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Market integration of domestic and imported seafood: Insights from the Sydney Fish Market*

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Australia has experienced a significant increase in seafood imports over the past two decades. Concurrently, Australian seafood producers have raised concerns that the low market prices of imported fish may negatively affect the prices of domestically produced seafood and, subsequently, the profitability of the Australian fishing industries. To validate this concern, this study examines the relationship between prices of domestically produced seafood and imported fish. Price data from the Sydney Fish Market (SFM), Australia's largest auction wholesale fish market and fish import data are used for a cointegration analysis which is conducted using the bivariate Johansen test. Results indicate that prices of most domestic species traded within the SFM are not cointegrated, implying that they largely develop independently of each other. However, imported fish, particularly fresh imports, were found to be cointegrated with Australian produced fresh fish supplies traded on the SFM. Although the law of one price (LOP) was only confirmed to hold for some price pairs, the results suggest a partial substitution relationship between imports and domestically caught fish. This implies that prices of domestically produced fish within the Australian market are likely impacted by price dynamics within the international seafood market.

Key words: Australia, cointegration, fish, imports, Law of One Price, seafood.

1. Introduction

Australia's seafood consumption has increased nearly twofold over the past 30 years (Figure 1) due to population growth and increasing household income (Hogan, 2018). To supply the domestic demand for fish products, Australia produces a wide range of wild-caught (e.g. tuna, prawns, shark and scale fish) and aquaculture (e.g. prawns, salmon, oysters, barramundi)

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seafood (ABARES, 2020). However, the total seafood volume produced domestically has remained relatively constant over time (Figure 1) (ABARE, 1991; ABARES, 2020). While the volume and diversity in aquaculture production have increased gradually over time and there is capacity and interest to further expand aquaculture production (e.g. Cobcroft et al. 2020), potential for increases in Australia's wild fisheries production is limited. This is due to the relatively low natural productivity of marine waters and harvest strategies in place that focus on ecologically sustainable and profitable use of Australia's fishery resources (Australian Government, 2015). Seafood export volumes continue to be stable but relatively small in volume with a focus on trade of high-value products (e.g. rock lobster, abalone, tuna) to Asian markets (e.g. China, Hong Kong, Japan) (ABARES, 2020; Australian Government, 2015).

Thus, imports have been an important source to supply the increasing domestic demand for seafood. Presently, about 65% of the fish products consumed in Australia by volume are imported, sourced predominantly from marine wild-catch and aquaculture production (ABARES, 2020). Seafood imports largely consist of lower value products including fresh whole fish, fresh and frozen fillets, frozen prawns, and canned fish and predominantly originate in Thailand, China, Vietnam and New Zealand (ABARES, 2020).

Australian seafood producers continuously raise the concern that the low market prices of imported seafood negatively affect the prices of domestically produced seafood and subsequently the profitability of fishing and aquaculture businesses (e.g. ABC 2018; ABC 2019). The economic viability of commercial wild-catch fisheries and aquaculture industries is important to Australia as they provide income opportunities to coastal communities.

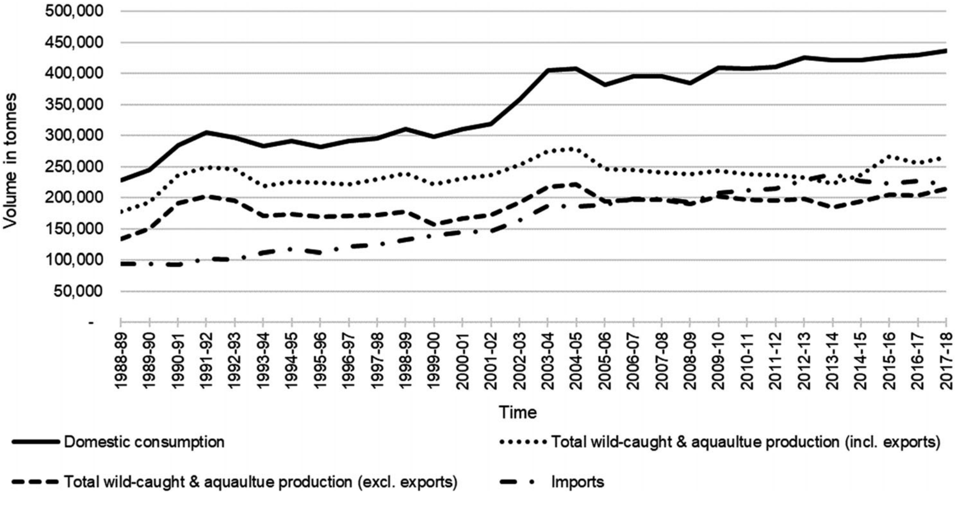

Figure 1 Australia's seafood production, consumption and trade volumes. Sources: ABARE (1991), ABARES (2020)

Relatively few studies with a focus on seafood market dynamics have been undertaken in Australia (e.g. Norman-López et al., 2014; Schrobback et al., 2014, 2019), and some of these are relatively dated (Bose, 2004; Pascoe et al., 1987; Smith et al., 1998). Yet, on a global scale there is extant literature investigating general seafood market dynamics (e.g. Ankamah-Yeboah et al., 2017; Asche et al., 2004; Blomquist, 2015; Bronnmann et al., 2016; Gordon et al., 1993; Jaffry et al., 1999) as well as the impact of imported fish on the domestic seafood market (e.g. Ankamah-Yeboah et al., 2017; Bronnmann et al., 2016; Bronnmann & Asche, 2017; Hoshino et al., 2015; Norman-López & Asche, 2008). Such assessments are useful in better understanding seafood markets and the potential need for policy interventions.

