	No - Full rank						
School Shark & Imported Other Fresh Fish	None	SC(n)	2	r<=1	3.1	6.5	8.18	11.65		5.09	0.02	No	46.91	0.85	No
				r=0	46.9	15.66	17.95	23.52	Yes						
School Shark & Imported Other Frozen Fish	None	SC(n)	2	r<=1	9.28	6.5	8.18	11.65					48.81	0.80	No
				r=0	53.31	15.66	17.95	23.52	No - Full rank						
School Shark & Imported Salmon	Constant	SC(n)	2	r<=1	7.32	7.52	9.24	12.97		14.55	0	No	44.89	0.90	No
				r=0	51.36	17.85	19.96	24.6	Yes						
Blue-eye Trevalla & Imported Aquaculture	Constant	AIC(n)	11	r<=1	4.45	7.52	9.24	12.97		16.72	0	No	22.65	0.42	No
				r=0	31.53	17.85	19.96	24.6	Yes						
Blue-eye Trevalla & Imported Hake	None	HQ(n)	3	r<=1	6.95	6.5	8.18	11.65					49.99	0.63	No
				r=0	26.65	15.66	17.95	23.52	No - Full rank						
Blue-eye Trevalla & Imported Other Fresh	Constant	SC(n)	2	r<=1	2.56	6.5	8.18	11.65		0.03	0.87	Yes	55.12	0.53	No
Fish				r=0	34.48	15.66	17.95	23.52	Yes						
Blue-eye Trevalla & Imported Other Frozen	None	AIC(n)	3	r<=1	4.31	6.5	8.18	11.65		0.08	0.77	Yes	48.94	0.67	No
Fish				r=0	25.4	15.66	17.95	23.52	Yes						
Blue-eye Trevalla & Imported Salmon	None	SC(n)	2	r<=1	6.38	6.5	8.18	11.65		5.33	0.02	No	59.60	0.42	No
				r=0	35.6	15.66	17.95	23.52	Yes						
Silver Trevally & Imported Aquaculture	None	AIC(n)	12	r<=1	1.99	6.5	8.18	11.65					40.14	0.00	Yes
				r=0	16.07	15.66	17.95	23.52	No						
Silver Trevally & Imported Hake	Constant	AIC(n)	8	r<=1	2.56	7.52	9.24	12.97		0.08	0.78	Yes	32.26	0.55	No
				r=0	39.04	17.85	19.96	24.6	Yes						
Silver Trevally & Imported Other Fresh Fish	None	AIC(n)	6	r<=1	0.09	6.5	8.18	11.65		3.03	0.08	No	33.28	0.83	No
				r=0	63.22	15.66	17.95	23.52	Yes						
Silver Trevally & Imported Other Frozen	None	SC(n)	3	r<=1	6.18	6.5	8.18	11.65		0.52	0.47	Yes	66.45	0.12	No
Fish				r=0	36.67	15.66	17.95	23.52	Yes						
Silver Trevally & Imported Salmon	None	AIC(n)	11	r<=1	1.95	6.5	8.18	11.65					36.11	0.03	Yes
				r=0	13.79	15.66	17.95	23.52	No						
Blue Warehou & Imported Aquaculture	None	SC(n)	2	r<=1	3.17	6.5	8.18	11.65		8.8	0	No	66.15	0.22	No
				r=0	28.94	15.66	17.95	23.52	Yes						
Blue Warehou & Imported Hake	None	AIC(n)	8	r<=1	0.9	6.5	8.18	11.65					42.54	0.15	No
				r=0	10.4	15.66	17.95	23.52	No						
Blue Warehou & Imported Other Fresh Fish	None	SC(n)	2	r<=1	3.37	6.5	8.18	11.65		5.45	0.02	No	56.13	0.55	No
				r=0	30.52	15.66	17.95	23.52	Yes						
Blue Warehou & Imported Other Frozen	None	AIC(n)	4	r<=1	3.39	6.5	8.18	11.65					57.67	0.21	No
Fish				r=0	14.94	15.66	17.95	23.52	No						

Table C.4 continued (4)

Variables	Assumption	Criterion	Lag	Rank	Trace Test Statistic	10%	5%	1%	Cointegration	Law of One Price			LM Test		
										Chi-squared	p-value	Substitutes	Chi-squared	p-value	Serial correlation
Blue Warehou & AUS Salmon	None	SC(n)	2	r<=1	6.88	6.5	8.18	11.65					62.91	0.31	No
				r=0	29.99	15.66	17.95	23.52	No - Full rank						
Silver Warehou & Imported Aquaculture	None	AIC(n)	5	r<=1	1.39	6.5	8.18	11.65					55.67	0.16	No
				r=0	13.45	15.66	17.95	23.52	No						
Silver Warehou & Imported Hake	None	AIC(n)	3	r<=1	7.83	6.5	8.18	11.65					51.81	0.56	No
				r=0	29.55	15.66	17.95	23.52	No - Full rank						
Silver Warehou & Imported Other Fresh Fish	None	SC(n)	2	r<=1	3.35	6.5	8.18	11.65		7.21	0.01	No	61.19	0.33	No
				r=0	24.64	15.66	17.95	23.52	Yes						
Silver Warehou & Imported Other Frozen Fish	None	AIC(n)	6	r<=1	1.22	6.5	8.18	11.65					38.50	0.63	No
				r=0	21.02	15.66	17.95	23.52	No						
Silver Warehou & Imported Salmon	None	HQ(n)	3	r<=1	4.01	6.5	8.18	11.65		13.35	0	No	62.09	0.21	No
				r=0	27.02	15.66	17.95	23.52	Yes						
Eastern School Whiting & Imported Aquaculture	None	SC(n)	2	r<=1	3.15	6.5	8.18	11.65					71.04	0.12	No
				r=0	15.08	15.66	17.95	23.52	No						
Eastern School Whiting & Imported Hake	None	SC(n)	2	r<=1	12.31	6.5	8.18	11.65					49.26	0.79	No
				r=0	33.32	15.66	17.95	23.52	No - Full rank						
Eastern School Whiting & Imported Other Fresh Fish	None	SC(n)	2	r<=1	3.43	6.5	8.18	11.65					57.46	0.50	No
				r=0	15.52	15.66	17.95	23.52	No						
Eastern School Whiting & Imported Other Frozen Fish	None	AIC(n)	4	r<=1	3.33	6.5	8.18	11.65					49.09	0.51	No
				r=0	15.15	15.66	17.95	23.52	No						
Eastern School Whiting & Imported Salmon	None	SC(n)	2	r<=1	6.85	6.5	8.18	11.65					52.71	0.67	No
				r=0	18.57	15.66	17.95	23.52	No						
Imported Aquaculture & Imported Hake	None	HQ(n)	3	r<=1	1.69	6.5	8.18	11.65		1.68	0.19	Yes	57.62	0.34	No
				r=0	27.58	15.66	17.95	23.52	Yes						
Imported Aquaculture & Imported Salmon	None	AIC(n)	4	r<=1	3.16	6.5	8.18	11.65					49.84	0.48	No
				r=0	12.47	15.66	17.95	23.52	No						
Imported Hake & Imported Other Fresh Fish	None	SC(n)	2	r<=1	3.13	6.5	8.18	11.65		0.85	0.36	Yes	51.58	0.71	No
				r=0	34.56	15.66	17.95	23.52	Yes						
Imported Hake & Imported Other Frozen Fish	None	HQ(n)	3	r<=1	5.04	6.5	8.18	11.65					48.62	0.68	No
				r=0	20.91	15.66	17.95	23.52	No						
Imported Other Fresh Fish & Imported Frozen Other Fish	None	SC(n)	2	r<=1	3.91	6.5	8.18	11.65					50.96	0.73	No
				r=0	18.6	15.66	17.95	23.52	No						
Imported Other Fresh Fish & Imported Salmon	None	SC(n)	2	r<=1	2.96	6.5	8.18	11.65					59.79	0.41	No
				r=0	16.85	15.66	17.95	23.52	No						
Imported Other Frozen Fish & Imported Salmon	None	SC(n)	2	r<=1	6.34	6.5	8.18	11.65					69.38	0.15	No
				r=0	19.41	15.66	17.95	23.52	No						

Notes: The lag selection criterion that returned the smallest lag order was selected unless the estimated model had serial correlation, or a full rank result was found. In these cases, the next highest lag order selected the remaining criteria was used for the estimation. Serial correlation was detected for a large number of pairs. Other assumptions and the highest selected lag order were used for the estimation in an attempt to remove the serial correlation which was unsuccessful in most cases.

Table C.5. ARDL bounds test results for selected prices pairs of Sydney Fish Market species (n=172)

