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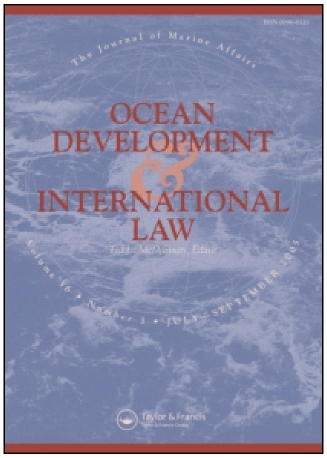

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## Is There a Global Market for Tuna? Policy Implications for Tropical Tuna Fisheries

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# Is There a Global Market for Tuna? Policy Implications for Tropical Tuna Fisheries

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*Regional ex-vessel markets for cannery-grade skipjack tuna throughout the globe are spatially integrated by price, but such markets for yellowfin tuna are spatially independent. The Americas exert primary price leadership in ex-vessel skipjack markets, but Bangkok and American Samoa also exert price leadership, and Ivory Coast, Japan, and Spain are largely price followers. Regional ex-vessel markets for skipjack and yellowfin are not integrated by prices. While price effects of this nature are simply evidence of a pecuniary externality, and thereby do not necessarily affect the overall size of global net benefits, in practice such price effects affect distribution among players—who wins and who loses—and in this manner, the eventual formation of, and compliance with, different management policies.*

**Keywords** global tuna markets, management of tuna fisheries, price linkages

## Introduction

The time is ripe for a major advance in the conservation and management of tropical and temperate tuna.[1] Much of the discussion centers on the need to limit fishing mortality as a consequence of stock assessments indicating that overfishing is occurring on bigeye and yellowfin stocks with yields approaching or beyond maximum sustainable yield for several

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The results presented in this article are not necessarily those of the National Marine Fisheries Service or the Forum Fisheries Agency. All errors remain the responsibility of the authors.

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yellowfin stocks. Discussion is also heightening over the control of fishing capacity, given the recent assessment of overcapacity in the purse seine and longline tuna fisheries of the world (Miyake 2005; Reid et al. 2003, 2005).[2]

Despite the recognition of the highly migratory nature of tuna, the global mobility of the longline and purse seine tuna fishing vessels, and the need for global coordination of management across the Regional Fisheries Management Organizations (RFMOs) areas that deal with tuna,[3] attention has yet to be given to whether or not the different regional tuna ex-vessel markets in Europe, West Africa, the Americas, American Samoa, Thailand, and Japan are global or independent.[4] While it is well known that there is movement of supply among these ex-vessel markets, what is completely unknown is whether or not these regional markets are linked by price, that is, whether or not there are spatial price linkages and market integration, thereby establishing a global market for cannery-grade tuna at the ex-vessel level. What is also unknown, if there is indeed a global market, is the spatial structure of this market in the sense of which is the regional tuna market (or markets) where ex-vessel prices are first formed and how these prices are then transmitted to other regional markets.

The answer to these questions can have important implications for the shape of conservation and management policies. If these regional ex-vessel markets are independent of one another in prices—there is not spatial market integration—then policies can be independently formed by each RFMO without consideration of the economic effects, transmitted by ex-vessel prices, from other RFMOs and vice versa. Economic impacts from policies limiting overall supply of different tuna species or the timing of supply into ex-vessel markets will be confined to the RFMO area through biological limits on catches or days at sea, stock rebuilding, reductions in fishing capacity from vessel buybacks or limited access, or even individual transferable quotas. If, however, these regional ex-vessel markets are spatially integrated by price, then policies formed in one RFMO area can reverberate to other RFMO regions, and perhaps even globally, through spatial market linkages.[5]

There are still further implications of the spatial structure of ex-vessel market integration among the regional tuna markets. Efforts to establish positive economic incentives to limit fishing capacity through revenue-sharing programs based on capacity management that in turn establish a floor for ex-vessel prices and share revenues above this floor will encounter unexpected difficulties if a price follower benchmark price is chosen rather than a price from a market that establishes price leadership (Squires et al. 2006).

The purpose of this article is to evaluate the spatial integration by prices of the world's regional ex-vessel markets for tropical cannery-grade tuna caught by purse seine vessels. Through the application of time series econometrics, what is assessed is the ex-vessel spatial price linkages of the key global markets for cannery-grade tuna—American Samoa (Pago Pago), Europe (Italy, Spain), Ivory Coast (Abidjan), Japan (Tokyo), Latin America (Puerto Rico and Ecuador), and Thailand (Bangkok)—for skipjack and yellowfin tunas. Specifically, what is first considered is the short-run and long-run ex-vessel price linkages in the skipjack tuna markets of Abidjan, Bangkok, Latin America, American Samoa, Spain, and Japan. Then, the ex-vessel yellowfin tuna markets for Thailand, Italy, and Japan are evaluated by testing them for cointegration and causality. Lastly, the analysis shifts to evaluating the ex-vessel market integration between skipjack and yellowfin tuna for Bangkok and Japan.

## Overview on Global Skipjack Tuna Market Data

The global tuna fisheries include four major regions: the Western and Central Pacific Ocean (WCPO) fishery, the Eastern Pacific Ocean (EPO) fishery, the Indian Ocean fishery, and the

Atlantic Ocean fishery. Within these major regions, over 70% of the reported catch in 2000 was taken in the Pacific Ocean while 17% came from the Indian Ocean (van Santen and Muller 2000). These fisheries are exploited by both coastal states and distant water fishing nations. For example, fleets from the United States, Japan, Korea, Taiwan, the Philippines, Papua New Guinea, the Solomon Islands, and the Federated States of Micronesia, among others, fish within the WCPO fishery. The catch is often transported by a fishing vessel or shipped to a given market after at-sea transshipment to a carrier vessel, such as to Bangkok, for example, for processing into canned tuna. Associated with these four major fishing regions and corresponding to tuna RFMOs are the six major processing markets: Japan, Bangkok (Thailand), Latin America, American Samoa of the Pacific Ocean region, and Abidjan and Spain of the Atlantic Ocean region, where product from the Indian Ocean flows to the Atlantic Ocean region and to a lesser extent to Bangkok.

