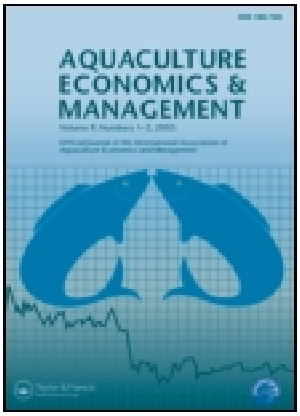


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# IS TILAPIA THE SAME PRODUCT WORLDWIDE OR ARE MARKETS SEGMENTED?

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# IS TILAPIA THE SAME PRODUCT WORLDWIDE OR ARE MARKETS SEGMENTED?

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□ *Tilapia is one of the fastest growing aquaculture species in the world. It is produced and consumed in all continents and in more countries than most other species, making the market more heterogeneous than for other successful aquaculture species such as salmon and shrimp. This paper investigates the degree of market integration between tilapia from the three largest production regions, Asia, Africa and South and Central America. We consider differences in the production methods, transport costs and qualities of these regions and determine whether tilapia products from different producers can essentially be considered the "same" product. This is important if the rapid worldwide development of farmed tilapia and its future development prospects are to be better understood.*

**Keywords** Africa, Asia, market integration, South and Central America, tilapia, world markets

## INTRODUCTION

The tilapia farming industry's rapid growth is interesting for a number of reasons. In addition to impressive increases in the volumes produced, production is widely dispersed throughout all continents. It is farmed in more than 80 countries worldwide, with production methods ranging from artisanal to intensive operations. Furthermore, demand exists within a highly diverse market base as farmed tilapia is simultaneously demanded by both, highly developed western markets and the poorest communities in developing countries.

With such a variety of markets and widespread production, a natural assumption would be that worldwide producers should supply tilapia to

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the most valuable markets. This, as for any good, would reduce differences in value between markets until the only difference left is the cost of transportation (Cournot, 1971). However, the large number of production environments and methods give rise to differences in quality and production costs. Different quality goods are often regarded as separate products and will, as such, command different market prices (Stigler & Sherwin, 1985). This market segmentation between different quality tilapia allows producers to incur different costs of production depending on the quality of their product. Furthermore, inadequate transport logistics and food safety issues can restrict the movement of tilapia to more profitable markets. This results in producers targeting specific markets and may create segmentation in the world's tilapia markets.

A significant factor that can separate developed and developing tilapia markets is their differing minimum quality standards. International developed markets require production methods to be compatible with the quality standards set by the Hazard Analysis and Critical Control Point (HACCP) system. This system is generally not required in developing markets. As a result, the production method chosen in developing countries will most likely influence which market is open to these producers and hence; the proportion of their tilapia reaching different markets. This relationship will affect the overall development of world tilapia markets as more than 95% of total farmed tilapia is produced in developing countries.

The largest producers of farmed tilapia are located in Asia, Africa and South and Central America. In 2005, these continents respectively contributed 78%, 12% and 9% of world farmed tilapia production (FAO FishStat Plus, Global datasets, Aquaculture Production: Quantities). Significant quantities are supplied to local markets although overall exports have increased over time as a result of emerging markets in developed countries. Low production costs within these regions, coupled with high international prices, have made it very profitable to export tilapia. Nevertheless, the quantities of tilapia exported to international markets differ between countries because of different production and transport costs, exchange rates and product qualities. For example, China and Egypt are the world's first and second largest producers of farmed tilapia respectively (FAO FishStat Plus, Global datasets, Aquaculture Production: Quantities). Chinas share of global farmed tilapia exports has increased from 7% to 22% over the period 2002 to 2005,[1] and in the process became the world largest exporter of tilapia (Bean & Xinping, 2006). On the other hand, Egypt does not export tilapia. High production costs and food safety concerns from the EU and U.S. has restricted most Egyptian tilapia to local markets, despite falling prices (Feidi, 2004).

International tilapia markets have expanded significantly from virtually nothing in 1991 to 340,000 tonnes (live weight equivalents) in 2005.[2]

This growth is primarily due to the expansion of the U.S. tilapia market. The U.S. imports three tilapia products: fresh and frozen fillets and whole frozen. This market has grown from no recorded imports in 1991 to 320,700 tonnes live weight equivalents in 2005. Producers exporting tilapia to the United States have different comparative advantages, and specialise in different product forms. Factors affecting this are the producers' different levels of production cost and their geographical proximity to the United States. As a result; Asia supplies most frozen imports into the United States because of their low technological investment to produce tilapia (Urch, 2001) and; South and Central America supply most fresh tilapia imports due to their relatively close proximity to the U.S.

The significant expansion of farmed tilapia production has, in terms of volume, situated this fish in the same league as farmed salmon. World farmed tilapia production has increased from 100 thousand tonnes in 1980 to over 2 million tonnes in 2005. Nevertheless, salmon is competitively exported all around the world despite being produced by a limited number of producers (Norway, Chile, Scotland/UK, Japan, U.S. and Canada. See Asche et al., 2004). Several studies have found the salmon markets to be highly integrated both globally, and for different product forms.[3] Each product form or species may not be directly substitutable with one another but with so many species and product forms that are substitutable, it is possible to say that there is a common price determination process. This may not be the case for tilapia as fresh and frozen fillets imported into the U.S. market have already been found to be separate products (Norman-López and Asche, 2008).

The purpose of this paper is to investigate the degree of market integration between tilapia from the three largest production regions. U.S. imports of fresh tilapia products from South and Central America and frozen tilapia products from Asia are used to represent the tilapia markets within these continents, as this will be the local markets opportunity cost. Fresh and frozen tilapia products from the largest Egyptian wholesale seafood market are used to represent tilapia prices within the African continent.