Price pair (Dependent variable & Independent variable)	Lags	Criterion	Assumption	R-square	Bounds Test		LM Test		Law of One Price							
												Level		1st difference		Result
					F-Statistic	Result	F-statistic	p-value	Assumption	Lags	Criterion	t-statistic	p-value	t-statistic	p-value	
John Dory & Blue Grenadier	ARDL(3, 0)	SIC	None	0.50	0.08	No	0.57	0.64								
Blue Grenadier & John Dory	ARDL(7, 0)	AIC	None	0.48	1.76	No	0.89	0.52								
John Dory & Pink Ling	ARDL(3, 0)	HQ	None	0.51	1.51	No	0.12	0.95								
Pink Ling & John Dory	ARDL(12, 0)	SIC	None	0.54	3.04*	Inconcl.	0.95	0.50								
John Dory & Jackass Morwong	ARDL(3, 0)	SIC	None	0.52	2.28	No	0.78	0.51								
Jackass Morwong & John Dory	ARDL(12, 0)	SIC	None	0.50	1.26	No	2.24	0.01								
John Dory & Reef Ocaen Perch	ARDL(3, 0)	SIC	None	0.51	0.24	No	0.13	0.94								
Reef Ocean Perch & John Dory	ARDL(3, 0)	SIC	None	0.17	8.39****	Yes	0.98	0.40	None	2	SIC	-0.61	0.45	-13.59	0.00	I(1)****
John Dory & School Shark	ARDL(3, 0)	SIC	None	0.51	0.21	No	0.27	0.85								
School Shark & John Dory	ARDL(2, 3)	AIC	None	0.01	49.85****	Yes	0.49	0.69	None	4	SIC	-0.57	0.47	-11.22	0.00	I(1)****
Reef Ocean Perch & Blue Grenadier	ARDL(3, 0)	SIC	None	0.12	2.58*	Inconcl.	2.04	0.11								
Blue Grenadier & Reef Ocean Perch	ARDL(7, 0)	AIC	None	0.48	2.25	No	0.91	0.50								
Reef Ocean Perch & Jackass Morwong	ARDL(2, 0)	SIC	None	0.17	16.22****	Yes	2.20	0.11	None	1	SIC	-3.97	0.00	-18.89	0.00	I(0)****
Jackass Morwong & Reef Ocean Perch	ARDL(12, 0)	SIC	None	0.52	4.45***	Inconcl.	2.09	0.02								
Reef Ocean Perch & Orange Roughy	ARDL(2, 1)	SIC	None	0.18	17.09****	Yes	1.39	0.25	None	2	SIC	-1.71	0.08	-18.34	0.00	I(0)*
Orange Roughy & Reef Ocean Perch	ARDL(12, 4)	AIC	None	0.26	4.47***	No	1.13	0.34								
Reef Ocean Perch & Royal Red Prawn	ARDL(3, 0)	SIC	None	0.11	2.04	No	1.58	0.20								
Royal Red Prawn & Reef Ocean Perch	ARDL(4, 0)	SIC	None	0.38	7.44****	Yes	1.13	0.35	None	2	SIC	-2.93	0.00	-16.73	0.00	I(0)****
Reef Ocean Perch & School Shark	ARDL(3, 0)	SIC	None	0.13	3.46**	Inconcl.	3.26	0.02								
School Shark & Reef Ocean Perch	ARDL(9, 3)	Adj.R-squa.	None	0.08	5.77****	Inconcl.	0.84	0.58								
Reef Ocean Perch & Blue Warehou	ARDL(3, 0)	SIC	None	0.13	3.81**	Inconcl.	1.94	0.12								
Blue Warehou & Reef Ocean Perch	ARDL(12, 4)	Adj. R-squa.	None	0.23	3.91**	Inconcl.	0.44	0.94								
Reef Ocean Perch & Silver Warehou	ARDL(5, 0)	AIC	None	0.15	1.26	No	0.55	0.74								
Silver Warehou & Reef Ocean Perch	ARDL(5, 0)	SIC	None	0.35	5.62****	Inconcl.	1.18	0.32								
Reef Ocean Perch & Easter School Whiting	ARDL(5, 0)	Adj. R-squa.	None	0.17	3.11*	Inconcl.	0.37	0.87								
Eastern School Whiting & Reef Ocean Perch	ARDL(2, 0)	SIC	None	0.63	7.32****	Yes	2.26	0.11	None	0	SIC	-7.08	0.00	-13.53	0.00	I(0)****
School Shark & Jackass Morwong	ARDL(9, 10)	Adj. R-squa.	None	0.19	5.04****	Inconcl.	0.63	0.79								
Jackass Morwong & School Shark	ARDL(1, 1)	SIC	Constant	0.41	15.13****	Yes	0.10	0.76	None	11	SIC	-0.57	0.47	-8.28	0.00	I(1)****
Blue-eye Trevalla & School Shark	ARDL(3, 0)	SIC	None	0.53	6.02****	Yes	1.60	0.19	None	6	SIC	-0.22	0.61	-9.25	0.00	I(1)****
School Shark & Blue-eye Trevalla	ARDL(4, 2)	Adj. R-squa.	Constant	0.10	34.70****	Yes	0.05	1.00	None	6	SIC	-0.22	0.61	-9.25	0.00	I(1)****
Blue Warehou & School Shark	ARDL(6, 0)	SIC	None	0.14	4.71**	Inconcl.	0.89	0.51								
School Shark & Blue Warehou	ARDL(9, 11)	Adj. R-squa.	None	0.12	3.41**	Inconcl.	0.85	0.59								
Eastern School Whiting & Royal Red Prawn	ARDL(2, 0)	SIC	None	0.61	3.45**	Inconcl.	0.36	0.70								
Royal Red Prawn & Eastern School Whiting	ARDL(4, 0)	SIC	None	0.40	9.61****	Yes	0.76	0.55	None	2	SIC	-3.25	0.00	-12.04	0.00	I(0)****
Eastern School Whiting & School Shark	ARDL(2, 0)	SIC	None	0.61	2.86*	Inconcl.	0.73	0.48								
School Shark & Eastern School Whiting	ARDL(9, 3)	Adj. R-squa.	None	0.03	3.79**	Inconcl.	0.65	0.76								
Eastern School Whiting & Blue Warehou	ARDL(2, 0)	SIC	None	0.60	0.71	No	0.98	0.38								
Blue Warehou & Eastern School Whiting	ARDL(6, 0)	HQ	None	0.13	4.11**	Inconcl.	0.54	0.78								

Notes: Adj. R-squa. for Adjusted R-square lag selection criterion, **** indicates significance at 1% level, *** indicates significance at 2.5% level, ** indicates significance at 5% level, * indicates significance at 10% level. “No” indicates No cointegration, “Yes” indicated cointegration, “Inconcl.” indicates that the result is inconclusive.

The ARDL bounds test was only conducted for price pairs that resulted in a full rank using the Johansen test. Like for the Johansen test, the lag selection criteria that returned the lowest lags was selected the respective ARDL model unless the result for the lowest selected lag order was serial correlated. In such case, the next highest lag combination was chosen to derive an estimate for which no serial correlation could be detected. There were a few cases for which serial correlation could not be removed by selecting up to a maximum of 12 lags or alternative assumptions (e.g., constant, trend). In such cases it was concluded that the pair was not cointegrated or inconclusive (e.g., Jackass Morwong & John Dory).

Table C.6. ARDL bounds test results for selected prices pairs including Sydney Fish Market species, imports and Australian farmed salmon (n=93)

Price pair (Dependent variable & Independent variable)	Lags	Criterion	Assumption	R-square	Bounds Test		LM Test		Law of One Price							
												Level		1st difference		
					F-Statistic	Result	F-statistic	p-value	Assumption	Lags	Criterion	t-statistic	p-value	t-statistic	p-value	Result
Imported Hake & Mirror Dory	ARDL(1, 1)	SIC	None	0.22	43.26****	Yes	0.00	0.98	None	4	SIC	-0.40	0.54	-8.22	0.00	I(1)****
Mirror Dory & Imported Hake	ARDL(4, 0)	SIC	None	0.33	0.03	No	1.57	0.19								
Imported Hake & Blue Grenadier	ARDL(3, 1)	SIC	None	0.12	0.50	No	0.60	0.62								
Blue Grenadier & Imported Hake	ARDL(11, 0)	Adj. R-squa.	None	0.07	0.94	No	2.29	0.02								
Imported Hake & Orange Roughy	ARDL(3, 2)	SIC	None	0.26	5.97****	Inconcl.	0.64	0.59								
Orange Routhy & Imported Hake	ARDL(12, 5)	Adj. R-squa.	None	0.23	0.55	No	1.10	0.38								
Imported Hake & Common Saw Shark	ARDL(3, 0)	SIC	None	0.08	0.40	No	0.92	0.44								
Common Saw Shark & Imported Shark	ARDL(1, 0)	SIC	None	0.37	5.02****	Inconcl.	0.95	0.33								
Imported Hake & School Shark	ARDL(3, 0)	SIC	None	0.08	0.49	No	0.99	0.40								
School Shark & Imported Hake	ARDL(10, 2)	Adj. R-squa.	None	0.04	0.70	No	0.56	0.84								
Imported Hake & Blue-eye Trevalla	ARDL(1, 1)	SIC	None	0.12	31.24****	Yes	1.31	0.26	None	2	SIC	-0.15	0.63	-12.97	0.00	I(1)****
Blue-eye Trevalla & Imported Hake	ARDL(3, 0)	SIC	None	0.11	0.33	No	1.80	0.15								
Imported Hake & Silver Warehou	ARDL(3, 0)	SIC	None	0.10	1.17	No	0.84	0.48								
Silver Warehou & Imported Hake	ARDL(2, 0)	SIC	None	0.05	4.65***	Inconcl.	1.04	0.36								
Imported Hake & Eastern School Whiting	ARDL(3, 0)	SIC	None	0.18	5.81***	Inconcl.	0.14	0.93								
Eastern School Whiting & Imported Hake	ARDL(8, 0)	AIC	None	0.53	0.09	No	0.55	0.82								
Imported Other Frozen Fish & Blue Grenadier	ARDL(4, 0)	SIC	None	0.41	0.22	No	1.77	0.14								
Blue Grenadier & Imported Hake	ARDL(11, 0)	Adj. R-squa.	None	0.15	4.19***	Inconcl.	1.96	0.05								
Blue Grenadier & Imported Salmon	ARDL(11, 0)	Adj. R-squa.	None	0.14	3.95**	Inconcl.	1.98	0.05								
Imported Salmon & Blue Grenadier	ARDL(8, 12)	Adj. R-squa.	None	0.66	3.10*	Inconcl.	1.25	0.28								
Imported Other Frozen Fish & Bigeye Ocean Perch	ARDL(4, 9)	Adj. R-squa.	None	0.44	3.42**	Inconcl.	0.11	1.00								
Bigeye Ocean Perch & Imported Other Frozen Fish	ARDL(12, 0)	AIC	None	0.28	0.01	No	0.83	0.62								
Imported Salmon & Bigeye Ocean Perch	ARDL(12, 0)	AIC	None	0.28	0.01	No	0.86	0.59								
Bigeye Ocean Perch & Imported Salmon	ARDL(8, 0)	AIC	None	0.63	5.33****	Inconcl.	0.65	0.73								
Imported Other Frozen Fish & School Shark	ARDL(4, 0)	SIC	None	0.41	0.21	No	1.90	0.12								
School Shark & Imported Other Frozen Fish	ARDL(2, 11)	Adj. R-squa.	None	0.15	18.59****	Yes	0.89	0.56	None	0	SIC	-5.68	0.00	-8.44	0.00	I(0)****
Imported Salmon & Blue Warehou	ARDL(5, 0)	AIC	None	0.60	0.80	No	0.48	0.79								
Blue Warehou & Imported Salmon	ARDL(7, 0)	AIC	None	0.17	1.69	No	0.26	0.97								

Notes: Adj. R-squa. for Adjusted R-square lag selection criterion, **** indicates significance at 1% level, *** indicates significance at 2.5% level, ** indicates significance at 5% level, * indicates significance at 10% level. "No" indicates No cointegration, "Yes" indicated cointegration, "Inconcl." indicates that the result is inconclusive. The ARDL bounds test was only conducted for price pairs that resulted in a full rank using the Johansen test. Like for the Johansen test, the lag selection criteria that returned the lowest lags was selected the respective ARDL model unless the result for the lowest selected lag order was serial correlated. In such case, the next highest lag combination was chosen to derive an estimate for which no serial correlation could be detected. There were a few cases for which serial correlation could not be removed by selecting up to a maximum of 12 lags or alternative assumptions (e.g., constant, trend). In such cases it was concluded that the pair was not cointegrated or inconclusive.