For skipjack tuna, this analysis will evaluate both short-term and longer-term spatial price linkages and elucidate the grid-line relationships among these markets by determining which markets provide price leadership, or whether prices are established simultaneously between different market centers. The relationship between skipjack and yellowfin tuna prices is examined for Bangkok, Italy, and Japan.

Comparable prices among different locations and different species can be justified by a standardized quotation method. The fish are usually graded by size with a premium attached to larger fish due to the associated higher yield and lower labor costs per ton of fish processed. The prices quoted in the respective markets, which are the main data source of this research, are for benchmark-size fish except in the case of the Japanese market where the prices are weighted averages across all fish sold. In particular, these prices (at compatible delivery terms in U.S. dollar per metric ton) are for skipjack weighing 4 to 7.5 pounds. The skipjack and yellowfin price data were provided by the Forum Fisheries Agency (FFA)[6] and are left in nominal rather than real (inflation-adjusted) prices because the tuna industry, FFA nations, and other interested parties refer to nominal prices in their negotiations.

The data for the spatial price linkage analysis on skipjack are available for different time periods as shown in Table 1. In general, monthly data for all six locations are available from 1995 to 2001, while data are available for only four locations (excluding Japan and Spain) from 1989 to 2001, enabling a longer-term analysis. A general statistical overview of these markets does not clearly suggest the order of the players in the global skipjack market. Bangkok (Thailand), American Samoa, the Americas, and Spain have similar median, maximum, and minimum prices, while Japan consistently has higher prices, and

**Table 1**

Summary ex-vessel skipjack tuna price statistics for six different locations

| Market | Mean | Median | Max | Min | *SD* | Obs. | Time period |
|---|---|---|---|---|---|---|---|
| Bangkok | 830.51 | 800.0 | 1250 | 380 | 180.47 | 225 | 1/84–9/02 |
| A. Samoa | 800.67 | 822.0 | 1136 | 433 | 175.43 | 156 | 1/89–12/01 |
| Americas | 805.92 | 814.5 | 1160 | 440 | 159.87 | 186 | 1/86–6/02 |
| Abidjan | 695.60 | 700.0 | 1013 | 296 | 154.89 | 171 | 1/88–9/02 |
| Japan | 981.83 | 981.5 | 1551 | 509 | 223.06 | 92 | 1/95–8/02 |
| Spain | 868.46 | 900.0 | 1420 | 340 | 241.33 | 104 | 6/93–9/02 |

Abidjan exhibits lower ones. Is it possible that Japan, the country with the highest prices, can lead the others, and Abidjan, with the lowest prices, can be only a follower? It may not be the case, since the other four major markets do not seem to follow Japan at such a high price level, but rather they are very close to each other, which might imply that the leader belongs to this four-member group.[7] More investigation is needed to identify the price leader in the skipjack market.

Looking separately at each national market, ex-vessel skipjack price fluctuations can be tracked throughout the time periods of interest. (See Figure 1.) One common point among these markets is that there was a dramatic slump in skipjack prices in late 1998, and