Our results offer an insight into the future development prospects of tilapia in world markets. This should be of interest to both the tilapia industry and academics alike. Since the presence or absence of market integration will indicate the extent to which transportation costs and trade barriers such as HACCP can affect the competitiveness of producers. Our results also allow us to speculate as to the numbers of countries likely to be supplying tilapia in the future. Will tilapia production follow that of salmon with only a handful of countries supplying the worldwide market? Will tilapia still be produced by local producers for local markets with only a handful of countries supplying international markets? Will the global market of tilapia remain as it is today, with local markets being supplied by local producers and international markets being supplied by a diverse range of producers? The results of this study allow consideration of the development pathways that tilapia may follow.

In the analysis, we study the relationship between prices from January 2000 to December 2006. The development of prices over time provides important information on the relationship between commodities. This has been recognised by economists such as Cournot (1971), Stigler (1969) and Marshall (1947). Also, the literature has used prices to study market integration between different seafood products. Examples include; Gordon, Salvanes, and Atkins (1993), Gordon and Hannesson (1996), Asche, Bjørndal, and Sissner (2003), Asche, Gordon, and Hannesson (2004), Asche and Sebulonsen (1998), Asche, Bremnes, and Wessells (1999), Asche, Guttormsen, and Tveterås (2001), Jaffry et al. (2000) and Nielsen (2005).

The present study is organised as follows: Next we discuss the situation of farmed tilapia as a worldwide produced species; The data used in this analysis as well as the time series properties of the data are reviewed, the methodology is presented, and we explain our empirical results some final comments.

## BACKGROUND

The relatively basic biology, feeding and veterinary requirements of tilapia has encouraged farmers to culture this fish in all continents using an array of different culture systems and management strategies. These systems include; earthen pond, cage, concrete tank, and raceway. There are also many different management strategies (extensive, semi-intensive, intensive, monosex culture, mixed sex culture, monoculture, polyculture, and integrated with agriculture or animal husbandry). This variety of production methods makes it feasible to produce tilapia at relatively low costs for subsistence, in large-scale commercial operations, and at any point in between. Furthermore, the variety of production methods has resulted in world tilapia production growing rapidly in a relative short period of time. Figure 1 shows world farmed and wild tilapia production from 1980 to 2005. World wild tilapia production only increased from 250,354 tons in 1980 to 669,935 tons in 2005. On the other hand, world farmed tilapia production has increased from 107,459 tons to 2,025,559 tons over the same period. This means world farmed tilapia production has increased from 30% of total world tilapia production in 1980 to 75% in 2005.

The culture system and management strategy farmers decide to use depends on their resources to build infrastructure, site characteristics, environmental conditions (in particular climate), socioeconomic factors, technical knowledge, and marketing feasibilities. It is this choice of

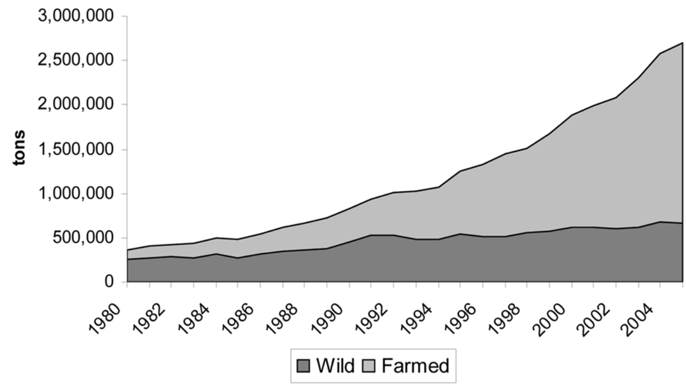


**FIGURE 1** Annual quantities of farmed and wild tilapia produced worldwide, 1980–2005. *Source*: FAO FishStat Plus. Global data sets, Aquaculture Production: Quantities and Capture Production.



production and management systems that ultimately determines the total costs of production.

In general, total tilapia production costs are higher in temperate than in tropical countries because tilapia is a tropical fish that cannot live in cold waters (Alceste & Jory, 2002). As such tilapia producers in temperate regions need to invest in more expensive systems. However, even within tropical areas, tilapia production costs vary significantly between producers. In South and Central America costs range between $1.20 and $1.80/kg live weight (Anderson, 2007). In Egypt costs are approximately $0.90/kg live weight (El-Naggar et al., 2006), while in Asia they can be as low as $0.50/kg live weight (Young & Muir, 2002). Overall, Asian tilapia producers face lower production costs than other continents because they require a lower level of technological investment (Urch, 2001).

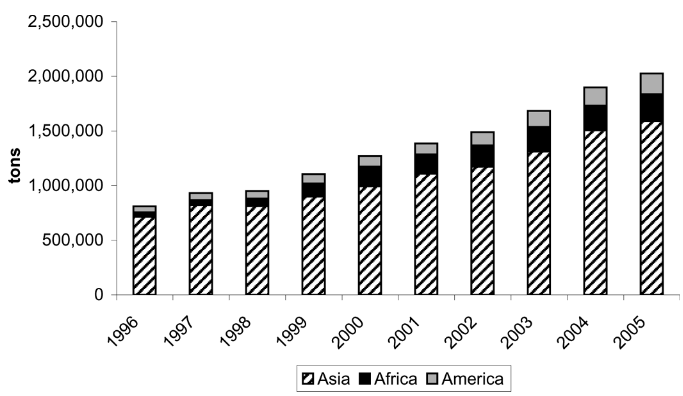


**FIGURE 2** Annual quantities of farmed tilapia produced in Asia, Africa and America, 1996–2005. *Source*: FAO FishStat Plus. Global data sets, Aquaculture Production: Quantities.