In the context of Australia, the concern about the effect that low priced imports have on domestically produced seafood has been investigated more recently by Schrobback et al. (2019). The authors analysed the price relationship between domestically produced prawns and imported prawns and found that the price of prawn imports did not have an effect on domestically produced prawn prices (Schrobback et al., 2019). While the previous study only focused on one type of seafood, research investigating the impact of imports on multiple seafood products produced in Australia has not been conducted.

Hence, the aim of this study was to examine the relationship between prices of seafood produced in Australia and imported seafood.

For the analysis in this study, data from the Sydney Fish Market (SFM) were used as it provides the most comprehensive and accessible seafood market records over time for Australia. To analyse the price relationship among various seafood products traded at the SFM (to fully understand price dynamics of this market) and imported seafood, the Johansen cointegration test was conducted.

This study contributes to the literature in the field of empirical market price assessments for fish products (e.g. Ankamah-Yeboah & Bronnmann, 2018; Asche et al., 2012; Bronnmann et al., 2016; Hoshino et al., 2015; Nielsen, 2005; Norman-López & Asche, 2008) as a case study for Australia.

2. Data and Methods

2.1 Data

Data from the SFM were used to investigate the price relationship between domestically produced seafood and imported seafood. The SFM is Australia's largest auction wholesale market for seafood, with total traded seafood quantity of 12,866 tonnes, worth A$146 million in 2019/2020 (SFM, 2020). Roughly half of the product (55.4% by quantity) is supplied from the New South Wales (NSW) fisheries where SFM is located, while products from interstate and imports contribute to the other half of the supply (SFM, 2020). The available data set included information about monthly values and quantities for 19 fish species sold as fresh or chilled at the SFM. These species represent the most important seafood products traded at this market and were considered to represent a proxy for price dynamics within the domestic seafood market. Recent data for other domestic fish species or seafood markets were not available.

The longest data period that offered an overlap for all 19 species covered the time between June 2005 to October 2019 (number of monthly observations, $n = 172$) (see Table 1), although for some species records dating back to 1999 were available.

Data for each of the 19 fish species provided a relatively wide range of product forms such as whole, gilled and gutted. To develop a consistent price, all weights were converted to whole-weight equivalents (WWE) using a series of conversion factors that were species and process specific. Detailed information about relevant conversion factors is provided in AFMA (2020). Consistent prices were then derived based on the ratio of value and WWE quantity. Descriptive statistics of the derived price data series after weight conversions are shown in Table 1. Missing values (see 'NA' in Table 1) were interpolated using the Kalman filter ('na_kalman') (Gomez & Maravall, 1994) offered in the 'imputeTS' package (Moritz & Bartz-Beielstein, 2017) in the R software (R Core Team, 2012). The Kalman filter is an established procedure to compute the likelihood of missing values in time series data (e.g. Afrifa-Yamoah et al., 2020; Hadeed et al., 2020). The statistics in Table 1 for species with missing values (e.g. blue grenadier, orange roughy) represent values derived after imputation.

During the reported data period, the three most important species at the SFM in terms of average monthly quantity traded were tiger flathead, pink ling and mirror dory, while the top three species in terms of average monthly unit price were John dory (A$10.98/kg WWE), blue-eye trevalla (A$10.00/kg WWE) and tiger flathead (A$6.7/kg WWE) (Table 1). The lowest average unit prices over the period of the data were recorded for common saw shark (A$1.69/kg WWE), silver warehou ($A1.97/kg WWE) and blue grenadier (A$2.05/kg WWE).

Import data were obtained from the Australian Bureau of Agriculture and Resource Economics and Science (ABARES). The import data set was specific for NSW, the state in which the SFM is located. It was assumed that the use of spatially specific data would appropriately reflect local market dynamics compared to using Australia wide import data for analysis. While some of the imports landed into NSW are destined for other states, and imports into other states (e.g. Queensland or Victoria) are sold in NSW; it was assumed that these interstate trades would largely cancel out. The monthly import data that were used for the analysis ranged from January 2012 to September 2019 (93 monthly observations for each series); hence, it was shorter than the data set for the SFM (Table 1). While earlier import data were available, changes in import classifications in 2012 resulted in earlier data being aggregated into categories less useful for cointegration analysis.

Table 1 Descriptive statistics of monthly Sydney Fish Market data and import data for NSW