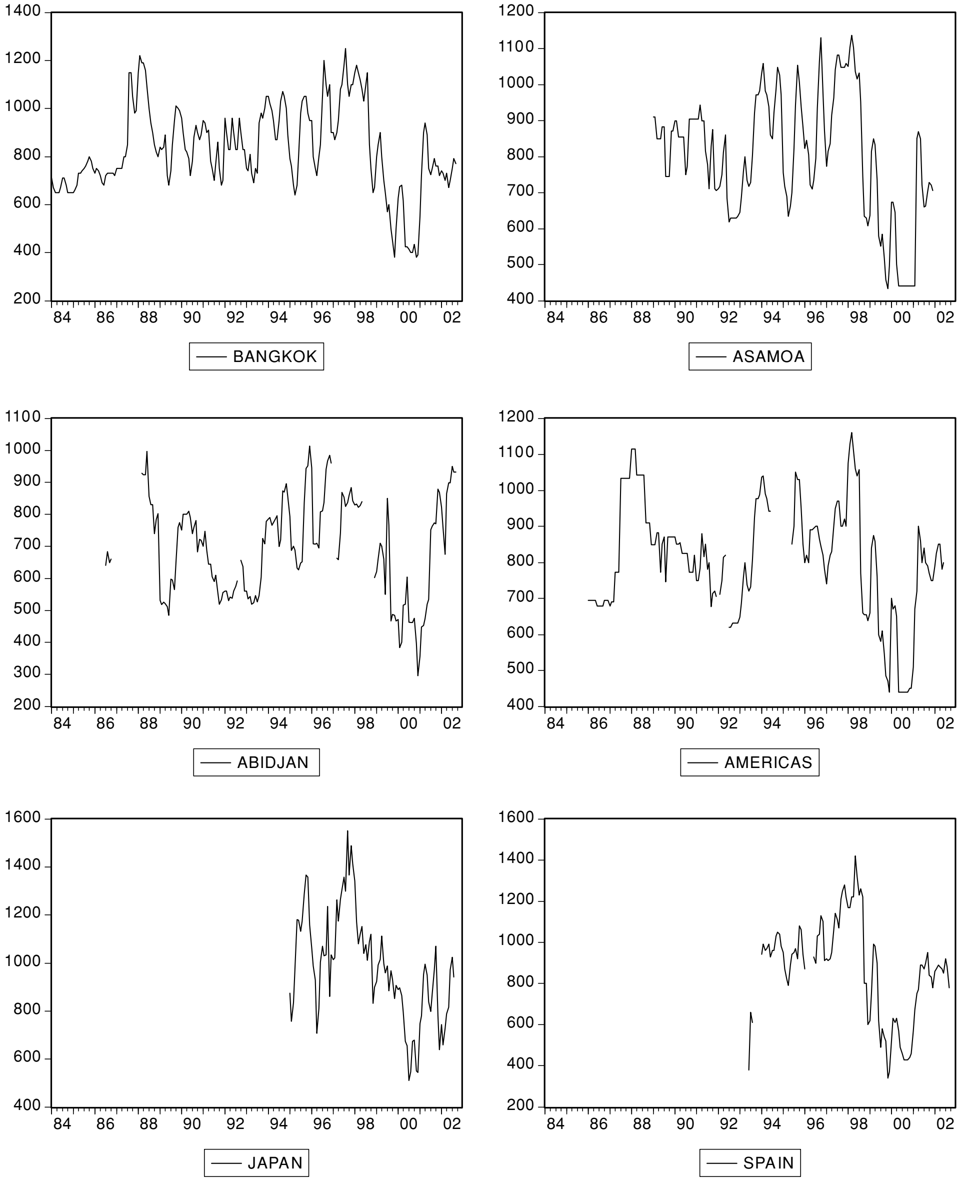

**Figure 1.** Skipjack tuna prices for six locations.

prices were extremely depressed throughout most of 1999 and 2000. This is most likely due to record high catches in the WCPO fishery throughout 1998, followed by additional record high catches in the EPO and Indian Ocean fisheries in 1999 (Reid et al. 2003). These catches appear to have led to an excess of inventories, which required time to work their way through the system. Prices recovered in 2001, but are still at relatively low levels when compared with the prices seen prior to 1998.[8] This systematic risk may cause more complication in investigating the price relationship among markets.

By considering the seasonality of yearly average prices over months in each market, a time-delayed reaction pattern is observed, and the “deepest” time of the market is located. Commercial fishing for skipjack tuna is generally carried out from December to March. The monthly level changes in tuna prices show an obvious rise in January in all markets except Abidjan. (See Table 2.) The Bangkok price slightly decreases from January to March, while prices in American Samoa, the Americas, and Spain continue to rise. Comparing Abidjan and Spain, which both take fish from the Atlantic Ocean, one interesting feature of Abidjan is that if Spain gains significantly through monthly price changes, Abidjan gains little or even witnesses a negative monthly price change, and vice versa. This dramatic opposite reaction in Abidjan is also displayed when it is compared to other markets. Up to this point, Abidjan appears to be the follower because it starts its “deepest” market time at the outset of the “thinnest” market times for the others. The uncertainty regarding which country is the leader, however, is still left unresolved here, but will be answered in the following section.

## Time Series Analysis on Global Tuna Markets

Markets are spatially integrated by prices when the prices in these markets do not behave independently. Price formation between two markets, say a local (peripheral) and a central market, may be simultaneous, disconnected, or extend from the central to the local market. In the short run, a change in the central market price will be passed on to the peripheral market over some relatively short time period, such as months, if these markets are integrated and the local market follows the central market price formation process. In the long run, when previous central market and past spatial price differentials are the primary determinants of local prices (rather than previous local prices), markets are well connected in the sense that supply and demand conditions in the central market are communicated effectively to the local and peripheral market. In the long run, the central market influences local, peripheral market prices irrespective of previous local conditions, even though the two markets may not be connected by commodity flows in the short run. If the central and local markets are segmented by price, then market prices independently form in each market, and each market price depends only on local supply and demand conditions and past values of its own prices.

The analysis that follows examines the co-movement between three different groups: the short-run and long-run effects of prices in the skipjack tuna markets, the ex-vessel yellowfin tuna markets, and the market integration between the skipjack and yellowfin tuna species.

First, the short-run effects of the ex-vessel skipjack case are considered using the Granger noncausality concept (Granger 1969). Due to the lack of data for Japan and Spain in the model, the time spans are divided into two periods, one for 1989–94 (without data for Japan and Spain) and the other for 1995–2001 (with data for Japan and Spain). For the sample period from 1989 to 1994, the markets hardly interacted with each other; only

**Table 2**
Seasonality check for skipjack tuna—yearly average prices over months

| | Bangkok | | A. Samoa | | Americas | | Japan | | Spain | | Abidjan | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Price | Change | Price | Change | Price | Change | Price | Change | Price | Change | Price | Change |
| Jan. | 842.37 | 37.37 | 788.57 | 9.41 | 794.47 | 34.54 | 949.17 | 7.80 | 824.44 | 41.94 | 684.79 | −36.14 |
| Feb. | 840.53 | −1.84 | 814.03 | 25.46 | 809.71 | 15.24 | 907.33 | −41.84 | 857.50 | 33.06 | 648.46 | −36.33 |
| Mar. | 835.26 | −5.27 | 842.28 | 28.25 | 838.81 | 29.10 | 957.86 | 50.53 | 895.00 | 37.50 | 660.67 | 12.21 |
| Apr. | 825.53 | −9.73 | 827.85 | −14.43 | 862.75 | 23.94 | 958.23 | 0.37 | 898.75 | 3.75 | 677.67 | 17.00 |
| May | 798.16 | −27.37 | 809.87 | −17.98 | 819.44 | −43.31 | 979.94 | 21.71 | 948.75 | 50.00 | 683.00 | 5.33 |
| June | 787.11 | −11.05 | 772.88 | −36.99 | 815.88 | −3.56 | 993.71 | 13.77 | 849.00 | −99.75 | 690.50 | 7.50 |
| July | 817.37 | 30.26 | 768.13 | −4.75 | 817.80 | 1.92 | 993.40 | −0.31 | 855.00 | 6.00 | 703.53 | 13.03 |
| Aug. | 882.11 | 64.74 | 782.80 | 14.67 | 805.93 | −11.87 | 969.91 | −23.49 | 869.00 | 14.00 | 704.87 | 1.34 |
| Sept. | 871.05 | −11.06 | 814.19 | 31.39 | 781.80 | −24.13 | 1081.94 | 112.03 | 902.22 | 33.22 | 721.71 | 16.84 |
| Oct. | 844.17 | −26.88 | 816.53 | 2.34 | 781.73 | −0.07 | 1109.19 | 27.25 | 887.50 | −14.72 | 714.57 | −7.14 |
| Nov. | 816.11 | −28.06 | 791.97 | −24.56 | 774.80 | −6.93 | 960.48 | −148.71 | 861.25 | −26.25 | 739.69 | 25.12 |
| Dec. | 805.00 | −11.11 | 779.16 | −12.81 | 759.93 | −14.87 | 941.37 | −19.11 | 782.50 | −78.75 | 720.93 | −18.76 |