Figure 2 illustrates the production of farmed tilapia in Africa, America and Asia from 1996 to 2005.[4] Europe is not included because production is negligible at 320 tonnes in 1996, growing to only 578 tonnes in 2005. The largest producers are located in Asia followed by Africa and America. Tilapia production has increased in the three continents, although the growth in the American continent primarily represents that of South and Central America. Asian tilapia production represents approximately 80% of world farmed tilapia production. Asian tilapia production has increased from 713,384 tons in 1996 to 1,589,495 tonnes in 2005. Overall, and despite differences in production, the spatial distribution of tilapia indicates the adaptability of this fish to a wide range of environmental conditions.

Despite the geographically broad distribution of tilapia, the majority of production originates from a few main countries. Table 1 presents the growth in production of the 7 largest producers of farmed tilapia worldwide from 1996–2005. China and Egypt are the largest producers of farmed tilapia followed by Indonesia, Philippines, Thailand, Taiwan and Brazil. Table 1 shows that in 2005, farmed tilapia from the 7 largest producers represented, respectively, 48%, 11%, 9%, 8%, 5%, 4%, and 3% of world-farmed tilapia production. Egypt has also had the largest growth with an almost 7-fold increase in farm production over those 10 years.

The large numbers of tilapia producers supplying world makes it a complex task to analyse the global market of tilapia. We have used U.S. imports of frozen and fresh tilapia products to represent prices in the Asian and South and Central American markets respectively. This is because over 96% of total U.S. imports of whole frozen tilapia and frozen tilapia fillets between 2000 and 2006 came from Asia. Furthermore, over 97% of total U.S. imports of fresh tilapia fillets for the same period came from South and Central America (Foreign Trade data set, NMFS). Moreover, the U.S. is the



**TABLE 1** Total Farm Production of the 7 Largest Producers From 1996–2005

| Year | China | Egypt | Indonesia | Philippines | Thailand | Taiwan | Brazil | World total |
|---|---|---|---|---|---|---|---|---|
| 1996 | 394,745 | 27,854 | 75,473 | 79,415 | 91,038 | 44,756 | 15,700 | 810,103 |
| 1997 | 486,538 | 30,416 | 73,222 | 91,834 | 91,580 | 42,158 | 16,845 | 931,061 |
| 1998 | 526,984 | 52,755 | 65,894 | 72,023 | 73,809 | 36,126 | 24,062 | 950,619 |
| 1999 | 562,879 | 103,988 | 74,005 | 83,832 | 76,621 | 57,183 | 27,104 | 1,103,691 |
| 2000 | 629,795 | 157,425 | 85,179 | 92,579 | 82,581 | 49,235 | 32,459 | 1,269,883 |
| 2001 | 672,307 | 152,515 | 105,106 | 106,746 | 84,510 | 82,781 | 35,830 | 1,385,134 |
| 2002 | 706,996 | 167,735 | 109,768 | 122,399 | 83,936 | 85,059 | 57,031 | 1,504,197 |
| 2003 | 806,580 | 199,557 | 123,748 | 129,996 | 98,376 | 85,351 | 64,857 | 1,685,851 |
| 2004 | 897,756 | 199,038 | 139,651 | 145,869 | 160,407 | 89,275 | 69,078 | 1,899,400 |
| 2005 | 978,653 | 217,019 | 189,570 | 163,004 | 155,065 | 83,435 | 67,851 | 2,067,685 |

*Source:* FAO FishStat Plus. Global datasets, Aquaculture Production: Quantities.

main import market for these exporters. Therefore, the export price to the U.S. represents the opportunity cost of fish consumed locally. Also, Egypt is used to represent African markets as it is the major producer of farmed tilapia in this continent (FAO FishStat Plus. Global dataset, Aquaculture Production: Quantities). However, as there is virtually no trade between Egypt and other African markets this assumption may be open to question. Assuming, this assumption does not hold, the results of our analysis will understate the heterogeneity of the African tilapia market.

In Egypt, El-Obour wholesale market is the largest and most important fish market in the country (Feidi, 2004). This market supplies whole fresh tilapia and frozen tilapia fillets. The majority of Egyptian tilapia is sold whole fresh as this is the preferred product form. El-Obour market mainly supplies three different grades of whole fresh tilapia according to quality and size.[5] Tilapia grade 1 is the most popular as its quality is the highest and its size the largest (1–5 fish/kg) (Feidi, 2004). Frozen tilapia fillets are supplied as one single grade mostly to restaurants and hotels catering for high-income Egyptians and tourists.

Figure 3 presents the volumes (tons) of different tilapia products in the Egyptian and U.S. markets over the years 2000 to 2006. U.S. tilapia imports are presented on the left Y axis and Egyptian production on the right Y axis due to the large differences in volumes between markets. For the Egyptian market, wholesale quantity of whole fresh tilapia (grade 1) and frozen tilapia fillets from El-Obour market are presented. For the U.S. market, imports of fresh tilapia fillets from South and Central America as well as imports of frozen tilapia fillets and whole frozen tilapia from Asia

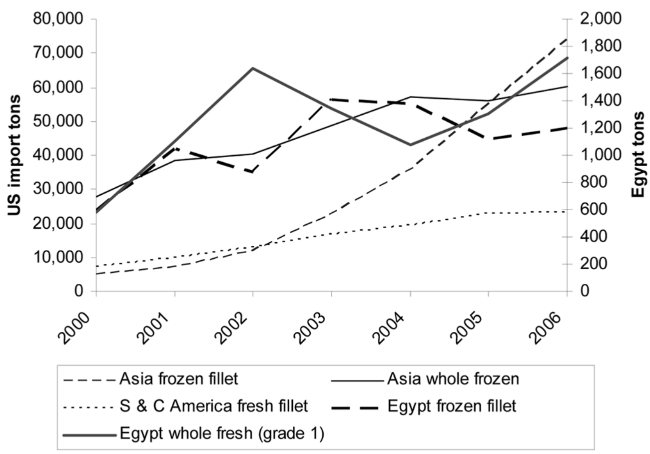


**FIGURE 3** Annual U.S. imports of whole frozen and frozen tilapia fillets from Asia and fresh tilapia fillets from South and Central America as well as El Obour wholesale quantities of Egyptian whole fresh tilapia (grade 1) and Egyptian frozen fillets from 2000 to 2006. *Source*: Obour market wholesale data and NMFS, foreign trade data.