Species	Data period	*N*	NAs	Mean quantity (kg)	Mean value (A$)	Mean Price (A$/kg WWE)	Price Std. Dev.
SFM data							
John Dory	Jun 2005-Oct 2019	172	0	8,711	92,022	10.98	1.85
Mirror Dory	Jun 2005-Oct 2019	172	0	20,536	72,216	4.59	1.33
Tiger Flathead	Jun 2005-Oct 2019	172	0	56,805	377,587	6.70	1.20
Gemfish	Jun 2005-Oct 2019	172	0	7,795	30,133	4.05	1.20
Blue Grenadier	Jun 2005-Oct 2019	146	26	1,622	2,521	2.05	0.96
Pink Ling	Jun 2005-Oct 2019	172	0	37,894	211,320	5.82	1.00
Morwong Jackass	Jun 2005-Oct 2019	172	0	16,096	59,822	4.12	1.03
Orange Roughy	Jun 2005-Oct 2019	124	48	1,954	11,423	6.14	1.91
Bigeye Ocean Perch	Jun 2005-Oct 2019	172	0	12,303	74,256	6.35	1.11
Reef Ocean Perch	Jun 2005-Oct 2019	172	0	941	3,014	3.19	0.85
Royal Red Prawn	Jun 2005-Oct 2019	145	27	1,321	4,101	3.95	2.03
Gummy Shark	Jun 2005-Oct 2019	172	0	1,845	6,147	3.21	0.71
Common Saw Shark	Jun 2005-Oct 2019	172	0	4,438	7,338	1.69	0.43
School Shark	Jun 2005-Oct 2019	161	11	515	1,294	2.48	1.13
Blue-eye Trevalla	Jun 2005-Oct 2019	172	0	13,616	129,240	10.00	2.17
Silver Trevally	Jun 2005-Oct 2019	172	0	16,566	74,728	5.56	2.31
Blue Warehou	Jun 2005-Oct 2019	143	29	674	2,626	4.10	1.97
Silver Warehou	Jun 2005-Oct 2019	172	0	4,138	8,350	1.97	0.63
Eastern School Whiting	Jun 2005-Oct 2019	172	0	34,758	111,458	3.30	0.77
Import data							
Imp. Aquaculture	Jan 2012-Sep 2019	93	0	1,014,201	1,496,196	1.47	0.24
Imp. Hake	Jan 2012-Sep 2019	93	0	633,436	962,696	1.56	0.30
Imp. Other Fresh Fish	Jan 2012-Sep 2019	93	0	476,275	3,217,166	6.79	0.59
Imp. Other Frozen Fish	Jan 2012-Sep 2019	93	0	2,614,330	8,414,758	3.22	0.39
Imp. Salmon	Jan 2012-Sep 2019	93	0	307,532	2,711,225	8.52	1.38

Note: ‘Quantity’ indicates the average monthly quantity traded, ‘Value’ indicates the average monthly values of the traded good, ‘N’ for number of observations, ‘NAs’ for number of missing values, ‘A$/kg WWE’ indicates values for average prices after weight conversion factors were applied to raw data set with ‘WWE’ for whole-weight equivalent, ‘Std. Dev.’ for standard deviation, ‘Imp.’ for imported product.

The data set for fish imports offered information about a range of species. Hence, the imported fish were aggregated into five groups: hake (fresh or frozen), aquaculture (fresh or frozen), salmon (fresh or frozen), other fresh fish and other frozen fish. The aggregation into groups was based on import quantity. As for the SFM data, the import data needed to be converted into WWE values as each category involved different product forms. Relevant conversion factors were derived from FAO (2017) which are presented in Table S1. As for the SFM data, import fish prices are derived from the ratio of the total product value and the total product WWE volume for each product category.

From Table 1, an extensive amount of fish has been imported to NSW, particularly aquaculture products (e.g. tilapia, basa) and other frozen fish (e.g. squids, octopus). Imported other fresh fish (e.g. tunas, swordfish) had a relatively high average price of $6.79/kg WWE, similar as to tiger flathead, orange roughy and bigeye ocean perch which are traded at the SFM. The average price of imported salmon (mostly from New Zealand and Norway) was $8.52/kg WWE, only domestically produced John dory and blue-eye trevalla traded in the SFM had a higher average price.

The standard deviations for the derived prices in Table 1 indicate that prices for imported fish were relatively close to the mean which implies limited price fluctuations over time, except for imported salmon. For prices of species traded at the SFM, dispersions from the mean price appear to be slightly higher over time, particularly for silver trevally, blue-eye trevalla and royal red prawn (Table 1).

The nominal price data were logged for the cointegration analysis. The relationship between imported seafood and seafood traded at the SFM was analysed using the shorter data set for the SFM species which overlapped with the time series for fish imports ($n = 93$).

2.2 Methods

To explore the relationship between prices for seafood traded at the SFM and their association with prices of imported fish, 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; Hoshino et al., 2015; Nielsen, 2005; Nielsen et al., 2007, 2009, 2012; Norman-López & Asche, 2008; Norman-López et al., 2014; Schrobback et al., 2014).

Prior to conducting the Johansen tests, the augmented Dickey–Filler (ADF) test (Dickey, 1981; Fuller & Dickey, 1979; Said & Dickey, 1984) was undertaken to ensure that the non-stationary preconditions of the price time series in their level were fulfilled.

The multivariate Johansen test (e.g. using three or more variables) can provide information about the number of cointegration vectors within a group of variables yet it cannot identify which specific variables within the group are cointegrated (Johansen & Juselius, 1990). Alternatively, the bivariate Johansen test assesses the relationship between two variables and can therefore offer more detailed information about the market dynamics in the context of this study compared to a multivariate analysis approach (Asche et al., 2005). Furthermore, the bivariate test method contains all structural information and avoids dimensionality issues (Asche et al., 2005).