Appendix D. Cointegration test results, Melbourne and Sydney markets

Table D.1. The results of the Augmented Dicky Fuller (ADF) for the Melbourne fish market

Species	Lag selection based on BIC (SC)						Lag selection based on AIC					Lag selection based on MAIC				
	n	Lag	Model	Level	First diff		Lag	Model	Level	First diff		Lag	Model	Level	First diff	
Blue-eye Trevalla	67	0	C	-8.154***		I(0)	0	C	-8.154***		I(0)	0	C	-8.154***		I(0)
Blue Grenadier	142	1	T	32.629***		I(0)	11	T	6.2931	25.068***	I(1)	0	T	-6.889		I(0)
Blue Warehou	142	1	C	25.093***		I(0)	11	N	0.8404	-10.986***	I(1)	1	T	-5.902***		I(0)
Gemfish	142	1	T	32.629 ***		I(0)	5	C	2.911	55.602***	I(1)	5	C	-3.067**		I(0)
Gummy School Shark	142	1	T	20.177***		I(0)	1	T	20.1768***		I(0)	9	T	-2.844	-21.191***	I(1)
Jackass Morwong	67	0	T	-8.152***		I(0)	12	C	-1.436	-14.772***	I(1)	0	T	-8.152		I(0)
John Dory	142	1	C	6.343 **		I(0)	2	C	6.3427**		I(0)	8	C	-2.111	-19.697***	I(1)
Mirror Dory	142	1	T	12.190***		I(0)	2	C	6.3427		I(0)	5	N	-0.310	-14.366***	I(1)
Ling (Pink)	67	1	T	21.582***		I(0)	11	C	-2.6605	-6.161***	I(1)	11	N	1.516	-16.513***	I(1)
Ocean Perch	67	0	C	-10.047***		I(0)	0	C	-10.664		I(0)	0	C	-10.047***		I(0)
Orange Roughy	142	0	C	-10.664***		I(0)	1	T	10.2962***		I(0)	0	C	-10.664***		I(0)
School Whiting	67	2	C	-4.109***		I(0)	2	C	-4.1086***		I(0)	2	C	-4.109***		I(0)
Silver Trevally	142	1	T	11.407***		I(0)	10	N	0.8845	-7.353***	I(1)	10	N	-0.932	-16.434***	I(1)
Silver Warehou	142	2	T	14.976***		I(0)	11	N	0.2881	-5.370***	I(1)	13	N	0.071	-9.103***	I(1)
Tiger Flathead	142	1	T	15.466***		I(0)	1	T	15.466 ***		I(0)	5	N	0.779	-15.527***	I(1)

Notes: Critical values are based on Hamilton (1994) and Dickey and Fuller (1981). T= trend and linear constant, C= Constant but no trend, N= Neither constant nor trend. ** indicates that the null hypothesis of no unit root was rejected at 5% significance level, *** at 1% level, hence the series is concluded as stationary (no unit root). The optimal lag length was selected based on BIC (SC), AIC and MIAC. Model T= Linear trend and constant, C= Constant only without trend, N = Neither trend nor constant included. Model selection was based on the procedures suggested by Pfaff (2008): we start with estimating the regression with trend and intercept (T) and move to the next complex model (C) when trend term is insignificant and so on.

Table D.2 The results of the Augmented Dicky Fuller (ADF) for the Sydney fish market

Species	**Lag selection based on SC (BIC)**					**Lag selection based on AIC**					**Lag selection based on MAIC**				
	Lag	Model	Level	First diff		1	C	8.1519 ***		I(0)	Lag	Model	Level	First diff	
Blue-eye Trevalla	1	C	8.152***		I(0)	1	T	17.1992***		I(0)	1	C	8.1519 ***		I(0)
Blue Grenadier	1	T	17.199***		I(0)	1	C	22.2466***		I(0)	1	T	17.199**		I(0)
Blue Warehou	1	C	22.247***		I(0)	11	N	-0.4128	-6.2801***	I(1)	1	C	22.247***		I(0)
Gemfish	4	C	4.507	80.094 ***	I(1)	11	N	0.4187	-3.6846***	I(1)	11	N	-0.413	-6.280***	I(1)
Gummy School Shark	9	N	-8.134***		I(0)	1	C	-3.463**		I(0)	11	N	0.4187	-3.685***	I(1)
Jackass Morwong	1	N	-5.798 ***		I(0)	8	C	4.0042	24.783***	I(1)	1	C	-3.463**		I(0)
John Dory	1	C	8.945 ***		I(0)	10	N	-0.2855	-9.0678***	I(1)	8	C	4.004	24.783***	I(1)
Mirror Dory	1	C	14.531***		I(0)	1	C	11.6517		I(0)	10	N	-0.286	-9.068***	I(1)
Ling (Pink)	1	C	12.748***		I(0)	3	N	-0.254	-7.7393 ***	I(1)	1	C	11.652		I(0)
Ocean Perch	1	C	3.625	29.349***	I(1)	2	T	13.6047***		I(0)	3	N	-0.254	-7.739 ***	I(1)
Orange Roughy	1	T	25.174***		I(0)	10	T	6.439	13.121***	I(1)	2	T	13.605***		I(0)
School Whiting	1	C	5.612 **		I(0)	10	N	0.1776	-9.1986***	I(1)	10	T	6.439	13.121***	I(1)
Silver Trevally	10	N	0.178	-9.199***	I(1)	4	C	3.703	43.1971***	I(1)	10	N	0.1776	-9.199***	I(1)
Silver Warehou	1	C	9.964 ***		I(0)	11	C	4.3576	19.9585***	I(1)	4	C	3.703	43.197***	I(1)
Tiger Flathead	2	C	2.617	36.949***	I(0)	1	C	8.1519 ***		I(0)	11	C	4.3576	19.959***	I(1)

Notes: Critical values are based on Hamilton (1994) and Dickey and Fuller (1981). T= trend and linear constant, C= Constant but no trend, N= Neither constant nor trend. ** indicates that the null hypothesis of no unit root was rejected at 5% significance level, *** at 1% level, hence the series is concluded as stationary (no unit root). The optimal lag length was selected based on SC (BIC), AIC and MIAC. Model T= Linear trend and constant, C= Constant only without trend, N = Neither trend nor constant included. Model selection was based on the procedures suggested by Pfaff (2008): we start with estimating the regression with trend and intercept (T) and move to the next complex model (C) when trend term is insignificant and so on.

Table D.3. ARDL bounds test results for pairwise price series of 12 species between the Melbourne and Sydney markets.

Species	Model	Lag	F-statistics	5% Critical value (CV)	Adj. R^2	BS LM test	Cointegrated	LOP hold?
Blue-eye trevally								No
Mel - Syd	4	1,0	16.58***	4.95-5.47	0.279	0.70	Yes	
Syd-Mel	2	1,0	22.21***	3.79-4.34	0.252	1.04	Yes	
Blue grenadier								Yes
Mel - Syd	5	4,0	19.12***	6.82-7.67	0.473	0.326	Yes	
Syd-Mel	4	1,3	22.84***	3.74-4.30	0.322	1.148	Yes	
Blue warehou								Yes
Mel - Syd	4	12,2	5.38**	3.74-4.30	0.613	0.53	Yes	
Syd-Mel	3	1,0	80.77***	5.06-5.93	0.202	0.00	Yes	
Jackass morwong								
Mel – Syd	5	1,0	40.33***	6.89-7.66	0.635	6.58**	Yes	Yes
Syd-Mel	3	1,0	42.30***	5.13-5.98	0.602	0.29	Yes	
John dory								Yes
Mel – Syd	2	3,0	6.40***	3.74-4.30	0.271	0.39	Yes	
Syd-Mel	3	1,2	21.12***	5.06-5.93	0.634	0.48	Yes	
Ocean perch								
Mel – Syd	3	10,11	4.68	5.13-6.05	0.257	0.257	No	
Syd-Mel	2	4,0	1.25	3.79-4.39	0.314	0.314	No	
Orange roughy								Yes
Mel - Syd	2	3,0	7.06***	3.74-4.30	0.270	0.60	Yes	
Syd-Mel	5	1,0	42.28***	6.82-7.67	0.221	0.03	Yes	
Pink ling								Yes
Mel - Syd	2	3,1	30.28***	3.79-4.34	0.485	2.425	Yes	
Syd-Mel	3	10,9	6.86***	5.13-6.05	0.605	1.278	Yes	
School whiting								
Mel - Syd	2	4,11	1.28	3.79-4.39	0.472	0.298	No	
Syd-Mel	3	10,7	5.47	5.13-6.05	0.470	0.884	Inconclusive	
Silver trevally								
Mel - Syd	5	4,0	37.84***	6.82-7.67	0.663	0.75	Yes	
Syd-Mel	2	11,3	1.49	3.74-4.30	0.804	1.26	No	
Silver warehou								Yes
Mel - Syd	2	12,1	9.23***	3.74-4.30	0.79	0.66	Yes	
Syd-Mel	3	5,0	18.59***	5.06-5.93	0.72	0.61	Yes	
Mirror dory								Yes
Mel - Syd	3	1,10	33.437***	5.06-5.93	0.722	0.511	Yes	
Syd-Mel	3	11,0	34.662***	5.06-5.93	0.718	0.709	Yes	

Notes: ** indicates the significance at 5% significance level, *** indicate the significance at 1% level. Aju. R^2 = adjusted R^2 to indicates the goodness to fit, LM test = Breusch-Godfrey serial correlation LM test (significance of the test means there is a serial correlation in the residual), LOP = Law of One Price test. Model 2= restricted constant, Model 3= constant, Model 4= restricted trend, Model 5= both trend and constant. We start with the most complex model (5) and if the coefficient is not significant move to the next complex model. The lag selection is based on AIC.