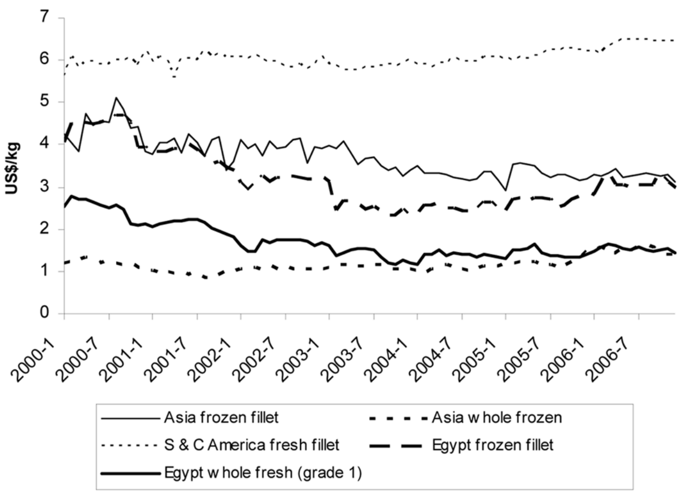


**FIGURE 4** Monthly U.S. import prices of whole frozen and frozen tilapia fillets from Asia and fresh tilapia fillets from South and Central America as well as El Obour wholesale prices for Egyptian fresh tilapia (grade 1) and Egyptian frozen fillets from 2000 to 2006. *Source*: Obour market wholesale data and NMFS, foreign trade data.



are presented. Figure 3 shows how all U.S. imports increased continuously over the period observed. The quantity of Egyptian whole fresh tilapia also increased over time except in 2003 and 2004 when supply dropped. The quantities of Egyptian frozen tilapia fillets follow to some extent an opposite trend to Egyptian whole fresh tilapia. Quantities of frozen fillets increased to a peak in 2003 but declined thereafter.

Figure 4 presents the evolution of prices from January 2000 to December 2006 for whole fresh tilapia (grade 1) and frozen tilapia fillets in the Egyptian market. It also shows U.S. import prices of whole frozen tilapia and frozen tilapia fillets from Asian countries and fresh tilapia fillets from South and Central American countries. For the U.S. market, prices of frozen import products have declined over time, while fresh fillet import prices have increased at a consistent rate since the year 2000. Prices of Egyptian whole fresh tilapia and frozen fillets show similar patterns. These prices declined continuously until December 2003 and increased thereafter.

## DATA

The rapid increase of tilapia imports into the U.S. market primarily occurred this century; before this date import quantities of fillets were very limited, resulting in prices being very unstable. As a consequence, our analysis concentrates on monthly price data from January 2000 to ensure a sensible analysis. The latest data available for El-Obour market at the time of analysis was December 2006. This results in a total of 84 monthly observations. The variables investigated from the U.S. market are import prices for Asian whole frozen tilapia, Asian frozen tilapia fillets and South and Central American fresh tilapia fillets. For the Egyptian market, two price variables are considered; whole fresh tilapia (grade 1) and frozen tilapia fillets. The data on U.S. tilapia imports were obtained from the National Marine Fisheries Survey (NMFS). The price data from the Egyptian market was obtained directly from El-Obour market. The price figures have been converted from Egyptian pounds into U.S. dollars in accordance with the official interbank exchange rate for the purpose of performing the analysis.

The descriptive statistics of the log nominal price series under investigation are presented in Table 2. These summary statistics include the mean, median, standard deviation, skewness, and kurtosis. The mean of all the series is very close to the median. The largest spread in the nominal price series is that for whole fresh Egyptian tilapia and frozen Egyptian tilapia fillets, which have a standard deviation of 0.22 and 0.20, respectively. All the price series are skewed towards the right (the skewness value is positive). The measure of kurtosis indicates how peaked or flat the data distribution is. The measures of kurtosis for all tilapia prices except U.S. imports of whole frozen tilapia are below 3, indicating all data series (except whole frozen tilapia prices) have a flat distribution (platykurtic). The kurtosis measure above 3 for whole frozen tilapia prices indicate this data series is packed around the mean (leptokertic).

Prior to investigating the market integration of different products of tilapia from different international producers we first studied the time series properties of the data. This was assessed using unit roots tests, specifically the Augmented Dickey Fuller (ADF) unit root test (Dickey & Fuller, 1979, 1981). If the price data in levels is found to be non-stationary (I(1)), this series does not have a constant mean, variance or covariance



**TABLE 2** Descriptive Statistics of Tilapia Logged Nominal Prices, January 2000–December 2006 ($n = 84$)

| | Egyptian frozen fillet | Egyptian whole fresh | U.S. Imports fresh fillet[1] | U.S. Imports frozen fillet[2] | U.S. Imports whole frozen[2] |
|---|---|---|---|---|---|
| Mean | 1.13 | 0.51 | 1.80 | 1.30 | 0.15 |
| Median | 1.12 | 0.44 | 1.79 | 1.27 | 0.12 |
| Std. Dev. | 0.20 | 0.22 | 0.03 | 0.12 | 0.14 |
| Skewness | 0.52 | 0.73 | 0.46 | 0.54 | 0.63 |
| Kurtosis | 2.20 | 2.52 | 2.89 | 2.50 | 3.06 |

Prices are in $/kg.
[1]U.S. import prices from South and Central America.
[2]U.S. import prices from Asia.