**Table 3**

Results from Granger causality tests for skipjack tuna—data from 1989 to 1994

| | Y | | | |
|---|---|---|---|---|
| | Abidjan | Americas | A. Samoa | Bangkok |
| X | | | | |
| Abidjan | | 1.334 | 0.531 | 0.988 |
| | | (0.267) | (0.714) | (0.421) |
| Americas | 1.915 | | 0.478 | 0.292 |
| | (0.119) | | (0.752) | (0.882) |
| A. Samoa | 0.372 | 1.268 | | 1.560 |
| | (0.827) | (0.293) | | (0.197) |
| Bangkok | 2.832 | 0.733 | 3.619 | |
| | (0.032) | (0.573) | (0.011) | |

*Note*. The values are $F$ statistics while the values in parentheses are corresponding $p$-values. The null hypothesis is that $X$ does not Granger-cause $Y$.

Bangkok weakly influenced Abidjan and American Samoa. (See Tables 3 and 4.) In other words, Bangkok was just a modest forerunner in the price change and the markets were basically segregated. The latter time period, however, yields results that are different from the former one.

Bangkok plays a leading role in nearly all of the other markets except for the Americas. (See Tables 5 and 6 and Figure 2.) For the second period from January 1995 to December 2001, the Americas emerge as a new leader, strongly affecting the Bangkok market, although still independent of the Japanese market. American Samoa slightly reacts to the Americas and only signals Abidjan and Spain, which are clearly the followers in the group. Japan operates separately from the other markets, besides a weak linkage with Bangkok. Therefore, in this period, the six markets can be classified into three groups. (See Figure 2.) The first is the leader group, which includes the Americas and Bangkok as the primary leaders, and American Samoa as the secondary leader. The next group, which we can classify as the follower group, includes Abidjan and Spain. The final group contains only the independent agent Japan.

**Table 4**

Interpretation from Granger causality tests for skipjack tuna—1989 to 1994

| | Y | | | |
|---|---|---|---|---|
| | Abidjan | Americas | A. Samoa | Bangkok |
| X | | | | |
| Abidjan | | No | No | No |
| Americas | No | | No | No |
| A. Samoa | No | No | | No |
| Bangkok | Weak | No | Weak | |

**Table 5**
Results from Granger causality tests for skipjack tuna—data from 1995 to 2001

| | *Y* | | | | | |
|---|---|---|---|---|---|---|
| | Abidjan | Americas | A. Samoa | Bangkok | Japan | Spain |
| *X* | | | | | | |
| Abidjan | | 2.366 | 2.655 | 2.307 | 1.267 | 1.458 |
| | | (0.060) | (0.039) | (0.066) | (0.291) | (0.223) |
| Americas | 4.455 | | 3.777 | 3.721 | 1.605 | 8.550 |
| | (0.003) | | (0.007) | (0.008) | (0.183) | (0.000) |
| A. Samoa | 4.119 | 2.693 | | 1.927 | 1.276 | 5.862 |
| | (0.004) | (0.037) | | (0.115) | (0.288) | (0.000) |
| Bangkok | 3.683 | 2.781 | 8.424 | | 5.105 | 7.440 |
| | (0.008) | (0.033) | (0.000) | | (0.001) | (0.000) |
| Japan | 1.605 | 0.999 | 1.497 | 1.859 | | 1.368 |
| | (0.183) | (0.414) | (0.212) | (0.127) | | (0.254) |
| Spain | 3.053 | 0.663 | 0.497 | 1.198 | 2.200 | |
| | (0.022) | (0.620) | (0.738) | (0.319) | (0.078) | |

The results of the period 1995–2001 are quite similar to those of the whole time series of 1989–2001 in that the Americas, Bangkok, and American Samoa lead, while Abidjan is a follower. (See Tables 7 and 8 and Figure 3.) That is, in the full-sample period, the price change in the Americas has led the price changes in both Abidjan and Bangkok completely without any feedback from these markets. The Americas also lead the price in American Samoa while receiving a strong Samoan reaction, indicating a bilateral interaction. In addition, American Samoa is a unilateral follower of Bangkok prices. Therefore, the short-run influence of each market can be ranked in the following order: the Americas are a potential primary leader; American Samoa and Bangkok are the secondary leaders; and Abidjan is consistently a follower.

Next, the focus of the analysis moves to examining the long-run effects using cointegration analysis (Engle and Granger 1987; Granger 1983). The long-run relationship

**Table 6**
Interpretation from Granger causality tests for skipjack tuna—1995 to 2001

| | *Y* | | | | | |
|---|---|---|---|---|---|---|
| | Abidjan | Americas | A. Samoa | Bangkok | Japan | Spain |
| *X* | | | | | | |
| Abidjan | | No | Weak | No | No | No |
| Americas | Strong | | Strong | Strong | No | Strong |
| A. Samoa | Strong | Weak | | No | No | Strong |
| Bangkok | Strong | Weak | Strong | | Strong | Strong |
| Japan | No | No | No | No | | No |
| Spain | Weak | No | No | No | No | |