Appendix E. Cointegration test results, Imports into New South Wales and Victoria

Table E.1. The results of the ARDL bounds tests and Law of One Price tests for the prices of imported fish at Victoria and New South Wales between January 2012 and September 2019

Species	Model	Lag	F-statistics	5% Critical value (CV)	Adj. R^2	LM test	Interpretation	LOP hold?		
Aquaculture								C	7.01***	Yes
VIC-New South Wales	3	2,2	13.48***	5.06-5.93	0.330	0.824	Cointegrated			
New South Wales-VIC	4	2,0	11.96***	3.74-4.30	0.745	0.116	Cointegrated			
Hake								C	22.90***	Yes
VIC-New South Wales	5	1,1	45.04***	6.82-7.67	0.197	0.667	Cointegrated			
New South Wales-VIC	5	1,1	41.00***	6.82-7.67	0.228	0.443	Cointegrated			
Fresh								C	9.46***	Yes
VIC-New South Wales	3	11,0	5.19	5.06-5.93	0.635	0.727	Inconclusive			
New South Wales-VIC	2	2,0	4.26	3.74-4.30	0.696	0.985	Inconclusive			
Frozen								C	12.78***	Yes
VIC-New South Wales	2	1,1	13.01***	3.74-4.30	0.516	1.261	Cointegrated			
New South Wales-VIC	2	2,3	8.92***	5.06-5.93	0.505	0.773	Cointegrated			
Salmon								C	3.66	No
VIC-New South Wales	2	2,1	9.99***	3.74-4.30	0.357	1.955	Cointegrated			
New South Wales-VIC	2	5,0	3.60	3.74-4.30	0.612	0.200	Inconclusive			
New South Wales Aqua-Fresh								C	3.33	No
Aqua-Fresh	4	2,0	5.17**	3.74-4.30	0.694	0.087	Cointegrated			
Fresh-Aqua	5	2,0	8.90**	6.82-7.67	0.701	0.157	Cointegrated			
New South Wales Aqua-Hake								C	16.21***	Yes
Aqua-Hake	4	2,1	5.90**	3.74-4.30	0.699	0.024	Cointegrated			
Hake-Aqua	5	1,0	45.56***	6.82-7.67	0.219	0.271	Cointegrated			
New South Wales Aqua-Frozen								C	12.17***	Yes
Aqua-Frozen	4	2,2	6.67	3.74-4.30	0.739	0.170	Cointegrated			
Frozen-Aqua	3	2,3	6.46	5.05-5.93	0.483	1.132	Cointegrated			
New South Wales Aqua-Salmon								C	1.82	No
Aqua-Salmon	3	4,12	9.71***	5.06-5.93	0.846	1.872	Cointegrated			
Salmon-Aqua	5	8,11	10.38***	6.82-7.67	0.709	1.468	Cointegrated			
New South Wales Fresh-Hake								C	2.61	No
Fresh-Hake	5	2,0	8.91**	6.82-7.67	0.709	0.202	Cointegrated			
Hake-Fresh	4	1,0	29.68***	3.74-4.30	0.210	0.011	Cointegrated			
New South Wales Fresh-Frozen								C	2.94	No
Fresh-Frozen	5	2,2	7.66	6.82-7.67	0.722	0.463	Inconclusive			
Frozen-Fresh	5	2,2	10.21**	6.82-7.67	0.460	0.669	Cointegrated			
New South Wales Fresh-Salmon								C	5.35**	Yes
Fresh-Salmon	5	2,0	8.89**	6.82-7.67	0.709	0.168	Cointegrated			
Salmon-Fresh	2	8,0	3.33	3.74-4.30	0.579	0.582	Not cointegrated			
New South Wales Frozen-Hake								C	6.01	Yes
Frozen-Hake	5	2,0	8.84**	6.82-7.67	0.435	0.813	Cointegrated			
Hake-Frozen	4	1,0	29.80***	3.74-4.30	0.211	0.003	Cointegrated			
New South Wales Frozen-salmon								N	0.05	No
Frozen-Salmon	5	2,0	10.58***	6.82-7.67	0.453	0.765	Cointegrated			
Salmon-Frozen	5	3,0	5.54	6.82-7.67	0.658	1.465	Not cointegrated			
New South Wales Hake-Salmon								C	2.39	No

Species	Model	Lag	F-statistics	5% Critical value (CV)	Adj. R^2	LM test	Interpretation	LOP hold?		
Hake-Salmon	4	1,0	30.18***	3.74-4.30	0.216	0.155	Cointegrated			
Salmon-Hake	2	3,0	1.60	3.74-4.30	0.632	2.869**	Not cointegrated			
VIC Aqua-Fresh								N	0.06	No
Aqua-Fresh	2	2,0	6.71***	3.74-4.30	0.222	1.364	Cointegrated			
Fresh-Aqua	5	1,0	23.54***	6.82-7.67	0.654	0.227	Cointegrated			
VIC Aqua-Hake								C	15.90***	Yes
Aqua-Hake	2	2,1	7.16***	3.74-4.30	0.224	1.279	Cointegrated			
Hake-Aqua	5	1,1	52.02***	6.82-7.67	0.205	0.211	Cointegrated			
VIC Aqua-Frozen								C	2.95	No
Aqua-Frozen	2	1,8	13.33***	3.74-4.30	0.325	0.488	Cointegrated			
Frozen-Aqua	3	3,1	10.48***	5.06-5.93	0.582	0.688	Cointegrated			
VIC Aqua-Salmon								C	4.89**	Yes
Aqua-Salmon	3	2,7	13.37***	5.06-5.93	0.584	0.248	Cointegrated			
Salmon-Aqua	5	2,0	10.55***	6.82-7.67	1.958	0.302	Cointegrated			
VIC Fresh-Hake								C	12.97***	Yes
Fresh-Hake	5	4,3	18.24***	6.82-7.67	1.660	0.680	Cointegrated			
Hake-Fresh	4	1,0	32.77***	3.74-4.30	0.043	0.182	Cointegrated			

Species	Model	Lag	F-statistics	5% Critical value (CV)	Adj. R^2	LM test	Interpretation	LOP hold?		
VIC Fresh-Frozen								C	3.20	No
Fresh-Frozen	5	1,0	23.67***	6.82-7.67	0.290	0.653	Cointegrated			
Frozen-Fresh	5	3,0	3.98	6.82-7.67	1.351	0.523	Not cointegrated			
VIC Fresh-Salmon								C	6.73***	Yes
Fresh-Salmon	5	1,0	23.13***	6.82-7.67	0.652	0.182	Cointegrated			
Salmon-Fresh	2	2,0	5.79**	3.74-4.30	0.282	1.467	Cointegrated			
VIC Frozen-Hake								C	10.37***	Yes
Frozen-Hake	5	3,0	3.92	6.82-7.67	0.523	0.744	Not cointegrated			
Hake-Frozen	5	1,0	48.60***	6.82-7.67	0.177	0.010	Cointegrated			
VIC Frozen-Salmon								C	6.65***	Yes
Frozen-Salmon	2	3,0	2.44	3.74-4.30	0.522	1.306	Not cointegrated			
Salmon-Frozen	3	2,9	6.29**	5.06-5.93	0.378	0.949	Cointegrated			
VIC Hake-Salmon								C	3.50	No
Hake-Salmon	5	1,0	32.32***	6.82-7.67	0.176	0.157	Cointegrated			
Salmon-Hake	5	3,3	6.89	6.82-7.67	0.301	0.274	Inconclusive			

Notes: ** indicates the significance at 5% significance level, *** indicate the significance at 1% level. Aju. R^2 = adjusted R^2 to indicates the goodness to fit, LM test = Breusch-Godfrey serial correlation LM test (significance of the test means there is a serial correlation in the residual), LOP = Law of One Price test. Model 2= restricted constant, Model 3= constant, Model 4= restricted trend, Model 5= both trend and constant. We start with the most complex model (5) and if the coefficient is not significant move to the next complex model. The lag selection is based on AIC. For LOP tests, C= constant, and N = neither constant or trend included.

Appendix F. Changes in catch and revenue by species if TACs were fully caught

Species Name	TAC After over/ undercatch (kg)	Catch (kg)	Average real price (A$/kg)	Revenue current catch (A$)	Own-price flexibility	% of original price	New price (A$/kg)	New Revenue (A$)
Blue-eye Trevalla	499,109	216,517	$11.61	$2,513,762	-30.20%	67.424%	$7.83	$3,907,016
Blue Grenadier	12,963,689	7,044,435	$2.44	$17,188,421	-42.40%	70.028%	$1.71	$22,150,814
Blue Warehou	118,000	10,099	$2.93	$29,590	-53.60%	0.326%	$0.01	$1,126
Flathead	2,695,077	1,966,582	$7.79	$15,319,674	-46.20%	84.270%	$6.56	$17,692,232
Gemfish (Eastern)	100,000	70,611	$4.78	$337,521	-32.90%	87.203%	$4.17	$416,830
Gummy Shark	1,897,200	1,779,348	$3.72	$6,619,175	0.00%	100.000%	$3.72	$7,057,584
Jackass Morwong	515,140	109,098	$4.81	$524,761	-45.60%	18.321%	$0.88	$453,952
John Dory	420,915	68,262	$12.85	$877,167	-49.30%	7.832%	$1.01	$423,627
Mirror Dory	212,486	116,500	$5.36	$624,440	-31.50%	77.141%	$4.13	$878,580
Ocean Perch	259,203	168,772	$7.40	$1,248,913	-31.70%	84.379%	$6.24	$1,618,471
Orange Roughy	979,238	618,541	$7.15	$4,422,568	-47.20%	75.939%	$5.43	$5,316,892
Pink Ling	1,378,087	832,689	$6.80	$5,662,285	-42.70%	75.603%	$5.14	$7,084,723
Saw Shark	470,071	188,763	$2.93	$553,076	-53.60%	44.988%	$1.32	$619,617
School Shark	188,988	184,029	$2.93	$539,205	-53.60%	98.566%	$2.89	$545,794
School Whiting	867,012	526,012	$3.83	$2,014,626	-53.00%	70.922%	$2.72	$2,355,085
Silver Trevally	322,700	20,968	$6.42	$134,615	-61.70%	0.014%	$0.00	$289
Silver Warehou	505,201	306,530	$2.34	$717,280	-50.50%	72.086%	$1.69	$852,184
Total	24,392,116	14,227,756		$59,327,078				$71,374,816
Trawl	20,881,979	11,584,312		$47,233,307				$56,906,847
GHT	3,510,137	2,643,444		$12,093,772				$14,467,970

Appendix G: How demand analysis can help improve fisheries and aquaculture performance

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Contents

Introduction

As it is currently applied in Australia, fisheries management is mainly focused on ensuring the sustainability of the resource while maximising the output from the fishery. This is largely achieved through setting total allowable catch (TAC) or equivalent effort restrictions to limit the quantity of landings from the fishery. In jurisdictions where economic outcomes are also important, more conservative catch and effort limits are generally set in recognition of the additional cost of harvesting the resource as stock size declines.