**TABLE 3** Unit Root Test (Augmented Dickey Fuller Test) Tilapia Logged Nominal Prices, January 2000–December 2006 ($n = 86$)

| | Levels | | First differences | |
|---|---|---|---|---|
| Variable | Constant | Constant & Trend | Constant | Constant & Trend |
| U.S. imports fresh fillet[1] | −0.380 (4) | −1.254 (4) | −6.286* (3) | −6.368* (3) |
| U.S. imports frozen fillet[2] | −1.124 (2) | −3.356 (2) | −10.457* (1) | −10.394* (1) |
| U.S. imports whole frozen[2] | −1.275 (0) | −2.158 (0) | −9.078* (0) | −9.150* (0) |
| Egyptian whole fresh | −1.854 (0) | −1.825 (0) | −8.348* (0) | −8.450* (0) |
| Egyptian frozen fillet | −1.552 (0) | −1.304 (0) | −9.564* (0) | −7.901* (1) |

The values in brackets indicate the number of lags.
*Indicate significance at 1% level; **indicate significance at 5% level.
[1]U.S. import prices from South and Central America.
[2]U.S. import prices from Asia.



and a regression including this data will result in a spurious regression. However, if a linear combination of two I(1) series generate a stationary (I(0)) series, there exists a cointegration relationship between the series. This is primarily a statistical relationship, implying that the series contain a common stochastic trend.

In the ADF test we need to set the adequate lag length to achieve white noise in the error term. We did this using the Schwarz information criteria and autocorrelation tests (LM). ADF tests for each series have been performed in levels and first differences with a constant as well as a constant and a trend. The null hypothesis in the ADF test is that each data series is I(1). Table 3 identifies nominal prices to be non-stationary in levels and stationary in first differences I(1).

## Testing for Market Integration

Cournot (1971, p. 10.6) defined a market as follows: “It is evident that an article capable of transportation must flow from the market where its value is less to the market where its value is greater, until difference in value, from one market to the other, represents no more than the cost of transportation”. Other definitions of a market apply this concept not to a geographical space but to product space, so quality differences will take the place of transportation costs (Stigler & Sherwin, 1985). Therefore, prices of related products may deviate from each other in the short run, but in the long run, arbitrage and substitutability will guarantee that these prices form an equilibrium relationship (that is, they are cointegrated). A variety of seafood studies have examined the market relationship between different goods by analysing their prices with tests for cointegration. Some of the studies include, Gordon and Hannesson (1996), Jaffry et al. (2000), Asche et al. (2004) and Nielsen (2005).

Two approaches are generally used to test for cointegration: the Engle and Granger test (1987) and the Johansen test (1988). Our study uses the Johansen test in the market integration analysis because it will also allow us to test hypothesis (e.g., law of one price (LOP)) on those variables that are found to have an equilibrium relationship. In our study, we test for market integration between two price series at a time. The Johansen test is based on a vector autoregressive (VAR) system. We start by setting a vector $\mathbf{z_t}$ containing two ($N$) of the price series we are investigating. Then, we model $\mathbf{z_t}$ as an unrestricted vector autoregression (VAR) model with "$k$ lags" containing these variables in levels, where, $z_t$ is $(n \times 1)$ and each of the $\Pi_i$ is an $(n \times n)$ matrix of parameters. The system is in reduced form with each variable in $z_t$ regressed on only lagged values of both itself and all other variables in the system. Then, the VAR model is turned into a vector error correction model (VECM) of the form:

$$\Delta z_t = \Gamma_1 \Delta z_{t-1} + \cdots + \Gamma_{k-1} \Delta z_{t-k+1} + \Pi z_{t-k} + \mu_t \tag{1}$$

where $\Gamma_i = -(I - \Pi_1 - \cdots - \Pi_i), (i = 1, \ldots, k-1)$, and $\Pi = -(I - \Pi_1 - \cdots - \Pi_k)$. The Johansen test centres on an examination of the $\Pi$ matrix. $\Pi_k$ is the long-run "level solution" to (1), because in equilibrium, all the first differences of the price series ($\mathbf{\Delta z_{t-i}}$) will be zero, and setting the error terms, $\mathbf{u}_t$, to their expected value of zero will leave $\Pi\mathbf{z_{t-k}} = \mathbf{0}$. Furthermore, $\Pi = \alpha\beta'$, where $\alpha$ represents the speed of adjustment, while $\beta$ is a matrix of long-run coefficients, such that the term $\beta'\mathbf{z_{t-k}}$ in equation (1) represents up to $(n-1)$ cointegration relationships.

There are two asymptotically equivalent tests for cointegration in the Johansen framework: the maximum eigenvalue test and the trace test. The test for cointegration between the $\mathbf{z_t}$ is calculated by looking at the rank of the $\Pi$ matrix via its eigen values. The rank of $\Pi_k$, $\mathbf{r}$, determines how many linear combinations of $\mathbf{z_t}$ are stationary. If $r = N$, the variables in levels are stationary. If $r = 0$, none of the linear combinations is stationary ($\Pi_k = 0$). When $0 < r < N$, there exist r linear stationary combinations of $\mathbf{z}_t$, or $r$ cointegration vectors. In this instance, we need to determine how many $r \leq (n-1)$ cointegration vectors exist in $\beta$. Thus the last $(n - r)$ columns of $\beta$ are non-stationary and do not enter equation (1). This amounts to equivalently testing which columns of $\alpha$ are zero. Therefore, it is possible to reduce the dimensions of $\alpha$ and $\beta$ to $(n \times r)$ by factorising $\Pi$. If the series are cointegrated, we further investigate whether the two price series are imperfect substitutes or whether they are perfect substitutes (LOP) so their relative price is constant. We test for the LOP by imposing the restriction $\beta' = (1, -1)'$.