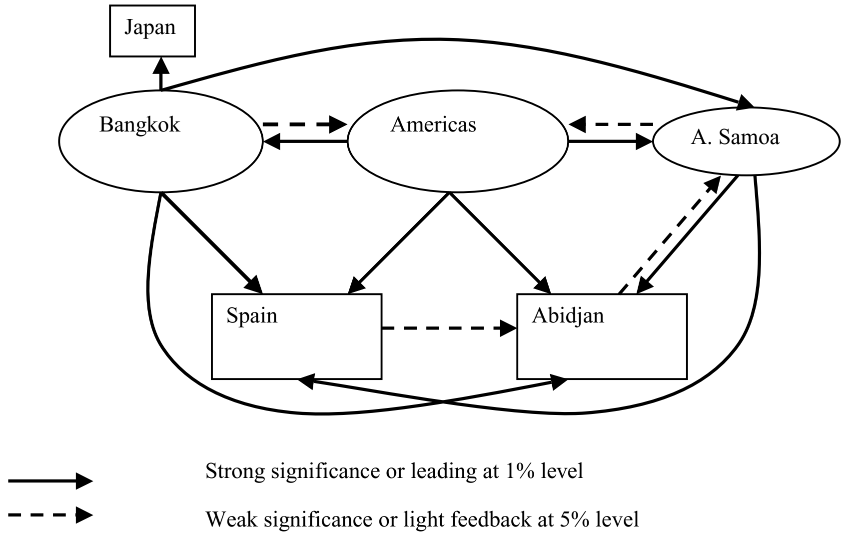

**Figure 2.** Diagrams on skipjack tuna causality (1995/01–2001/12).

among prices of different markets serves as a signpost for the future. That is, the prices in different markets may diverge from one another in the short run, but as long as some cointegration exists among them, they eventually converge to a common trend with stable differences and co-movement in the long run.

In order to examine the long-run relationship of the skipjack prices in different markets, cointegration tests such as trace and max eigen value test statistics are employed (Hamilton 1994). The results indicate that, for the group of six markets (Bangkok, American Samoa, Abidjan, the Americas, Japan, Spain), which is the most comprehensive case with data availability covering the time span 1995–2002, cointegration tests yield one cointegration (CI) at the 5% level of significance. (See Table 9.) These findings indicate the existence of undoubted price co-movements among the six skipjack markets in the long run.

**Table 7**
Results from Granger causality tests for skipjack tuna with full sample period

| | *Y* | | | |
|---|---|---|---|---|
| | Abidjan | Americas | A. Samoa | Bangkok |
| *X* | | | | |
| Abidjan | | 1.463 | 2.442 | 2.596 |
| | | (0.216) | (0.049) | (0.039) |
| Americas | 4.925 | | 4.881 | 3.953 |
| | (0.000) | | (0.001) | (0.004) |
| A. Samoa | 4.527 | 4.473 | | 1.961 |
| | (0.002) | (0.002) | | (0.104) |
| Bangkok | 6.351 | 2.427 | 10.193 | |
| | (0.000) | (0.050) | (0.000) | |

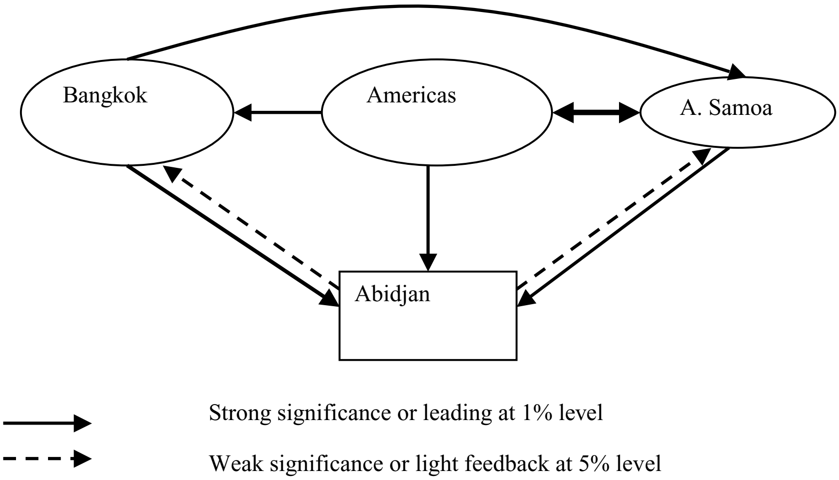

**Figure 3.** Causality for skipjack tuna using the whole sample (1989/01–2001/12).

For the group of four markets (Bangkok, American Samoa, Abidjan, the Americas), two time periods are considered—the first half from 1989 to 1994, and the second from 1995 to 2002—so that the group could be compared with the six-market group whose data is available only during this period. Further, to obtain an overall picture, cointegration tests for the whole time period from 1989 to 2002 are needed.

The cointegration test result for the four markets from 1995 to 2002 is consistent with the result for all six countries. One long-run relationship is confirmed by both trace and max eigen value tests. However, for the first subperiod 1989–94, cointegration tests of trace and max eigen value do not reach any agreement. While the trace test reveals one CI at the 1% significance level, and even two CI at the 5% level, the max eigen value test finds no CI at either level. These conflicting results provide ambiguous conclusions for the cointegrating relations, and the choice depends on subjective interpretation. Therefore, the long-run relationship among the four locations has not been determined, or may not exist. For the entire time period from 1989 to 2002, the trace test shows one CI at the 1% significance level and two CI at the 5% level, while the max eigen value test reveals one CI at both the 1% and 5% levels. Thus, it is concluded that there is one long-term relationship,

**Table 8**

Interpretation from Granger causality tests for skipjack tuna with full sample period

| | *Y* | | | |
|---|---|---|---|---|
| | Abidjan | Americas | A. Samoa | Bangkok |
| *X* | | | | |
| Abidjan | | No | Weak | Weak |
| Americas | Strong | | Strong | Strong |
| A. Samoa | Strong | Strong | | No |
| Bangkok | Strong | No | Strong | |