For aquaculture, while not directly subject to production limits in the same way that wild-caught fisheries are, regulation can affect output levels in other ways. For example, the number of licenced pens or the area available for oyster leases in an estuary may be restricted. Changes in these restrictions, such as through expanding the area available for aquaculture, will change the productive capacity of the sector, and subsequently change the level of output.

What happens after the catch is landed or product is harvested is generally considered a business decision of the fisher/farmer. Where they sell their catch, and how much they get for it, is not generally under the control of managers. However, how much is caught or farmed can affect the price received, and this is directly under the control of managers.

While fishers have many options (e.g., different auction markets, direct to processors or retailer, or even direct to public), the prices in all these markets are generally linked to the overall quantity of fish landed or produced. At the individual fisher/farmer level, the impact of the amount they catch or produce on the total quantity supplied to the market will often be small, and the link between their level of production and the price received may not be apparent. However, at the industry level, the quantity produced can have a substantial impact on the price all producers receive. This, in turn, is directly affected by fisheries and aquaculture management through the catch or effort limits imposed or the other restrictions placed on production.

The aim of this document is to highlight the importance of taking market effects into account when prices vary with quantity landed, and to present some key economic concepts that managers and industry can factor into decision making. The scope of the document does not include a description of how the relationship between price and quantity landed is estimated[7], but aims to help mangers and industry understand the outputs of these analyses and how they may be considered in management decisions.

https://www.sydneyfishmarket.com.au/Seafood-Trading

[7] These are covered in more detail in Pascoe *et al.* (2021).

Key concepts and terminology

The analysis of the relationship between quantity and price, known as demand analysis, involves several key concepts and terms which may appear jargonistic. Most studies in the area have been published in academic journals, and an understanding of the terminology commonly used will be of benefit to managers and industry members trying to apply the key concepts to their decision making. In this section, some of the basic theory underpinning these analyses is presented, along with a description of the common terminology used.

What factors affect seafood price?

Seafood production through fishing and aquaculture is a commercial business, and the price received for the product is as important to determining revenue as the quantity landed or produced. The relationship between quantity produced and price received is determined by the demand for the product on the markets. The analyses of these relationships is consequently known as demand analysis.

The price received is determined by a number of factors, many of which are beyond the control of the individual producer. The importance of these factors varies from species to species, depending on where it is sold (i.e., domestic or export market) as well as the characteristics of the individual species. However, a key factor, and one that is under the control of fisheries and aquaculture managers, is the quantity landed at an industry level (not at an individual firm level) or produced of the different species.

Changes in the quantity landed or produced of a species can also impact the prices received of other species, with this impact depending on the characteristics of the species. Characteristics in this case refers to those important to consumers (e.g., taste, firmness, size of bones, etc), not biological characteristics. Species with similar characteristics are potential substitutes, regardless of whether they are landed/produced domestically or imported.

Seasonal factors can also affect the level of demand, and subsequent price of fish and seafood. For example, prawn prices tend to increase around Christmas, New Year and Easter. Similarly, prices of exported species also tend to increase around festival periods in the countries to which they are exported.

Furthermore, changes in global production can impact on prices of Australian products if they are sold into the export market. If Australia has only a small market share on the export market, then what happens in other countries will have – potentially – a greater impact on prices received than how much is produced in Australia.

On the domestic market, increased global production is likely to result in increased imports. The increased supply of imported substitute goods can impact domestic prices of Australian produced product. The magnitude of the impact will depend on the degree of substitutability, which will vary due to the characteristics of the imports and the domestically produced species.

Changes in income can also affect the demand for seafood, impacting on its price. For example, increase in higher income population tend to increase in demand for premium seafood. These impacts can be assessed through separate modelling techniques, which are not detailed further in this overview document.

Sustainability certification by third parties (e.g. Marine Stewardship Council) is becoming increasingly important to access some markets, and in some cases has been shown to influence the price received. This can be influenced by management, as certification often requires management instruments are in place to enable fish to be harvested or produced in a sustainable manner with minimum environmental impact.

Other shocks, such as oils or chemical spills and toxic algae blooms, can impact the demand for fisheries products even beyond those directly affected by the initial problem. For example, toxic algal blooms have been found to negatively impact shellfish supplied from unaffected regions (Wessells *et al.* 1995), while prices for fish from unaffected regions of Japan declined following the Fukushima disaster (Wakamatsu and Miyata 2017).

As noted above, most of these factors are beyond the control of managers. While managers need to be aware of the potential implications of changes in the market environment, the factor that they can control is the quantity landed or produced of different species.

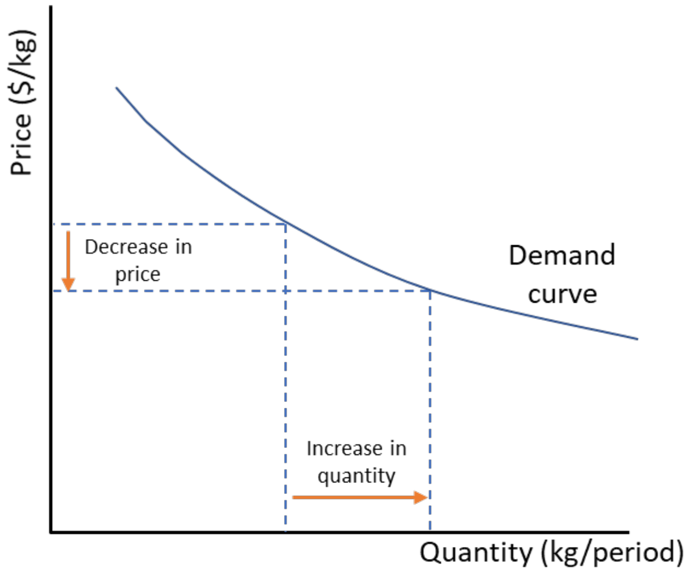
"Demand curves" and the relationship between price and quantity

In economics, demand analysis is the study of the relationship between quantities of a good on the market and its price. There is substantial economic theory underpinning demand analysis, but the simple version is that there is an inverse relationship between price and quantity. In the case of fisheries and aquaculture, prices change with the amount landed or produced.

This is generally represented by a downward sloping *demand curve*. This can be considered from the perspective of both the consumer and the producer. From the consumers' perspective, a decrease in the price will lead to more of the product being bought. From the producers' perspective, lower prices result in more product being sold. In the case of fisheries and aquaculture producers, who are generally price takers and unable to influence the price received directly, the price they receive will depend on the total supply to the market and the strength of the price-quantity relationship (i.e., the slope of the demand curve).

Price elasticity versus price flexibility

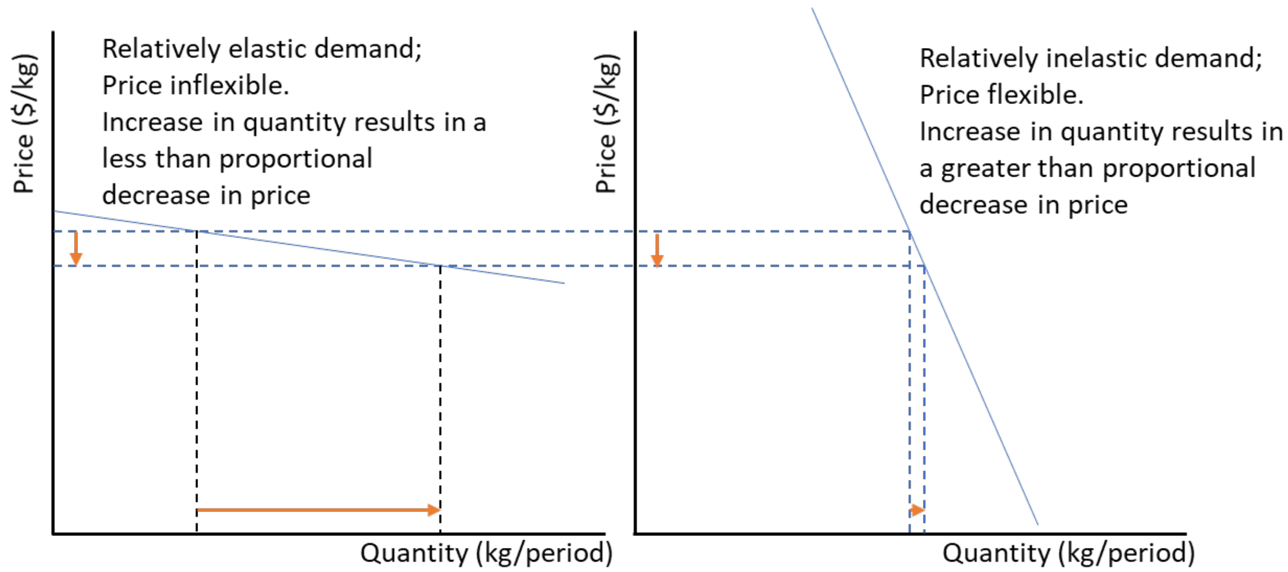
Economics has two related measures of the relationship between price to quantity. From the consumers' perspective, price is a given (i.e., in the supermarket), and is a key factor in the decision of how much to buy (if any). The change in quantity bought as price changes determines the ***price elasticity*** of the good. Price elasticity represents the percentage change in quantity demanded due to a 1 per cent change in the price. For example, for a good with a price elasticity of -2, a 1% reduction in the price of the good will result in a 2% increase in quantity demanded.



In contrast, fishers and aquaculturalists are largely price takers. Their product is highly perishable, and once on the market, must be sold. In these cases, the market price adjusts to clear the available supply. Of relevance to producers is the ***price flexibility*** – the percentage change in price due to a 1% change in quantity supplied to the market. For example, for a fish species with a price flexibility of -2, a 1% increase in the quantity landed will result in a 2% decrease in price received.