## Empirical Analysis

The optimal lag length for the bivariate VAR models, which are the base of the Johansen test, were chosen using the Schwartz information criteria. The Schwartz information criteria (SIC) for VAR systems indicated that 1 lag was optimal for the following bivariate relationships; Egypt whole fresh/Egypt frozen fillet, Egypt whole fresh/U.S. frozen fillet, Egypt whole fresh/U.S. whole frozen, Egypt frozen fillet/U.S. frozen fillet, Egypt frozen fillet/U.S. whole frozen, U.S. frozen fillet/U.S. whole frozen. The rest of the bivariate relationships investigated used 2 lags following the SIC recommendation.

To investigate the degree of market integration in the tilapia market, we performed bivariate Johansen cointegration tests (Johansen, 1988) between the five price series of interest. The Johansen cointegration framework was performed with the econometric software package EViews 5.0. The software allows the cointegration tests to be undertaken using five



**TABLE 4** Bivariate Johansen Test for Cointegration, January 2000–December 2006 ($n = 84$)

| | Null hypothesis[a] | | | |
|---|---|---|---|---|
| | Rank ($\rho$) = 0 | | Rank ($\rho$) $\leq$ 1 | |
| Nominal prices | Max[b] | Trace[c] | Max[b] | Trace[c] |
| Egypt whole fresh/Egypt frozen fillet | 8.02 | 8.18 | 0.16 | 0.16 |
| (Probability)[d] | (0.17) | (0.22) | (0.74) | (0.74) |
| Egypt whole fresh/U.S. fresh fillets | 6.53 | 7.11 | 0.58 | 0.58 |
| (Probability)[d] | (0.29) | (0.31) | (0.51) | (0.51) |
| Egypt whole fresh/U.S. frozen fillets | 7.83 | 8.91 | 1.08 | 1.08 |
| (Probability)[d] | (0.19) | (0.17) | (0.35) | (0.35) |
| Egypt whole fresh/U.S. whole frozen | 5.03 | 5.68 | 0.65 | 0.65 |
| (Probability)[d] | (0.47) | (0.48) | (0.48) | (0.48) |
| Egypt frozen fillets/U.S. fresh fillets | 4.93 | 5.72 | 0.79 | 0.79 |
| (Probability)[d] | (0.49) | (0.47) | (0.43) | (0.43) |
| Egypt frozen fillets/U.S. frozen fillets | 5.76 | 7.10 | 1.34 | 1.34 |
| (Probability)[d] | (0.38) | (0.32) | (0.29) | (0.29) |
| Egypt frozen fillets/U.S. whole frozen | 4.47 | 4.86 | 0.39 | 0.39 |
| (Probability)[d] | (0.55) | (0.59) | (0.60) | (0.60) |
| U.S. fresh fillets/U.S. frozen fillets | 1.84 | 2.64 | 0.80 | 0.80 |
| (Probability)[d] | (0.94) | (0.89) | (0.43) | (0.43) |
| U.S. fresh fillets/U.S. whole frozen | 3.81 | 4.92 | 1.11 | 1.11 |
| (Probability)[d] | (0.66) | (0.58) | (0.34) | (0.34) |
| U.S. frozen fillets/U.S. whole frozen | 1.90 | 2.25 | 0.36 | 0.36 |
| (Probability)[d] | (0.93) | (0.93) | (0.61) | (0.61) |

Results from Schwarz IC.
[a]The null hypothesis is that the number of cointegrating vectors is equal to $\rho$.
[b]Maximum eignevalue test.
[c]Trace test.
[d]Mackinnon-Haug-Michelis (1999) p-values equal to $\rho$.

different trend assumptions. We chose to have no intercept or trend in the cointegration test or VAR model following the Schwarz information criteria. The results are reported in Table 4. As one can see all of the pairwise tests fail to reject the null hypothesis of no cointegration vector with rank = 0 at the 10% level.

These results indicate there is no long-run relationship between imports of frozen tilapia products (whole and fillets) and fresh tilapia fillets in the U.S. market. A similar lack of relationship between fresh and frozen fillets in the U.S. market has already been reported by Norman-López and Asche (2008). Furthermore, the results indicate no long-run relationship between imports of whole frozen tilapia and frozen tilapia fillets in the U.S. market. Therefore, we can say from our results that none of the tilapia products imported into the United States are in the same market. This indicates that there are three different market segments of tilapia in the United States and that segmentation is by product form. The lack of relationship between the imported Asian frozen tilapia products and South and Central American fresh tilapia products could be expected; given the significant difference in transportation costs between these two continents. However, it is somewhat more surprising that there does not seem to be arbitrage opportunities between whole and frozen fillets. This indicates that, despite these two frozen products being imported from Asia, processing costs have a significant impact on the production costs for fillets.

The market integration tests for the two Egyptian tilapia products, namely whole fresh (grade 1) and frozen fillets, indicate these two tilapia products do not form a long-run relationship in the Egyptian market. This conforms to expectation as Egyptians are reported to prefer fresh to frozen fish (Feidi, 2004). In addition, the market integration tests indicated that none of the Egyptian tilapia products compete with any of the three tilapia products imported into the U.S. market. This result was also expected since the quality of Egyptian tilapia is too low for international standards (El-Gayar, 2003). Therefore, the tilapia products imported into the U.S. market cannot be considered to be the same to the Egyptian products supplied to the market in Egypt. Finally, given that none of the prices were found to be related, tests for the Law of One Price (LOP) were not undertaken.