The bivariate Johansen test, where the number of tested variables (k) equals two (k = 2), is based on a vector autoregressive (VAR) system of the variables and can be expressed as following:

$$y_t = \beta_0 + \beta_1 y_{t-n} + u_t \tag{1}$$

with y as a $(k \times 1)$ price vector, and u_t for the error term vector which is assumed to be normally distributed with a mean of zero (Johansen & Juselius, 1990). β_0 is the coefficient for the constant, and β_1 identifies the coefficient vector of long-run linear combinations for the price variables. Other deterministic terms are excluded for simplicity. The number of observations for the vector autoregressive process is represented by t with $t = 1, \ldots, T$, and n denotes the number of selected lags, with $n < T$. The lag order n of the VAR (n) was selected using the Schwartz information criterion (SIC) (Schwarz, 1978) with preference as this criterion typically returns the smallest lag length within a range of available selection criteria (e.g. Akaike information criterion (AIC), Hannan–Quinn information criterion (HQIC)) (Akaike, 1974; Hannan & Quinn, 1979; Koehler & Murphree, 1988).
In a matrix form, equation 1 can be presented as:

$$\begin{pmatrix} y_{1t} \\ y_{2t} \end{pmatrix} = \begin{pmatrix} \beta_{10} \\ \beta_{20} \end{pmatrix} + \begin{pmatrix} \beta_{11} & \alpha_{11} \\ \alpha_{21} & \beta_{21} \end{pmatrix} \begin{pmatrix} y_{1t-n} \\ y_{2t-n} \end{pmatrix} + \begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix} \tag{2}$$

with β and α representing long-run coefficient in the cointegrating vectors and adjustment weights, respectively (Johansen & Juselius, 1990). The vector error correction representation of (1) and (2) is as follows:

$$\begin{pmatrix} y_{1t} - y_{1t-n} \\ y_{2t} - y_{2t-n} \end{pmatrix} = \begin{pmatrix} \beta_{10} \\ \beta_{20} \end{pmatrix} + \begin{pmatrix} \beta_{11} - 1 & \alpha_{11} \\ \alpha_{21} & \beta_{21} - 1 \end{pmatrix} \begin{pmatrix} y_{1t-n} \\ y_{2t-n} \end{pmatrix} + \begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix} \tag{3}$$

which can be transformed into:

$$\begin{pmatrix} \Delta y_{1t} \\ \Delta y_{2t} \end{pmatrix} = \begin{pmatrix} \beta_{10} \\ \beta_{20} \end{pmatrix} + \begin{pmatrix} \pi_{11} & \pi_{12} \\ \pi_{21} & \pi_{22} \end{pmatrix} \begin{pmatrix} y_{1t-n} \\ y_{2t-n} \end{pmatrix} + \begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix} \tag{4}$$

with $\pi_{11} = \beta_{11} - 1$, $\pi_{12} = \alpha_{11}$, $\pi_{21} = \alpha_{21}$, $\pi_{22} = \beta_{21} - 1$. In reduced notation that is

$$\Delta Y_t = \beta_0 + \Pi Y_{t-1} + u_t \qquad (5)$$

where $\Pi = \alpha\beta'$ denotes the matrix for the long-run relationship among the variables. To test the existence of a long-run cointegration relationship between the non-stationary variables y_1 and y_2, the rank (r) for the matrix Π (equation 5) is to be tested. The rank of a matrix is the number of linear independent rows and columns.

Johansen and Juselius (1990) describe possible scenarios and interpretations for rank results. For example, in a bivariate system the maximum rank of matrix Π is two ($r = 2$), meaning that the matrix contains two cointegrating vectors. However, this result ($r = 2$) describes a 'full rank' and occurs if $y_{1\,t}$ and $y_{2\,t}$ are stationary in their levels where both series fail to comply with the precondition (i.e. unit-root test) of the Johnsen test. Hence, any linear combinations of stationary variables are also stationary and are not cointegrated. If $y_{1\,t}$ and $y_{2\,t}$ are both non-stationary in their levels and a linear combination of the variables exists which is stationary the rank of Π is one ($r = 1$). In this case, $y_{1\,t}$ and $y_{2\,t}$ are cointegrated and follow a long-run relationship. The rank of Π is zero if $y_{1\,t}$ and $y_{2\,t}$ are both non-stationary in their levels and no stationary linear combination of the variables exists ($r = 0$) (Johansen & Juselius, 1990). Both variables are not cointegrated implying that they do not follow a long-run relationship.

The rank of matrix Π can be assessed using either the maximum eigenvalue statistic or trace test statistic. 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 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 is that the rank equals zero (H0: $r = 0$). In case the null hypothesis cannot be rejected, 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. Where the null hypothesis (H0: $r = 0$) is rejected, the test procedure continues by assessing the test statistics result for at most one cointegrating rank ($r \leq 1$). If the null hypothesis (H0: $r \leq 1$) cannot be rejected, 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. However, if the null hypothesis (H0: $r \leq 1$) is rejected, it implies a full rank result meaning no cointegration, and the series are stationary in level failing the precondition for the Johansen test.

Since the Johansen test is sensitive to the selected optimal lag length (n) and deterministic assumptions (e.g. constant, trend or none), various combinations were tested to determine the relationship between price variables.

Price pairs that were found to be cointegrated (i.e. rank of $\Pi = \alpha\beta'$ equals 1) were tested for the LOP (Asche et al., 1999). This test was used to determine the strength of the relationship between the two cointegrated prices (e.g.

substitutes or not) (e.g. Asche et al., 1999, 2004). To perform the LOP test the restriction, $\beta' = (1, -1)$ was imposed on the matrix Π (equation 5). The null hypothesis for the LOP is that the cointegrated price pairs are substitutes. A rejection of the null hypothesis suggests that the price pairs are likely not cointegrated to a degree that the fish products can be considered as close substitutes from a market perspective. Studies that have previously tested the LOP 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).