Understanding the distinction between price elasticity and price flexibility is important, as some studies focus on one measure and other studies on the other. Both price elasticities and price flexibilities are always negative. A good with a price elasticity less than -1 (e.g. -2), the demand for the good is said to be ***price elastic***, while a price elasticity greater than -1 (e.g. -0.5), demand is ***price inelastic***. Conversely, a product with a price flexibility less than -1 (e.g. -2) is said to be ***price flexible***, while a price flexibility greater than -1 (e.g. -0.5) is ***price inflexible***.

There is an inverse relationship between price elasticity and price flexibility. A good that is price elastic (from the consumer perspective) is price inflexible (from the producer perspective).



Examples of price flexibilities for seafood in Australian markets

From the perspective of fishers and aquaculture producers, of key relevance is the price flexibility of their product. Fish supplied to the market is highly perishable, and must be sold. The price adjusts to clear the market. ***Own-price flexibility*** reflects the percentage change in price of a species due to a 1% change in the quantity landed (or produced) of that species.

Several recent studies which focus on demand analysis of Australian seafood products have estimated own-price flexibilities for key fish species on the Sydney Fish Market (Pascoe *et al.* 2021), salmon (Pascoe *et al.* 2021), prawns (Schrobback *et al.* 2019a) and oysters (Schrobback *et al.* 2014) (**Error! Reference source not found.**).

Fish species were generally found to be relatively price inflexible, such that a change in quantity landed/produced results in a less than proportional change in price. Further details on price flexibilities of individual fish species are given in the Appendix.

Table G.1. Own-price flexibilities from recent Australian studies

Wild-caught species	Own-price flexibility	Aquaculture species	Own-price flexibility
High valued fish species	-0.350	Salmon	-0.652
Low valued fish species	-0.519	Prawns	-0.483
Prawns	-0.996	Sydney Rock Oysters	-1.359
		Pacific Oysters	-0.353

Wild-caught prawns sold domestically were found to be almost unit flexible (i.e., price flexibility is about -1). This suggests that prices on the market decrease proportionally with changes in quantity landed. Farmed prawns, however, were relatively price inflexible. This most likely reflects their small market share, as a change in quantity produced has only a small impact on the total supplies to the market, and hence only a small price response, all else being equal.

Sydney rock oysters were found to be price flexible, such that a change in the quantity supplied has a greater than proportional impact on prices received (Table G.1). That is, increasing the supply of Sydney Rock Oysters to the market results in a greater than proportional decrease in the price received by producers. In contrast, Pacific oysters were price inflexible.

What affects own-price flexibility?

Price flexibility is affected by a number of factors, including the number of substitutes available and the share of the product in the total market. While not fisheries examples, the demand for fuel and tobacco is highly inelastic due to the lack of substitutes, hence efforts by consortiums such as OPEC to restrict oil supply to maintain high fuel prices and high taxes on tobacco to try and reduce its consumption.

Individual fish species have many potential substitutes (i.e., other fish species or even other protein sources). As a result, fish species generally have price flexibilities greater than -1 (i.e., between -1 and zero). Other seafood products, such as prawns and oysters, are not as substitutable as they are less of a staple food and eaten more on special occasions. A larger proportional reduction in price is needed to attract consumers to buy more than they would normally than, say, for fish. As a result, their price flexibilities are higher.

Market share is also an important determinant of own-price flexibility. For exported fish products, where Australia is only a small contributor to the global market, prices are driven by the total global supply rather than how much is landed domestically. That is, own-price flexibility relating to Australian production may be zero (perfectly inflexible; demand perfectly elastic), and prices received may be totally independent of the quantity of product landed. However, at the global level, prices are likely to be more flexible. Hence, prices may move with changes in total global supplies, and these changes are subsequently imposed on the Australian product irrespective of its own production level.

An example of this latter effect is evident on the prices received by Australian prawn producers exporting to the global market. Over recent decades, prices received by Australian exporters have decreased by more than 50% in real terms due to increased global supplies, even though Australian production has not changed substantially other than through year to year fluctuations due to environmental factors.

Market interactions between species and substitute goods

Cross price elasticity reflects the change in quantity demanded of a good due to a change in the price of a substitute or complementary good. For example, if chicken was a substitute for fish, then a reduction in the price of chicken would be expected to result in an increase in the quantity of chicken demanded, and a subsequent reduction in the quantity of fish demanded. From the perspective of the fish producer, an increase of the supply of chicken to the market results in a reduction in the price they receive in order to sell their product. Consequently, the ***cross-price flexibility*** will also be negative in the case of a substitute product (and positive in the case of a complementary good).

The above example was hypothetical to illustrate the concepts of cross-price flexibilities and substitution effects. Most fisheries related demand studies internationally have focused on the potential substitution between different species, or their origin, and the effect of this on price formation.

The most obvious substitute for one fish species is another fish species. Different species have different characteristics (e.g. taste, firmness, size etc) so substitution is not universal. But species with similar characteristics are likely to attract similar prices, and changes in their quantity landed is likely to impact not only their own price but also of the price of the similar species. This substitution effect can apply not just to other domestically produced species, but also imports.

Examples of cross-price flexibilities between species on the NSW market, derived from Pascoe *et al.* (2021), are shown in Table G.2. These impacts are not necessarily symmetrical. For example, changes in the quantity landed of fish species into NSW has little impact on salmon prices, but changes in the quantity of salmon sent to the NSW market has a substantial impact on the price of the wild-caught fish. Similarly, quantities of wild-caught fish landed has little impact on import prices, but the level of imports – particularly fresh imports – has an impact on the price of low value fish species, and to a much lesser extent high valued fish species. The relationship between the wild-caught fish species themselves is also not symmetrical;

changes in the quantity landed of high value fish species has a larger (negative) impact on the price of low value species than the converse.

Table G.2. Cross-price flexibilities for fish species on the NSW market

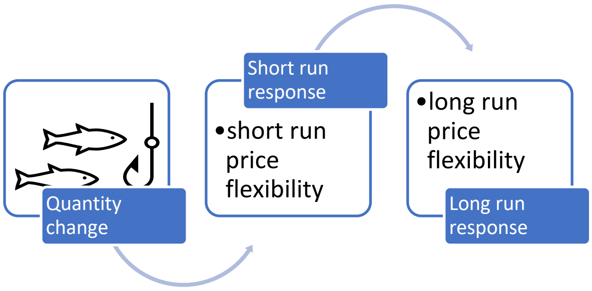
Prices of:	Changes in the quantity of:				
	Fresh imports	Frozen imports	Salmon	High value fish	Low value fish
Fresh imports	-	-0.176	-0.446		-0.051
Frozen imports		-	-0.172		0.040
Salmon	-0.104	-0.246	-	-0.051	-0.027
High value fish	-0.151		-0.997	-	-0.134
Low value fish	-0.652	0.852	-1.209	-0.295	-

Market dynamics – short run and long run price flexibilities

The price flexibilities presented in the examples above are long run flexibilities. That is, they are the impact of a change in quantity on prices once a new "equilibrium" position in the market has been achieved. Markets, however, do not always react immediately to a change in landings or production, and in some instances may over-react to a change. As a result, short-term price changes may be greater than, or less than, the long run price change.

The most recent estimates of short run and long run own and cross-price flexibilities for a range of key fish species, prawns and oysters are presented in the Appendix.

The short run may be fairly short: all other things being equal, for most species on the Sydney Fish Market, the long run equilibrium was achieved in 2-4 months, and for some species, nearly all price adjustment (70%) occurred in the first month (Pascoe *et al.* 2021). The difference between the short run and long run flexibilities were also generally found to be less than +/- 10%.



Markets are also constantly subject to short-term fluctuations in quantities supplied. For example, landings may vary widely on a daily or weekly basis due to the activities of the fishers as well as other factors such as weather conditions or "luck". With the short-term dynamics noted above, prices may fluctuate widely over the year. Over the course of a fishing season, however, prices are expected to change, on average, by the degree described by the long run price flexibility.

Given the short run dynamics inherent in the price formation process as well as the constant fluctuations in landings of different species, estimation of own and cross-price flexibilities require more than a simple statistical model linking quantities landed to prices. In the case of fisheries products, estimation of dynamic inverse demand systems is generally applied, and was the basis of the estimation of the price flexibilities discussed above. Detailed descriptions of these systems are given in Pascoe *et al.* (2021).

Implications of price flexibilities for fisheries and aquaculture management

Price flexibilities provide a useful guide to managers and industry as to how revenues may change as a result of decisions that affect the quantity landed or produced. Except for the case of perfectly inflexible prices (i.e., price flexibility equals zero), an increase in output will result in a less than proportional increase in revenue as prices decline, and may even result in an overall decrease in revenue.

In this section, we present some examples as to how fishery and aquaculture economic performance may change as a result of changes in production when prices are flexible (i.e., prices change with quantity landed or produced).

Price flexibility, revenues and profits

Revenue is determined by the quantity multiplied by the price. As these both move in opposite directions (the degree to which is determined by the price flexibility), a change in quantity does not result in a proportional change in revenue. Increasing production also requires higher costs, such that profits may increase by less than any increase in quantity, and may even decrease. These effects are illustrated by some examples below.

When prices are inflexible (i.e., when demand is elastic), an increase in the quantity supplied will result in a less than proportional reduction in price (and vice versa). For example, if the quantity of fish landed increased by 10% and its price flexibility was -0.5 (i.e., price inflexible), then prices would fall by 5%. The net effect would be a 4.5% increase in revenue (i.e., 1.1 (catch) * 0.95 (price) = 1.045, as the lower price applies to the whole catch or production, see Table G.3). Conversely, if catch or production fell by 10%, prices would increase by 5% and revenue would only fall by 5.5% (i.e., 0.9 (catch) * 1.05 (price) = 0.945).

Table G.3. Impact of quantity change when price flexibility is -0.5 (inflexible)

Change	Quantity	Price	Revenue
Base	1.0	1.00	1.000
Increase 10%	1.1	0.95	1.045
Decrease 10%	0.9	1.05	0.945

When prices are flexible (i.e. demand is inelastic), an increase in the quantity supplied will result in a greater than proportional reduction in prices. Using the above example, if the quantity of fish landed or produced increased by 10% and its price flexibility was -2.0 (i.e. price flexible), then prices would fall by 20%. The net effect would be a 12% decrease in revenue (i.e. 1.1 (catch) * 0.8 (price) = 0.88, as the lower price applies to the whole catch or production). Conversely, if catch or production fell by 10%, prices would increase by 20% and revenue would only increase by 8% (i.e., 0.9 (catch) * 1.2 (price) = 1.08).