**Table 9**

Long-run transmission mechanism (cointegration test) for skipjack tuna

| | | Hypothesized | Eigen | Trace test | | Critical value | | Max eigen value test | | Critical value | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Series | Period | no. of CE(s) | Value | Statistic | Decision | 5% | 1% | Statistic | Decision | 5% | 1% | Comment |
| Bangkok | 1995–2002 | None** | 0.45 | 115.26 | | 102.14 | 111.01 | 46.67 | | 40.30 | 46.82 | |
| A. Samoa | | At most 1 | 0.32 | 68.60 | 1 CI at 1% | 76.07 | 84.45 | 30.73 | 0 CI at 1% | 34.40 | 39.79 | 1 CI at 5% |
| Abidjan | | At most 2 | 0.26 | 37.87 | 1 CI at 5% | 53.12 | 60.16 | 23.31 | 1 CI at 5% | 28.14 | 33.24 | |
| Americas | | At most 3 | 0.11 | 14.56 | | 34.91 | 41.07 | 9.05 | | 22.00 | 26.81 | |
| Japan | | At most 4 | 0.05 | 5.50 | | 19.96 | 24.60 | 4.26 | | 15.67 | 20.20 | |
| Spain | | At most 5 | 0.02 | 1.25 | | 9.24 | 12.97 | 1.25 | | 9.24 | 12.97 | |
| Bangkok | 1995–2002 | None** | 0.34 | 63.74 | | 53.12 | 60.16 | 35.06 | | 28.14 | 33.24 | |
| A. Samoa | | At most 1 | 0.21 | 28.67 | 1 CI at 1% | 34.91 | 41.07 | 19.58 | 1 CI at 1% | 22.00 | 26.81 | 1 CI at 5% |
| Abidjan | | At most 2 | 0.08 | 9.09 | 1 CI at 5% | 19.96 | 24.60 | 7.44 | 1 CI at 5% | 15.67 | 20.20 | |
| Americas | | At most 3 | 0.02 | 1.65 | | 9.24 | 12.97 | 1.65 | | 9.24 | 12.97 | |
| Bangkok | 1989–1994 | None** | 0.34 | 62.38 | | 53.12 | 60.16 | 27.44 | | 28.14 | 33.24 | Undetermined |
| A. Samoa | | At most 1* | 0.25 | 34.94 | 1 CI at 1% | 34.91 | 41.07 | 18.83 | 0 CI at 1% | 22.00 | 26.81 | or |
| Abidjan | | At most 2 | 0.18 | 16.10 | 2 CI at 5% | 19.96 | 24.60 | 13.47 | 0 CI at 5% | 15.67 | 20.20 | no long-run |
| Americas | | At most 3 | 0.04 | 2.63 | | 9.24 | 12.97 | 2.63 | | 9.24 | 12.97 | relationship |
| Bangkok | 1989–2002 | None** | 0.25 | 80.62 | | 53.12 | 60.16 | 43.92 | | 28.14 | 33.24 | |
| A. Samoa | | At most 1* | 0.13 | 36.69 | 1 CI at 1% | 34.91 | 41.07 | 21.90 | 1 CI at 1% | 22.00 | 26.81 | |
| Abidjan | | At most 2 | 0.07 | 14.80 | 2 CI at 5% | 19.96 | 24.60 | 10.80 | 1 CI at 5% | 15.67 | 20.20 | 1 or 2 CI |
| Americas | | At most 3 | 0.03 | 4.00 | | 9.24 | 12.97 | 4.00 | | 9.24 | 12.97 | |

*Note*. The linear deterministic trend is assumed with four lags in each regression.

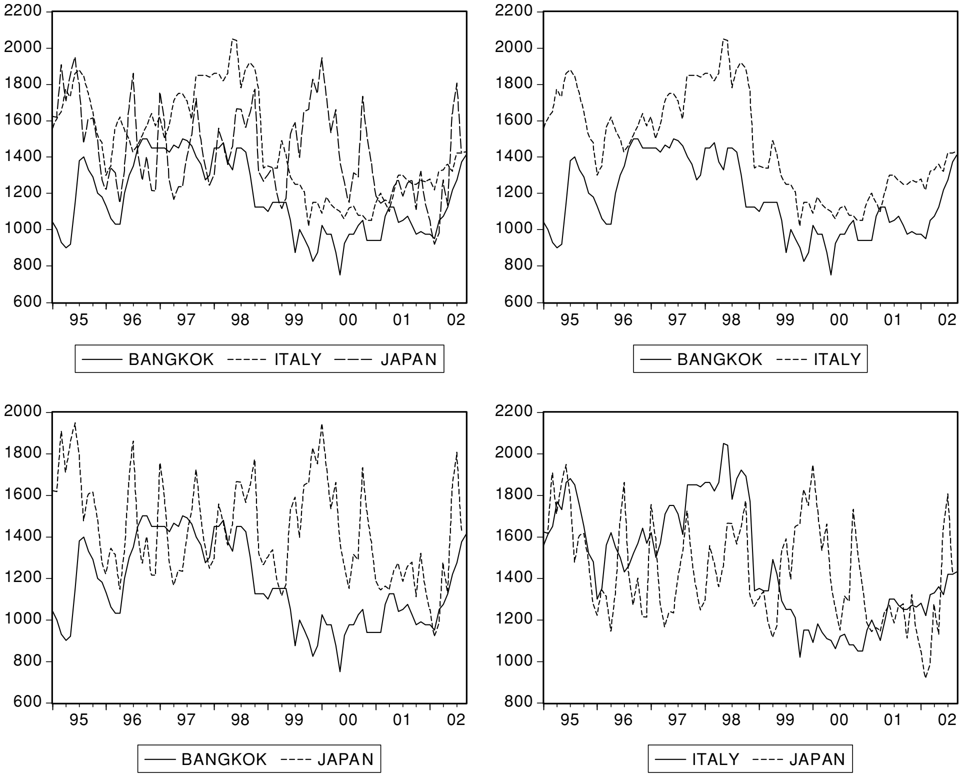

**Figure 4.** Yellowfin tuna markets: Three locations.

although there may be two CI, depending on the undetermined cointegration in the first sub-time period.