## DISCUSSION AND CONCLUSIONS

The purpose of this paper was to investigate whether tilapia products from the three largest tilapia producing regions, as well as different product forms can essentially be considered the same product. Determining this is important because the increase in international trade is likely to raise competition between tilapia producers across regions, each wanting to reach the most profitable markets. Given that producers ability to compete is a function of differences in production and transport costs as well as product qualities, it is likely that in an integrated market some producers will be forced out of international markets. This situation would change the global market of tilapia from as it stands today, where local markets are supplied by local producers and international markets are supplied by a wide range of international producers.

In the future, an integrated global tilapia market may resemble salmon markets with only a few producers supplying local and international markets. It is likely this would have negative social and economic implications for developing countries because; the livelihoods of small scale producers currently supplying local markets would be disrupted; and the benefits to the local economy of supplying international markets would cease for the excluded countries. Alternatively, local tilapia markets could continue being supplied by local producers while international markets are only supplied by a handful of producers. This situation would still have negative economic implications for those countries that are forced out of international markets.

Our results indicate no long-run relationship between imports of frozen tilapia products (whole and fillets) and fresh tilapia fillets in the U.S. market.[6] The lack of competition between fresh and frozen tilapia products is believed to be the result of varying production technologies, quality and/or transportation costs between different tilapia producer countries (Norman-López & Asche, 2008). In particular, both frozen tilapia products are supplied by South-East Asian countries, while fresh tilapia fillets are imported from South and Central American producers. Therefore, the most likely explanation for the lack of cointegration between fresh and frozen products is the difference in transport costs and shipping times required for the different products (aeroplane for fresh and ship for frozen). Furthermore, freshness has been identified as the most important attribute determining retailer preference for tilapia (Halbrendt et al., 1995). Therefore, the lack of competition between fresh and frozen tilapia may also be due to consumers actively differentiating between these two products.

Our results also indicate no long-run relationship between imports of whole frozen tilapia and frozen tilapia fillets in the U.S. market. This is likely due to the change in consumers' lifestyle in the United States. Consumers are increasingly demanding seafood products, especially fillets, that are nutritious, require less preparation time and are easier to consume (Gempesaw et al., 1995; Foltz et al., 1999). Therefore, U.S. consumers are likely to deem that these two frozen tilapia products are not substitutes for one another. Our results for the U.S. tilapia market lead us to the conclusion that none of the tilapia products imported into the United States are in the same market.

The market integration tests for the Egyptian tilapia market have been performed on the highest quality whole fresh tilapia (grade 1) and frozen tilapia fillets. Our results indicate no long-run relationship between these two tilapia products. The lack of relationship is likely due to Egyptians' preference for fresh to frozen fish and within fresh fish, whole fresh (Feidi, 2004). A. Nasr-Alla (2006, pers. comm., December, 2005) has also suggested that different consumer groups typically buy different tilapia products. Whole fresh tilapia (grade 1) is most often bought by restaurants and high income Egyptians. On the other hand, frozen tilapia fillets tend to be bought by hotels which mainly cater for foreigners in Egypt. As a result, the niche markets for differing tilapia products are likely to keep whole fresh tilapia and frozen tilapia fillets segmented within Egypt.

Finally, our results indicate there is no long-run relationship between the tilapia products imported into the U.S. market and the Egyptian products considered. The results come as no great surprise due to the quality of Egyptian tilapia products being below international standards (El-Gayar, 2003). These results indicate that the tilapia products from the largest producing regions in Asia, Africa and South and Central America cannot be considered to be the "same" product. Therefore, we can conclude that despite differences in competitiveness across regions, the large range of producers supplying different products to local and international markets will prevail for at least the near future.

In the long-run, we speculate that; the development of vertically integrated large-scale operations coupled with low production costs at the high technological end; may lead to the evolution of an industrial concentration similar to that witnessed in farmed Atlantic salmon (Young & Muir, 2002). This situation would change the structure of world tilapia markets. Many producers in developing countries currently supplying international markets with traditional production methods would be out competed. As a result, the number of countries supplying tilapia to international markets would decline. Nevertheless, the difference in the quality demanded in developing and developed tilapia markets is likely to allow local producers to continue supplying local markets.

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## NOTES

1. Export statistics obtained from FAO FishStat Plus, Global dataset, Fisheries Commodities Production and Trade. In 2002, China exported 9,121 tons of frozen tilapia fillets, 73 tons of

fresh tilapia and 20,833 tons of frozen tilapia fillets. In 2005, China's exports were 53,491 tons of frozen tilapia fillets, 21 tons of fresh tilapia and 38,761 tons of whole frozen tilapia. The live-weight equivalents were then calculated as 1.1 times the weight of whole tilapia and 3.3 times the weight of fillets (Fitzsimmons, 1999; Urch, 2001).

2. FAO FishStat Plus, Global dataset, Fisheries Commodities Production and Trade statistics indicate in 2005; 73,261 tons of fresh and frozen fillets and 89,253 tons of whole fresh and frozen tilapia were exported. The live-weight equivalents were then calculated as 1.1 times the weight of whole tilapia and 3.3 times the weight of fillets (Fitzsimmons, 1999; Urch, 2001).
3. For example, Asche and Sebulonsen (1998), Asche, Bremnes, and Wessells (1999), Asche (2001) and Asche, Guttormsen, and Tveterås (2001).
4. Africa includes the Middle East. Asia includes several islands in Oceania. America includes North, South and Central America.
5. The region of Aswan also supplies whole fresh tilapia to El-Obour market although the large distance from Aswan to this market (over 1000 km) affects the freshness (quality) and hence its price compared to other whole fresh tilapia in El-Obour market.
6. No relationship was found when comparing levels of monthly data at the same point in time. However, an equilibrium relationship could still exist at lagged values.