3. Results

The ADF unit-root test for each logged nominal series of the sample which includes only data from the SFM ($n = 172$ per species) and the sample which includes imported fish data and SFM data ($n = 93$ per species) was performed in levels and first differences for various deterministic assumptions. All time series were found to be non-stationary in levels but were stationary in first differences assuming neither a trend nor a constant or only a constant as deterministic characteristic (Table S2 and Table S3 in the supplementary file). However, when a trend was included, most series were stationary and did not meet the precondition for the Johansen test. Having stationary variables in the system is theoretically not an issue since the Johansen test has the ability to reveal whether the price series are stationary when the result suggests a full cointegration rank (Hjalmarsson & Österholm, 2010; Johansen, 1995). Therefore, we proceeded with the Johansen test, assuming that the non-stationary characteristic of the price series fulfilled the precondition for the analysis.

A bivariate Johansen test was conducted for 171 price pairs ($\sum_{n=1}^{N}(n-1)$, with $N = 19$) of fish species traded at the SFM using data for the period June 2015 to October 2019 (172 observations per species). A summary of the trace test results is shown in Figure 2, Figure 3 and Table 2, where each line connecting two boxes (species) in both figures signify a cointegration relationship as listed in Table 2. The results indicate that there are only a few species (19 out of 171 price pairs) within the SFM for which prices were found to be cointegrated (see Figure 2, Table 2). This suggests that prices of most seafood species move independently within the market and do not affect each other. Yet, one price series that stood out was blue-eye trevalla, which was found to be cointegrated with eight other species within the SFM and hence appears to be the seafood product that mostly influences prices of other species in this market. The LOP was identified to hold for four of the eight 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, a priori, may be considered as relative substitutes, for example, gummy shark, common saw shark and school shark, were found to have no long-run cointegration relationship of their prices.

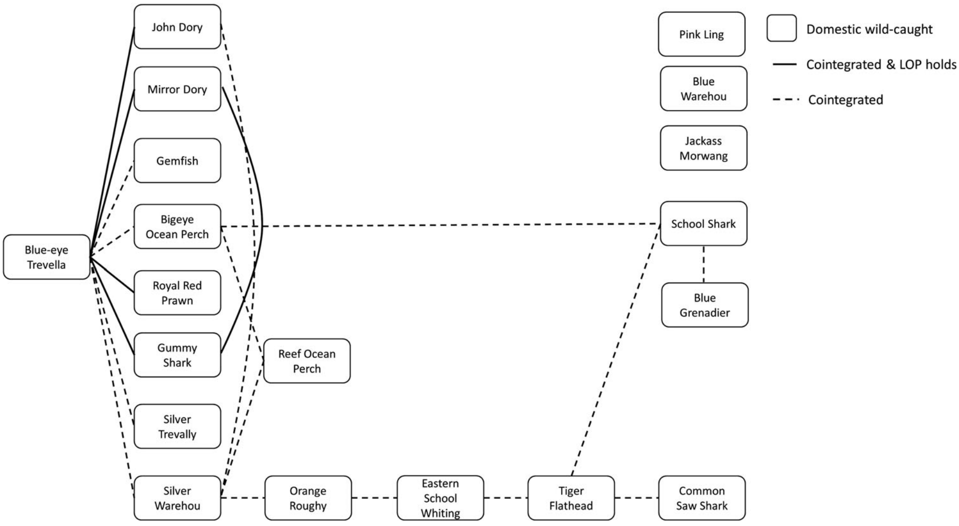

Figure 2 Co-integration relationships for domestic wild-caught fish at the SFM. Notes: A line (dashed or full) between two boxes (species) signifies a cointegrating relationship among two fish species. Detailed results for cointegrated price pairs are presented in Table 2. Source: Derived from authors' analysis (Table 2)

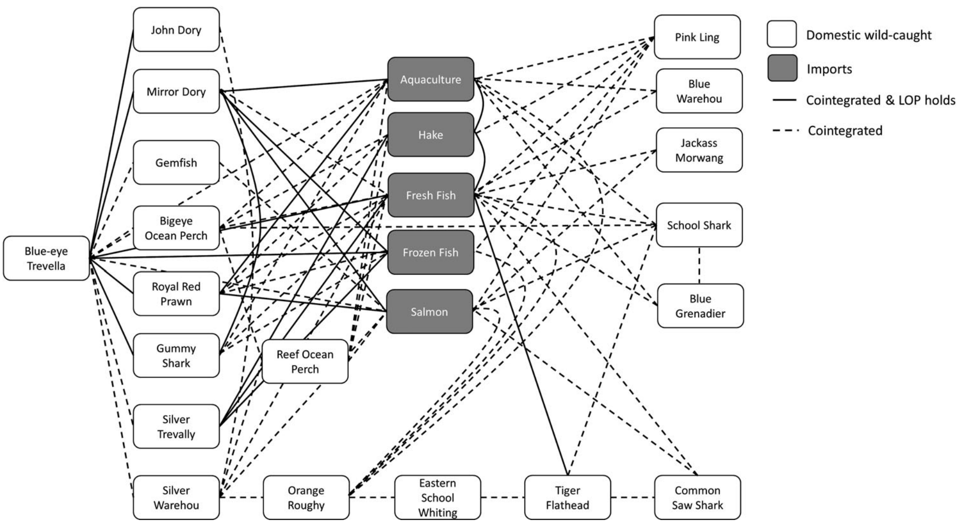

Figure 3 Co-integration relationships for domestic wild-caught and imported fish. Notes: A line (dashed or full) between two boxes (species) signifies a cointegrating relationship among two fish species. Detailed results for cointegrated price pairs are presented in Table 2. Source: Derived from authors' analysis (Table 2)

The Johansen test was also used to assess the price relationship between seafood species traded at the SFM and imported seafood in Australia for using data for the period January 2012 to October 2019 (93 observations per species). The results in Figure 3 and Table 2 suggest that there are a very high