In summary, the results of cointegration tests shed more light on long-run interactions among global skipjack tuna markets. Furthermore, the cointegration analysis supports the causality result, which draws interactive grids among players in the market, not only in the short run, but also over the long term.

The focus of analysis now shifts to the yellowfin tuna market. The level series for the yellowfin prices of Bangkok and Italy are nonstationary, while their differences are stationary. (See Table 10.) For the Japanese market, however, both tests of augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) can reject the null hypothesis of nonstationarity, which implies that the Japanese yellowfin price follows only a stationary trend. The ADF test employs four different lag structures, and Akaike Information Criteria (AIC) is considered for lag selections as well. (See Table 10.) The findings on the unit root test are robust for different specifications of ADF and also confirmed by the PP test.

The cointegration test is used only for nonstationary processes and is aimed at examining whether their linear combination can be stationary. Because the Japanese yellowfin price indicates stationarity in Table 10, it is excluded from the cointegration test. At first glance, the prices of Bangkok and Italy seem to move together. (See Figure 4.) When implementing cointegration tests such as trace and max eigen value, however, no long-term relationship between Bangkok and Italy can be detected. (See Table 11.)

**Table 10**
Unit root tests for yellowfin tuna

| | | ADF test statistic | | | | PP test | | |
|---|---|---|---|---|---|---|---|---|
| | Yellowfin | lag 1 | lag 2 | lag 3 | lag 4 | statistic | H0 of I(1) | Comment |
| Bangkok | (a) Level | −2.415 | −2.194 | −2.125 | −1.761* | −2.002 | Cannot reject | Nonstationary |
| | (b) Difference | −6.542 | −5.642* | −5.813 | −4.355 | −7.006 | Reject | Stationary |
| Italy | (a) Level | −1.765 | −1.559 | −1.579 | −1.401* | −1.633 | Cannot reject | Nonstationary |
| | (b) Difference | −7.446 | −6.186 | −5.631* | −4.302 | −8.945 | Reject | Stationary |
| Japan | (a)Level | −4.249 | −3.682 | −3.506* | −3.862 | −4.165 | Reject | Stationary |
| | (b) Difference | −8.958 | −6.740 | −5.635* | −6.053 | −10.114 | Reject | Stationary |

*Note*. ADF = Augmented Dickey-Fuller test; PP = Phillips-Perron test.
*Denotes the lag section by Akaike Information Criterion.

**Table 11**
Long-run transmission mechanism for yellowfin tuna

| | | | | Critical value | | | Critical value | | |
|---|---|---|---|---|---|---|---|---|---|
| Series | Hypothesized no. of CE(s) | Eigen value | Trace test statistic | 5% | 1% | Max eigen value test | 5% | 1% | Comment |
| Bangkok | None | 0.154 | 16.88 | 19.96 | 24.60 | 14.70 | 15.67 | 20.20 | No CI |
| Italy | At most 1 | 0.024 | 2.17 | 9.24 | 12.97 | 2.17 | 9.24 | 12.95 | |

*Note*. A cointegration test is employed only for Bangkok and Italy because Japanese yellowfin shows stationarity. The data cover 1995:01–2002:08.

**Table 12**
Short-run transmission mechanism (Granger causality test) for yellowfin tuna

| | Null hypothesis | $F$-statistic | $p$-value |
|---|---|---|---|
| Italy vs. Bangkok | $\Delta$(Italy) does not Granger-cause $\Delta$(Bangkok) | 2.30 | 0.065 |
| | $\Delta$(Bangkok) does not Granger-cause $\Delta$(Italy) | 1.01 | 0.41 |
| Japan vs. Bangkok | Japan does not Granger-cause $\Delta$(Bangkok) | 0.38 | 0.82 |
| | $\Delta$(Bangkok) does not Granger-cause Japan | 1.21 | 0.31 |
| Japan vs. Italy | Japan does not Granger-cause $\Delta$(Italy) | 1.04 | 0.39 |
| | $\Delta$(Italy) does not Granger-cause Japan | 1.29 | 0.28 |

*Note*. $\Delta$(Bangkok) = Bangkok(t)-Bangkok(t-1) and the four lags are included in each causality regression. The data covers 1995:01–2002:08.

Contrary to interactions of skipjack prices among different markets, the yellowfin price in one market does not Granger-cause another or, in other words, there is no causality among three markets. (See Table 12.) Only weak evidence at the 6.5% significance level reveals short-run causality from the Italian to the Bangkok markets. Therefore, the three markets for the yellowfin are not integrated, but Italy may be a price leader to Bangkok.

Finally, the market integration between two different species, the yellowfin and the skipjack, is considered. We do not apply a cointegration test on the Japanese market because of its stationarity feature. Cointegration tests for the Bangkok market do not detect any long-term relationship between yellowfin and skipjack. (See Table 13.) Unlike the unanimous characteristic of nonstationarity in skipjack prices, the yellowfin prices indicate stationarity for the Japanese market and nonstationarity for the Bangkok market. The short-term analysis indicates that none of the markets show Granger causality in dual directions. (See Table 14.) Overall, the short-term and long-term results suggest that the markets for yellowfin and skipjack are not integrated in either Bangkok or Japan.

## Concluding Remarks

The central findings are threefold. First, the regional ex-vessel markets for cannery-grade skipjack tuna are spatially integrated by price to form a global market; the Americas exert primary price leadership, but Bangkok and American Samoa also exert price leadership; and Ivory Coast, Japan, and Spain are largely price followers. Second, the three ex-vessel markets for cannery-grade yellowfin tuna are not integrated by price, although there is weak evidence that Italy may be a price leader to Bangkok. Third, the short-term and long-term results suggest that the ex-vessel markets for yellowfin and skipjack are not integrated in either Bangkok or Japanese markets, so there is neither a short-term nor long-term relationship between skipjack and yellowfin ex-vessel prices, and thus there is no evidence of price transmission between the two tuna species.