## REFERENCES

Alceste, C.C. & Jory, D.E. (2002) *World Tilapia Farming 2002*. Aquaculture Magazine. http://www.aquaculturemag.com/siteenglish/printed/buyers/web-tilapia.pdf

Anderson, J.L. (2007) *The International Seafood Trade*. Woodhead Publishing Limited and CRC Press, Cambridge.

Asche, F. (2001) Testing the effect of an anti-dumping duty: The U.S. salmon market. *Empirical Economics*, **26**, 343–355.

Asche, F., Bjørndal, T., & Sissner, E.H. (2003) Relative productivity development in salmon aquaculture. Thalassorama. *Marine Resource Economics*, **18**(2), 205–210.

Asche, F., Bjørndal, T., & Young, J.A. (2001) Market interactions for aquaculture products. *Aquaculture Economics and Management,* **5**, 303–318.

Asche, F., Bremnes, H., & Wessells, C.R. (1999) Product aggregation, market integration and relationships between prices: An Application to world salmon markets. *American Journal of Agricultural Economics*, **81**, 568–581.

Asche, F., Gordon, D.V., & Hannesson, R. (2004) Test for Market integration and the law of one price: The market for whitefish in france. *Marine Resource Economics*, **19**, 195–210.

Asche, F., Guttormsen, A., & Tveterås, S. (2001) Aggregation over different qualities: Are there generic commodities? *Economics Bulletin*, **3**(13), 1–6.

Asche, F. & Sebulonsen, T. (1998) Salmon prices in France and the UK: Does origin or market place matter? *Aquaculture Economics and Management*, **2**, 21–30.

Bean, C. & Xinping, W. (2006) China's tilapia production situation. China, peoples republic of fishery products. GAIN Report–CH6029. USDA Foreign Agricultural Service, Washington, DC.

Cournot, A.A. (1971) *Researches into the Mathematical Principles of the Theory of Wealth*. A. M. Kelly, New York.

Dickey, D.A. & Fuller, W.A. (1979) Distribution of the estimators for autoregressive time series with unit root. *Journal of the American Statistical Association*, **74**, 427–431.

Dickey, D.A. & Fuller, W.A. (1981) Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica*, **49**, 1057–1072.

El-Gayar, O. (2003) Aquaculture in Egypt and issues for sustainable development. *Aquaculture Economics and Management*, **7**(12), 137–154.

El-Naggar, G., Nasr-Alla, A., & Kareem, R.O. (2006) Factors influencing fish farm productivity in Egypt. (A case study of Behera province). *Journal of Egyptian Aquaculture Society*, **1**, 47–57.

Engle, R.F. & Granger, C.W.J. (1987) Co-integration and error correction: Representation, estimation and testing. *Econometrica*, **55**, 251–276.

Feidi, I. H. (2004) The market for seafood in the area of greater cairo (Egypt). *Center for Marketing Information and Advisory Services for Fishery Products in the Arab Region (INFOSAMAK)*, March 2004.

Fitzsimmons, K. (1999) Marketing of tilapia in the USA. In: *The Fifth Roche Aquaculture Conference*, August 26, 1999. pp. 12–25. Bangkok, Thailand.

Foltz, J., Dasgupta, S., & Devadoss, S. (1999) Consumper perceptions of trout as a food item. *International Food and Agribusiness Management Review*, **2**(1), 83–101.

Gempesaw II, C.M., Bacon, J.R., Wessells, C.R., & Manalo, A. (1995) Consumer perceptions of aquaculture products. *American Journal of Agriculture Economics*, **77**, 1306–1312.

Gordon, D.V. & Hannesson, R. (1996) On prices of fresh and frozen cod. *Marine Resource Economics*, **11**, 223–238.

Gordon, D.V., Salvanes, K.G., & Atkins, F. (1993) A fish is a fish is a fish: Testing for market linkage on the Paris fish market. *Marine Resource Economics*, **8**, 331–343.

Halbrendt, C., Wang, Q., Fraiz, C., & O'Dierno, L. (1995) Marketing problems and opportunities in mid-atlantic seafood retailing. *American Journal of Agricultural Economics*, **77**(December), 1313–1318.

Jaffry, S.A., Pascoe, S., Taylor, G., & Zabala, U. (2000) Price interactions between salmon and wild caught species on the spanish market. *Aquaculture Economics and Management*, **4**, 157–167.

Johansen, S. (1988) Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control*, **12**, 231–254.

Marshall, A. (1947) *Principles of Economics*. Macmillan, London.

Nielsen, M. (2005) Price formation and market integration on the European first-hand market for whitefish. *Marine Resource Economics*, **20**, 185–202.

Norman-López, A. & Asche, F. (2008) Competition between imported tilapia and U.S. catfish in the U.S. market. *Marine Resource Economics*, **23**(2), 199–214.

Stigler, G.J. (1969) *The Theory of Price*. Macmillan, London.

Stigler, G.J. & Sherwin, R.A. (1985) The extent of a market. *Journal of Law and Economics*, **28**, 555–585.

Urch, M. (2001) Tilapia set for new markets. *Seafood International*, **16**(9), 29–34.

Young, J.A. & Muir, J.F. (2002). Tilapia: both fish and fowl? Perspectives. *Marine Resource Economics*. **17**, 163–173.