Table 2 Significant trace test results

Variables	Assumption	Criterion	Lags	Null Hypotheses		LOP		Breusch–Godfrey (LM) test	
				Rank (r) = 0	Rank (r) ≤ 1	Chi-squared	Substitutes	Chi-squared	Serial correlation
Results for cointegration relationships between domestically produced species traded at the SFM (n = 172) (see Figure 2)									
John Dory & Blue-eye Trevalla	None	SIC	3	25.60***	5.69	0.90	Yes	60.62	No
John Dory & Silver Warehou	Constant	AIC	6	33.58***	6.29	20.99***	No	48.99	No
Mirror Dory & Gummy Shark	None	HQIC	6	28.64***	4.55	1.49	Yes	52.23	No
Mirror Dory & Blue-eye Trevalla	None	HQIC	5	40.79***	1.95	0.03	Yes	37.29	No
Tiger Flathead & Common Saw Shark	None	HQIC	5	25.46***	1.16	20.25***	No	58.21	No
Tiger Flathead & School Shark	None	AIC	5	51.31***	3.22	27.71***	No	45.01	No
Tiger Flathead & Eastern School Whiting	None	HQIC	5	28.61***	3.26	0.06	Yes	53.03	No
Gemfish & Blue-eye Trevalla	None	SIC	3	53.91***	4.08	93.81**	No	45.64	No
Blue Grenadier & School Shark	None	HQIC	6	37.70***	4.65	27.99***	No	48.48	No
Orange Roughy & Silver Warehou	Constant	AIC	8	25.74***	1.60	22.5***	No	37.44	No
Orange Roughy & Eastern School Whiting	None	AIC	6	31.57***	7.85	3.11*	No	45.13	No
Bigeye Ocean Perch & Reef Ocean Perch	None	AIC	12	24.37***	6.09	1.22	Yes	22.65	No
Bigeye Ocean Perch & Gummy Shark	None	HQIC	6	41.99***	4.77	16.75***	No	40.75	No
Bigeye Ocean Perch & School Shark	None	AIC	12	29.08***	6.13	4.52**	No	22.93	No
Bigeye Ocean Perch & Blue-eye Trevalla	None	HQIC	5	38.51***	2.80	8.75***	No	52.72	No
Royal Red Prawn & Blue-eye Trevalla	None	SIC	3	23.70***	5.74	0.13	Yes	52.82	No
Gummy Shark & Blue-eye Trevalla	None	SIC	3	41.17***	5.75	0.13	Yes	26.45	No
Blue-eye Trevally & Silver Trevally	Constant	HQIC	5	56.54***	3.66	4.85**	No	55.09	No
Blue-eye Trevally & Silver Warehou	None	AIC	9	20.79***	0.36	19.7***	No	30.75	No
Results for cointegration relationships between domestically produced species traded at the SFM and imported fish (n = 93) (see Figure 3)									
Mirror Dory & Imported Aquaculture	None	SIC	2	25.92***	2.98	0.38	Yes	40.66	No
Mirror Dory & Imported Other Fresh Fish	None	SIC	2	30.44***	2.50	3.00*	No	60.65	No

Table 2 (*Continued*)

Variables	Assumption	Criterion	Lags	Null Hypotheses		LOP		Breusch–Godfrey (LM) test	
				Rank (r) = 0	Rank (r) ≤ 1	Chi-squared	Substitutes	Chi-squared	Serial correlation
Mirror Dory & Imported Other Frozen Fish	None	SIC	2	32.48***	6.72	1.15	Yes	67.40	No
Mirror Dory & Imported Salmon	None	SIC	2	34.73***	6.13	0.18	Yes	61.33	No
Tiger Flathead & Imported Other Fresh Fish	None	SIC	2	23.86***	1.89	0.82	Yes	58.71	No
Gemfish & Imported Salmon	None	SIC	2	30.57***	5.81	15.37***	No	68.03	No
Blue Grenadier & Imported Aquaculture	None	SIC	2	34.64***	3.11	10.52***	No	71.16	No
Blue Grenadier & Imported Other Fresh Fish	None	SIC	2	35.15***	3.57	3.31*	No	48.23	No
Pink Ling & Imported Aquaculture	Constant	AIC	8	47.75***	1.58	43.11***	No	44.24	No
Pink Ling & Imported Hake	Constant	AIC	8	48.45***	2.86	40.24***	No	29.33	No
Pink Ling & Imported Other Fresh Fish	Constant	AIC	10	26.17***	2.52	21.04***	No	28.71	No
Pink Ling & Imported Other Frozen Fish	Constant	AIC	8	50.03***	4.17	36.03***	No	40.58	No
Pink Ling & Imported Salmon	Constant	AIC	8	53.43***	5.16	42.61***	No	27.60	No
Jackass Morwong & Imported Other Fresh Fish	Constant	AIC	8	42.04***	1.48	32.59***	No	33.37	No
Jackass Morwong & Imported Salmon	None	AIC	3	33.31***	3.94	16.53***	No	59.61	No
Orange Roughy & Imported Aquaculture	None	SIC	3	32.59***	2.8	15.6***	No	54.41	No
Orange Roughy & Imported Other Fresh Fish	None	SIC	2	68.28***	3.22	9.71***	No	45.76	No
Orange Roughy & Imported Other Frozen Fish	None	SIC	3	39.30***	6.47	7.16**	No	62.26	No
Orange Roughy & Imported Salmon	None	HQIC	3	35.65***	4.08	16.09***	No	53.67	No
Bigeye Ocean Perch & Imported Aquaculture	Constant	AIC	9	28.95***	2.77	23.11***	No	23.05	No
Bigeye Ocean Perch & Imported Hake	Constant	AIC	8	40.80***	2.42	34.21***	No	28.74	No
Bigeye Ocean Perch & Imported Other Fresh Fish	None	SIC	2	31.00***	3.32	11.16***	No	69.41	No
Reef Ocean Perch & Imported Aquaculture	None	SIC	2	26.37***	3.07	9.23***	No	68.87	No