The key policy conclusion is that the economic effects from conservation and management policies for skipjack tuna taken in one RFMO jurisdictional area, to the extent they affect the volume or timing of ex-vessel supply and prices, can have global repercussions on skipjack prices, although not yellowfin prices. This conclusion is

**Table 13**

Long-run transmission mechanism for different tuna species in Bangkok market

| | | | | Critical value | | | Critical value | | |
|---|---|---|---|---|---|---|---|---|---|
| Series | Hypothesized no. of CE(s) | Eigen value | Trace test statistic | 5% | 1% | Max eigen value test | 5% | 1% | Comment |
| Skipjack | None | 0.131 | 14.880 | 15.41 | 20.04 | 12.350 | 14.07 | 18.63 | No CI |
| Yellowfin | At most 1 | 0.028 | 2.530 | 3.76 | 6.65 | 2.530 | 3.76 | 6.65 | |

*Note*. The cointegration test for skipjack and yellowfin shows no long-term relationship in the Japanese market because Japanese yellowfin shows stationarity. The data cover 1995:01–2002:08.

**Table 14**
Short-run transmission mechanism for skipjack and yellowfin tuna

| | Null hypothesis | $F$-statistic | $p$-value |
|---|---|---|---|
| Bangkok market | $\Delta$(yellowfin) does not Granger-cause $\Delta$(skipjack) | 0.789 | 0.535 |
| | $\Delta$(skipjack) does not Granger-cause $\Delta$(yellowfin) | 1.495 | 0.212 |
| Japanese market | yellowfin does not Granger-cause $\Delta$(skipjack) | 0.837 | 0.506 |
| | $\Delta$(skipjack) does not Granger-cause yellowfin | 0.299 | 0.878 |

*Note*. $\Delta$(yellowfin) = yellowfin(t)-yellowfin(t-1); $\Delta$(skipjack) = skipjack(t)-skipjack(t-1) and the four lags are included in each causality regression. The data cover 1995:01–2002:08.

particularly important for measures taken in the Pacific Ocean, where the large volumes of landings of cannery-grade skipjack tuna dominate global supplies and where global price leadership is established. The limited empirical evidence available suggests that the demand elasticity for raw tuna supplied to canning markets by purse seine and pole-and-line fleets is price elastic, so that a reduced (increased) supply of cannery-grade tunas due to changes in market conditions or public regulation should yield a greater than proportionate rise (drop) in ex-vessel revenues and resource rents to the extent that this price elasticity holds in all of the regional markets (Bertignac et al. 2000). Also, the ex-vessel price effects from yellowfin tuna conservation and management measures taken in one RFMO area are confined to that region.

Developing country policies to expand their tuna fleets also cannot operate independently of global tuna markets for skipjack, and skipjack revenues may not be as stable as hoped. In the Pacific, these investments have largely been made by the public sector and many have failed to yield a positive financial return (Petersen 2006). The potential uncertainty in skipjack revenues can only aggravate this situation by contributing to financial uncertainty. Seasonal and interannual climatic variations, including large-scale oceanographic changes, can also affect the availability of tuna in any area, and climate-driven variations in supply for skipjack can globally reverberate through ex-vessel markets.

The results have implications for further economic research. Previous research on tuna ex-vessel market integration (Herrick and Squires 1989; Squires et al. 2006) considered only regional markets in isolation, and did not allow for a global market for skipjack. Even highly sophisticated economic studies that allow regional prices to change, such as the bioeconomic model of Campbell (2000), require extension to allow for the effects of global ex-vessel price linkages for skipjack tuna. Future research may, in a number of instances, have to evaluate economic effects and impacts with an eye on the global ex-vessel skipjack market.

## Notes

1. The member nations of the Regional Fisheries Management Organizations (RFMOs) that deal with tuna are meeting in Kobe, Japan, in January 2007 to discuss enhanced conservation

and management measures. The recent meetings of the FAO Technical Consulting Group and the Technical Advisory Committee on managing tuna capacity, the first meeting of the Western and Central Pacific Fishery Commission (WCPFC) in December 2005, the formation of Regional Vessel Registers (RVRs) by the different RFMOs, review of the 1995 UN Straddling Stocks Agreement, movement toward a limited effort day management regime by the parties to the Nauru Agreement, and other recent events all point toward a reinvigorated interest in strengthened tuna management.

2. One of the emerging policy recommendations recognizes the need for global monitoring and management of fishing vessels because these highly mobile vessels can rapidly expand their presence in different RFMO regions. Other emerging policy recommendations include strengthening of rights-based management, with an immediate emphasis on deterring entry and extending closed Regional Vessel Registries from the Inter-Atlantic Tropical Tuna Commission (IATTC) to the other RFMO regions, and in effect establishing limited access rights in other RFMO regions under customary international law (Bayliff et al. 2005; FAO 2006; Joseph et al. 2006).

3. The Western and Central Pacific Fishery Commission (WCPFC), the Inter-American Tropical Tuna Commission (IATTC), the Indian Ocean Tuna Commission (IOTC), and the International Commission for the Conservation of Atlantic Tuna (ICCAT).

4. See Bayliff et al. (2005), FAO (2006), Joseph (2005), and Joseph et al. (2006).

5. For example, policies to limit catch and fishing capacity in an RFMO region that affect the quantity and timing of ex-vessel tuna supply, whose regional ex-vessel market exerts price leadership over the regional ex-vessel market of another RFMO region, will also affect the latter fleets' profitability and distribution of economic benefits among vessels. Conversely, such catch and capacity policies in the price-follower RFMO region mean that such RFMO actions will have much less effect on the profitability of the follower region's vessels and distribution of economic benefits than might otherwise have been expected.

6. The Forum Fisheries Agency (FFA) is a body established by the island countries of the South Pacific to help them manage and develop their marine living resources.

7. Note the reason for this high price is that most of the purse seine caught fish sold at Yaizu market are not actually destined for the canning market; rather, they are used for Katsuobushi.

8. Prices have started to recover since the end of the data set.

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