Table G.4. Impact of quantity change when price flexibility is -2.0 (flexible)

Change	Quantity	Price	Revenue
Base	1.0	1.00	1.00
Increase 10%	1.1	0.80	0.88
Decrease 10%	0.9	1.20	1.08

While revenues increase less than proportionally with increased catch, costs of fishing also increase. Applying additional fishing effort to take the additional catch requires additional fuel, while higher catches also require more packaging and labour. This may result in a smaller increase in fishery profits, or potentially a decrease.

To illustrate this we present an example based on the trawl sector of the South Eastern Shark and Scalefish fishery (SESSF), using economic (cost and earnings data and price data) from ABARES (Bath *et al.* 2018; Steven *et al.* 2020) and catch and total allowable catch (TAC) information from AFMA (AFMA 2020a). We use the 2014-15 fishing year for the example.

In 2014-15, the trawl sector landed roughly 55% of the available total allowable catch. This ranged from as low as 7% for some species to 73% for others. There are a number of reasons for this under-catch (Knuckey *et al.* 2018), including potential market impacts of taking the full TAC.

For the purposes of the hypothetical example, we assume that the full TAC of each species was taken (which may not be possible in reality due to technical interactions in the fishery). Based on the estimated price flexibilities for these species (Pascoe *et al.* 2021), average revenue would increase only by 20% as the higher catches result in lower prices for the individual species. Assuming the additional fishing effort required to take the additional catch is proportional to the increase in catch, then variable costs (which are a function of fishing effort and catch) would increase by 52%.

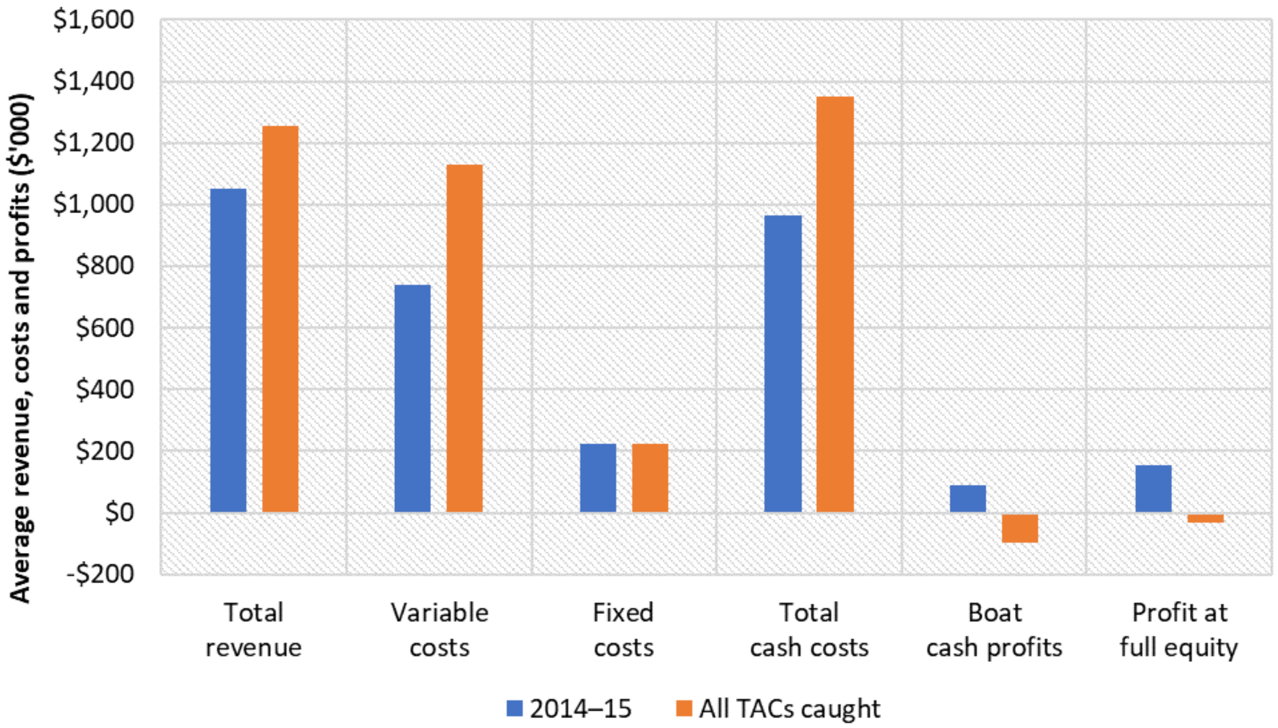
The net effect of this is a decrease in average boat cash profits from a positive value to a negative value. After adjusting for non-cash costs (e.g. depreciation) and leasing costs, full equity profits also change from a positive value to a negative value. Consequently, the trawl fleet would be worse off from an economic perspective if it filled the available TAC than if it caught less than the full TAC.

As noted above, this is a hypothetical example, as no doubt fishers would not continue to fish if their additional revenue was less than the cost of fishing. It does, however, illustrate the importance of market interactions in understanding the potential causes of quota under-catch. Higher TACs are not always beneficial to the industry, nor under-caught TACs a sign of irrational fisher behaviour.

Unanticipated effects of TAC and aquaculture production changes

Because of the cross-price interactions, a change in the TAC of one species may have implications for the prices received for other species. These effects are not uniform across species. For example, the increase in blue grenadier quota in 2019 (if filled) would impact on the price of blue grenadier, but as there were no significant cross price effects would not affect the price of other species on the market.

In contrast, changing the quota for pink ling (if caught) would also have an impact on the prices of most of the other species on the market, particularly tiger flathead. For example, based on the price flexibilities presented in the Appendix, a 10 % increase in the landings of pink ling would decrease the price of ling by around 4 %, but also decrease the price of flathead by



around 3 %, even if flathead landings remained the same. While these proportions seem small, the combined effect of the reduced ling and flathead prices may offset the increased quantity of ling landed, resulting in a no-sum-gain for the fishery.

Being aware of the potential cross price effects (as well as the own price effects) of changing TACs is consequently important to fisheries managers if they wish to improve the economic performance of the fishery.

A similar need to understand the impact of changes in production in the aquaculture sector on prices is important for policy development in this area. At an individual farm level, changes in production are unlikely to have a substantial impact on prices, and farmers can be considered price takers. At an industry level, however, increased output will impact not only on the price of their own product, but also the prices received by wild-caught fisheries.

Changes in salmon production was found to have an impact on the prices of wild-caught fish. Based on the estimated cross-price flexibilities presented previously, a 10 % increase in salmon production will reduce the price of higher valued fish species by almost 10 %, and lower valued fish species by around 12 %. Similarly, for prawn aquaculture, a 10 % increase in farmed prawn production will reduce the price of wild prawns on the domestic market by 1 %.

The potential for growth of this sector is large, with both State and Commonwealth policy targeting its expansion. Factoring in the potential impact on the wild-caught sector of aquaculture expansion needs to be considered as part of policy development.

Changes in trade: imports and exports

As noted above, imports can impact on the price of fish and seafood on the domestic market. For fish species, imports of fresh fish (such as Basa) has a negative impact on fish species on the Sydney Fish Market, with the impact on the lower valued species being greater than the higher valued species due to their degree of similarity in characteristics (see Table 2).

For example, imports of fresh and frozen fish decreased over the first half of 2020 as a result of transportation issues arising from the COVID-19 pandemic. Fresh imports decreased by 10% between March and May compared with 2019; although increased to historically average levels from June. From the price flexibilities in Table 2, this would have been expected to have had a positive impact on low valued SESSF species prices of around 6%, with an increase in high valued SESSF species of around 1.5%. Similarly, frozen imports increased by around 11% over the same period. Due to the complementary nature of frozen imports, this would have been expected to have increased the price of low valued SESSF species by a further 11%, giving a total increase of around 18%. Anecdotal evidence from industry supports price increases of this magnitude.

Similarly, the temporary moratorium on imported prawns in 2017 as a result of the white spot disease outbreak in South East Queensland, the loss of production from the affected farms and the high seasonal demand at that time (i.e., over Christmas and New Year) resulted in substantial increases in prawn prices.

The COVID-19 pandemic has also affected export markets, through increased complexity in transporting product as well as reduced demand for high valued seafood product in the destination countries due to restrictions in social gatherings. Key export species such as rock lobster, prawns, abalone and coral trout were particularly affected. Some of this product was diverted to the domestic market, although this increase supply to the domestic market resulted in decreases in prices received. Trade issues with China in late 2020 for lobsters caused ongoing issues for the industry. Price flexibility for lobster, abalone and coral trout are not available, so it is difficult to determine best approach for fishers in terms of changing markets or production levels. However, during this period, domestic consumers have benefited due to rediverted quantity of seafood products to the domestic market, and subsequently lower prices.

Price flexibility and benefits to consumers

While lower prices may not always benefit producers, lower prices do benefit consumers. This is particularly of relevance when considering TAC changes as well as developing policy promoting the expansion of aquaculture. Gains and losses due to price changes do not just affect fishers or aquaculture producers, but also extend to consumers.

The difference between what buyers are willing to pay (defined by the demand curve) and what they are required to pay given the market clearing price is known as ***consumer surplus***. This is a non-monetary benefit to consumers. As prices decrease, consumer surplus increases (and vice versa).

An example of an increases in consumer surplus is the lower prices for rock lobster on the domestic market as a result of trade restriction with China in 2020. People who were previously willing to pay the higher market price were now able to buy the rock lobster at the lower price, the difference representing their consumer surplus. Individuals who were not willing to pay the previous price but were willing to pay the new lower price also gained some consumer surplus, depending on the difference between what they were willing to pay and were required to pay at the market clearing price.

Conversely, the reduction in prawn imports and aquaculture production following the white spot disease outbreak in 2017 resulted in higher prawn prices on the domestic market and a reduction in consumer surplus to consumers.

The amount of consumer surplus generated is largely dependent on the slope of the demand curve, which also reflects the price flexibility. When prices are highly inflexible, the demand curve is effectively flat, with little or no consumer surplus being generated. That is, any benefits from changes in quantities landed accrue only to fishers.

In contrast, if prices have some level of flexibility, then consumer surplus is also affected by the level of landings, and both consumers and producers are impacted by management changes.

Balancing the benefits between fishers/farmers and consumers requires an understanding of how prices change with quantity landed/produced.