Table 2 (*Continued*)

Variables	Assumption	Criterion	Lags	Null Hypotheses		LOP		Breusch–Godfrey (LM) test	
				Rank (r) = 0	Rank (r) ≤ 1	Chi-squared	Substitutes	Chi-squared	Serial correlation
Reef Ocean Perch & Imported Hake	Constant	AIC	3	26.22***	7.32	9.76***	No	52.79	No
Reef Ocean Perch & Imported Other Fresh Fish	None	SIC	2	26.07***	3.32	3.37*	No	69.79	No
Reef Ocean Perch & Imported Salmon	Constant	SIC	2	30.59***	7.43	5.61***	No	57.83	No
Royal Red Prawn & Imported Aquaculture	None	SIC	2	35.60***	2.67	0.71	Yes	59.81	No
Royal Red Prawn & Imported Hake	None	HQIC	4	25.71***	2.72	34.20**	No	33.21	No
Royal Red Prawn & Imported Other Fresh Fish	None	SIC	2	35.60***	1.88	7.94***	No	50.13	No
Royal Red Prawn & Imported Other Frozen Fish	None	SIC	2	32.52***	5.46	2.71*	No	46.24	No
Royal Red Prawn & Imported Salmon	None	SIC	2	34.22***	5.63	0.60	Yes	58.30	No
Gummy Shark & Imported Aquaculture	None	SIC	2	38.05***	3.08	24.86***	No	63.87	No
Gummy Shark & Imported Other Fresh Fish	None	SIC	2	36.71***	2.9	9.77***	No	65.31	No
Gummy Shark & Imported Other Frozen Fish	None	SIC	3	26.45***	5.82	5.15**	No	58.16	No
Common Saw Shark & Imported Other Fresh Fish	None	SIC	2	24.09***	2.98	10.22***	No	65.02	No
Common Saw Shark & Imported Salmon	Constant	SIC	2	31.35***	7.63	13.22***	No	56.29	No
School Shark & Imported Aquaculture	None	SIC	2	54.24***	3.34	19.85***	No	65.80	No
School Shark & Imported Other Fresh Fish	None	SIC	2	46.90***	3.1	5.09**	No	46.91	No
School Shark & Imported Salmon	Constant	SIC	2	51.36***	7.32	14.55***	No	44.89	No
Blue-eye Trevalla & Imported Aquaculture	Constant	AIC	11	31.53***	4.45	16.72***	No	22.65	No
Blue-eye Trevalla & Imported Other Fresh Fish	Constant	SIC	2	34.48***	2.56	0.03	Yes	55.12	No
Blue-eye Trevalla & Imported Other Frozen Fish	None	AIC	3	25.40***	4.31	0.08	Yes	48.94	No
Blue-eye Trevalla & Imported Salmon	None	SIC	2	35.60***	6.38	5.33**	No	59.60	No

Table 2 (*Continued*)

Variables	Assumption	Criterion	Lags	Null Hypotheses		LOP		Breusch–Godfrey (LM) test	
				Rank (r) = 0	Rank (r) ≤ 1	Chi-squared	Substitutes	Chi-squared	Serial correlation
Silver Trevally & Imported Hake	Constant	AIC	8	39.04***	2.56	0.08	Yes	32.26	No
Silver Trevally & Imported Other Fresh Fish	None	AIC	6	63.22***	0.09	3.03*	No	33.28	No
Silver Trevally & Imported Other Frozen Fish	None	SIC	3	36.67***	6.18	0.52	Yes	66.45	No
Blue Warehou & Imported Aquaculture	None	SIC	2	28.94***	3.17	8.8***	No	66.15	No
Blue Warehou & Imported Other Fresh Fish	None	SIC	2	30.52***	3.37	5.45**	No	56.13	No
Silver Warehou & Imported Other Fresh Fish	None	SIC	2	24.64***	3.35	7.21**	No	61.19	No
Silver Warehou & Imported Salmon	None	HQIC	3	27.02***	4.01	13.35***	No	62.09	No
Imported Aquaculture & Imported Hake	None	HQIC	3	27.58***	1.69	1.68	Yes	57.62	No
Imported Hake & Imported Other Fresh Fish	None	SIC	2	34.56***	3.13	0.85	Yes	51.58	No

Notes: The lag selection criterion that returned the smallest lag order was selected. *** Indicates significance at 1% level, ** indicates significance at 5% level, * indicates significance at 10% level. 'LM' test for Lagrange multiplier.

number of cointegrated price pairs between seafood traded at the SFM and imported seafood.

While some of the SFM 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 with all imported seafood categories (e.g. pink ling, royal red prawn).

From the analysis of prices for species traded at the SFM, 18 price pairs were found to have a full rank and the same was identified for 14 pairs when comparing the price relationship between SFM species and imported fish. We concluded no cointegration of these pairs as they did not meet the prerequisite for the Johansen tests. However, for completeness we have explored those pairs with full rank using an alternative cointegration approach (i.e. autoregressive distributed lag (ARDL) bounds tests) which does not rely on the unit-root assumption (Pesaran et al., 2001), but a cointegration relationship was not found and therefore results are not reported here.