Conclusions

Changes in the quantity produced at the level of the industry can have an impact on the prices that producers receive. These price changes may extend beyond just one species in question, impacting also on potential substitute species.

The critical measures of this change are the own and cross-price flexibilities. Own-price flexibilities define the percentage change in the price of a species due to a 1 per cent change in landings or production, while cross-price flexibilities represent the percentage change in a different species due to the production change of a given species.

Individually, own and cross-price flexibilities are generally small. In the case of key fish species, they are mostly between -0.5 and zero, indicating a less than proportional change in price with landings or production. However, this means that changes in revenues from, say, a TAC increase will result in a less than proportional change in revenue, and with cross price impacts also, increasing TACs may result in negligible revenue improvements. Fisheries managers in particular need to be aware of these changes, as increasing a TAC does not necessarily mean better returns to the fishery. Conversely, higher returns may be earned at lower levels of catch due to the combination of higher prices and less cost in catching the fish.

While lower prices may be bad for producers, lower fish prices provide benefits to consumers. Hence, what is optimal for the fishery or aquaculture industry may not be optimal for the community overall. Including consumer benefits into economic analyses underlying TAC and other decisions that impact production is an area of further consideration by fisheries and aquaculture managers.

Considering impacts of decision on prices

What is the product market?

Export or Domestic?

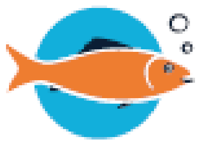
If it is an export market, prices are usually determined by factors beyond the control of managers.

If it is domestic market, then prices are most likely to respond to quantity produced

Has a demand study been undertaken

Do you know the own-price flexibility?

Given the flexibility, the impact of the production change on price and revenue can be estimated.



Impacts on other species?

Do you know the cross-price flexibility?

Changes in production of one species can have an impact on the proce of another.

Impacts on consumers?

How will consumer surplus be affected?

Increases in price are of benefit to industry, but impose a cost to consumers. Conversely, lower prices benefit consumers but may disadvantage producers. The more flexible the price, the greater the potential change in consumer surplus.

Unsure of any of these?

Maybe you need to organise a demand study to be undertaken

For an industry with predominantly domestic market, understnding how decisions affect prices is an important consideration when making decisions that affect production levels.

Appendix: Estimated short and long run price flexibilities

Fish species

Table G.5. Short run own and cross-price flexibilities at the mean for fish species on the Australian domestic market

High value species	John Dory	Tiger Flathead	Orange Roughy	Bigeye Ocean Perch	Blue eye Trevalla	Pink Ling	Silver Trevally	Low valued species	
John Dory	-0.478	-0.154			-0.081	-0.156		-0.267	
Tiger Flathead	-0.024	-0.456	-0.007	-0.059	-0.068	-0.137	-0.037	-0.172	
Orange Roughy			-0.472						
Bigeye Ocean Perch		-0.268		-0.295	-0.096	-0.099	-0.058		
Blue eye Trevalla	-0.043	-0.195		-0.061	-0.314	-0.109	-0.046	-0.179	
Pink Ling	-0.058	-0.256	-0.006	-0.044	-0.072	-0.437		-0.112	
Silver Trevally		-0.169		-0.059	-0.071		-0.467	-0.112	
Low value species	**Blue Grenadier**	**Eastern School Whiting**	**Gemfish**	**Gummy Shark**	**Jackass Morwong**	**Mirror Dory**	**Silver Warehou**	**Other**	**High Valued species**
Blue Grenadier	-0.403								
Eastern School Whiting		-0.494	-0.022		-0.030	-0.038	-0.015	-0.009	-0.408
Gemfish		-0.088	-0.366						-0.482
Gummy Shark								-0.181	-0.491
Jackass Morwong		-0.066	-0.071		-0.427	-0.042		-0.027	-0.491
Mirror Dory		-0.058				-0.349	-0.017		-0.541
Silver Warehou		-0.214				-0.154	-0.550		
Other				-0.060	-0.094			0.173	-1.107

Table G.6. Long run own and cross-price flexibilities at the mean for fish species on the Australian domestic market

High value species	John Dory	Tiger Flathead	Orange Roughy	Bigeye Ocean Perch	Blue eye Trevalla	Pink Ling	Silver Trevally	Low valued species	
John Dory	-0.493	-0.111		-0.033	-0.084	-0.132		-0.250	
Tiger Flathead		-0.462		-0.055	-0.069	-0.152	-0.039	-0.169	
Orange Roughy			-0.472						
Bigeye Ocean Perch		-0.236		-0.317	-0.101	-0.091	-0.054		
Blue eye Trevalla	-0.049	-0.188		-0.064	-0.302	-0.115	-0.037	-0.157	
Pink Ling	-0.053	-0.282		-0.042	-0.079	-0.427		-0.113	
Silver Trevally		-0.162		-0.053	-0.057		-0.617	-0.113	

Low value species	Blue Grenadier	Eastern School Whiting	Gemfish	Gummy Shark	Jackass Morwong	Mirror Dory	Silver Warehou	Other	High Valued species
Blue Grenadier	-0.424								
Eastern School Whiting		-0.530	-0.022		-0.034	-0.056	-0.018		-0.374
Gemfish		-0.086	-0.329			0.058	0.035		-0.487
Gummy Shark							0.066	-0.188	-0.599
Jackass Morwong		-0.079	-0.074		-0.456			-0.040	-0.599
Mirror Dory		-0.041	0.022			-0.315	-0.017		-0.579
Silver Warehou		-0.254	0.106	0.045		-0.143	-0.505	-0.098	-0.360
Other				-0.055	-0.125		-0.040	-0.536	-1.072

Prawns

Table G.7. Own and cross-price flexibilities at the mean for prawns on the Australian domestic market

	Wild-caught	Aquaculture	Imported
Short run			
Wild	-0.447	-0.116	-0.379
Aquaculture	-0.456	-0.595	-0.414
Imported	-0.218	-0.028	-0.998
Long run			
Wild	-0.996	-0.114	-0.160
Aquaculture	-0.030	-0.483	-0.929
Imported	-0.096	-0.155	-0.976

Source: Schrobback *et al.* (2019a)

Oysters

Table G.8. Own and cross-price flexibilities at the mean for oysters on the Australian domestic market

	Sydney Rock Oyster	Pacific Oyster
Short run		
Sydney Rock Oyster	-0.804	0
Pacific Oyster	-0.008	-0.262
Long run		
Sydney Rock Oyster	-1.359	0
Pacific Oyster	-0.147	-0.353

Source: Schrobback *et al.* (2014)

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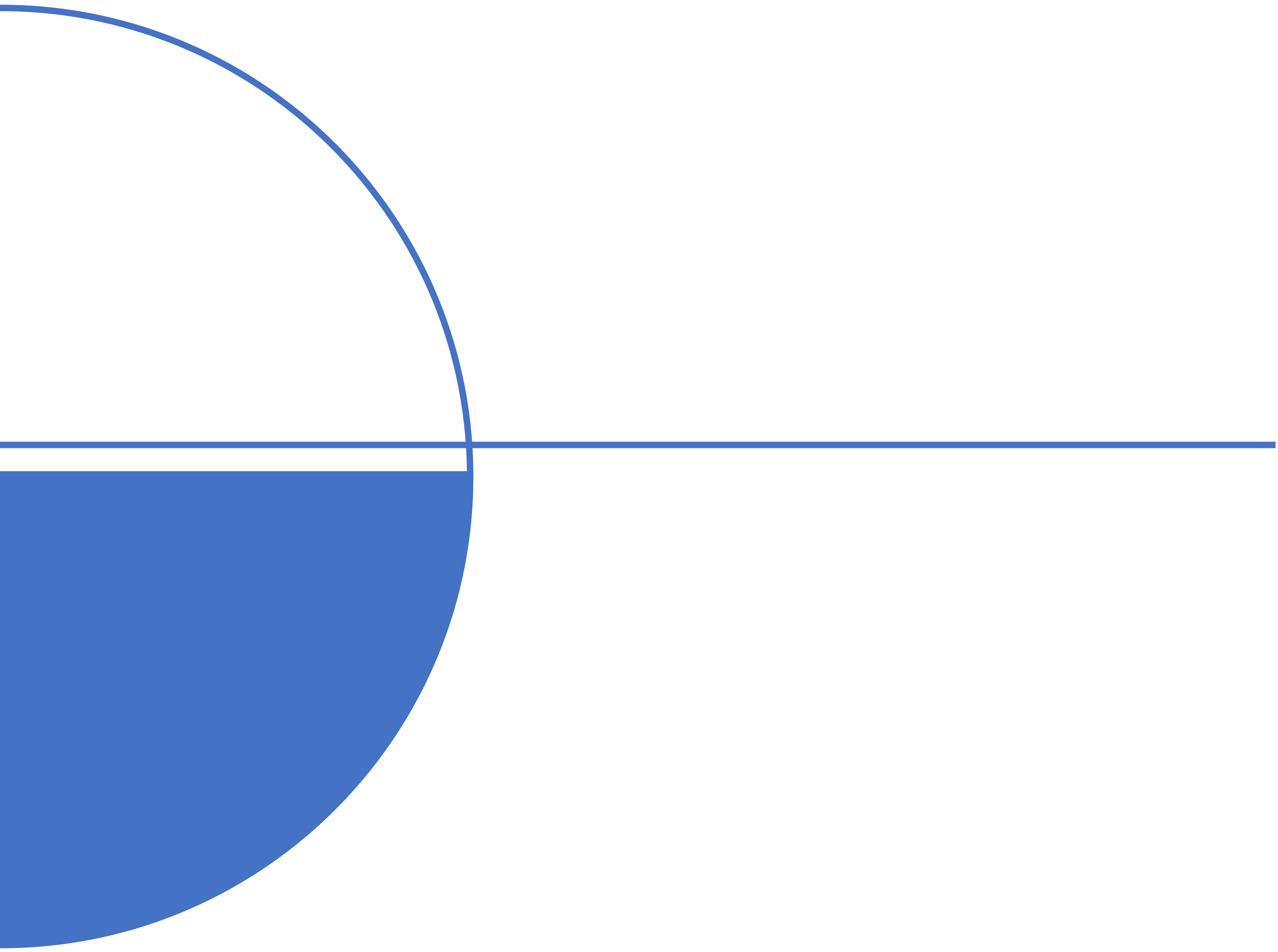

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