4. Discussion

The findings for the analysis of seafood traded within the SFM indicate that prices of most species develop independently of the prices of other species (Figure 2). 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, with the second highest mean price (A$10.00/kg WWE) over the period under review across all seafood species in the sample (see Table 1), it can be concluded that this species may be the market leader with respect to prices within the SFM.

The very small number (six out of 171 pairs) of seafood products for which the LOP could be identified to hold further suggests that most products traded within the SFM are not considered as identical goods. Therefore, it can be concluded that attributes other than arbitrage likely determine prices within the SFM.

The results also suggest that there is a high degree of price cointegration between seafood traded at the SFM and seafood imports (Figure 2, Table 2). This implies that prices within the SFM are likely more affected by external price dynamics (e.g. imports) than price dynamics within Australia's domestic wholesale fish 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 product groups. This suggests that the price dynamics within the international seafood market likely affect prices for fish products that are produced and consumed in Australia. However, as the LOP 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 that investigated the impact of import prices on the prices of domestically produced seafood reported similar findings (e.g. Asche et al., 2012; Norman-López & Asche, 2008).

Domestically caught royal red prawns were found to be cointegrated with all imported fish products, and even to be a substitute to imported aquaculture species (e.g. basa) and imported salmon (Figure 3, Table 2). The finding contradicts results presented by Schrobback et al. (2019) who concluded that imported prawns were not cointegrated with Australian wild-caught prawns. An explanation for this finding could be that Schrobback et al. (2019) 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. (2019) 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 (as are other prawn species) (AFMA, 2021). In this regard, they are more closely related to fish such as imported basa. Hence, differences in findings between the present study and Schrobback et al. (2019) may not be surprising.

While it is apparent that seafood imports negatively impact prices of domestic fish producers, they may have positively impacted 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 seafood import for Australia (Nielsen et al., 2007).

The potential for better product labelling, both sustainability labelling and provenance labelling (e.g. not only country of origin labelling), has been considered as an option to improve consumer demand for the domestic wild-caught product. For example, seafood sold at food services (e.g. restaurants, pubs) currently remains exempt from labelling in Australia, 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 & 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 fish producers' social licence, which will have longer term implications for domestically caught fish on the market.

A possible shortcoming of this study is the aggregation of the import data into composite goods (e.g. imported aquaculture, imported other fresh fish). More disaggregated goods (e.g. individual imported species) may have provided different results, but the large number of import categories—many of which were already aggregated to differing degrees—made such an analysis infeasible.

Furthermore, the analysis in this study only focusses on species that are traded at the SFM as proxies for entire domestic Australian seafood market. Australia produces a range of other wild-catch (e.g. banana prawn, tuna, barramundi) and aquaculture species (e.g. salmon) (ABARES, 2020) which were not included in this study due to the lack of access to commercially confidential wholesale data from other fish markets. It is possible that the price relationships between other domestic seafood species and imports are different than found in this study.

The use of conversion factors for deriving whole-weight equivalents as a common unit on which basis values were transferred into unit prices could be another source of bias which could affect the robustness of the study findings. Conversion factors were used to adjust the weight of the product, 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.

5. Implications and Conclusions

The aim of this study was to examine the relationship between prices of seafood produced in Australia and imported seafood.

Using data from the SFM as a proxy for the domestic seafood market in Australia, the findings suggest that prices of domestic fish products mostly develop independently of each other. However, the results also show that prices of a large proportion of domestically produced fish and fish imports hold a long-run relationship. Hence, there is evidence that imported seafood is considered as partial or close substitutes to the fish species caught domestically. This finding implies that prices of imported fish affect the price determination process of domestically produced fish at wholesale level. While this may benefit consumers in terms of lower product prices, domestic seafood producers likely experience a decrease in the prices that they receive for their product, which in turn may adversely affect the profitability of their business, confirming their concerns about the impact of imports on domestic seafood prices.

Considering the perspective of Australian seafood consumers and domestic producers, policy interventions such as improved product labelling requirements, specifically for seafood sold within the food service sector, coupled with better promotion of domestically produced seafood and consumer education could contribute to an increasing demand for locally produced seafood and consumer's willingness to pay a price premium for such products compared to imported fish. These interventions could assist in ensuring profitability of domestic seafood producing industries and subsequently economic growth in coastal regions of Australia.

A potential extension of the price cointegration analysis presented in this study may consider conducting an ARDL bounds test for all price pairs. This test could provide additional detail about the direction of the price relationships for each price pair. To gain even further insight about how increased quantities of imported fish affect domestic fish prices, a demand analysis which assesses the cross-price flexibilities between domestic seafood and imported seafood may be undertaken. The study highlights the importance of access to disaggregated time series data for an analysis that can provide information about seafood market dynamics as a basis for policy review and possible interventions.

Data Availability Statement

Data used in this study cannot be shared with any third party due to a confidentiality agreement between the author's institutions and the data owner, the Sydney Fish Market (SFM). Data requests should be addressed to the SFM.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Conversion factors used for import data and number of applications of these factors to import categories.

Table S2. Results for ADF unit root test for logged nominal price data of seafood traded at the Sydney Fish Market ($n = 172$).

Table S3. Results for ADF unit root test for logged nominal price data of seafood traded at the Sydney Fish Market and seafood imports to NSW ($n = 93$).