VERTICAL AND HORIZONTAL INTEGRATION IN THE UGANDAN FISH SUPPLY CHAIN: MEASURING FOR FEEDBACK EFFECTS TO FISHERMEN

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ABSTRACT

The purpose of this article is to report the results of a statistical investigation of links in the fish supply chain in Uganda. We are particularly interested in the extent of ex-vessel prices impacting links downstream in the fish supply chain. We test for vertical and horizontal co-integration for five important fish species using the Johansen vector error correction model. We search for price leadership using the Toda and Yamamoto (1995) procedure to test for Granger causality. And ARIMA models are used to forecast ex-vessel prices. Our results show that ex-vessel prices are only weakly related to downstream markets.

INTRODUCTION

Uganda is a landlocked country yet produces substantial quantities of both capture and farmed fish. Capture harvest is based on fresh water lakes, particularly Lake Victoria, abundant in the country and the Nile River.[a] Capture harvest levels have varied widely from just over 200,000 tonnes in 1997 to reach a maximum of twice this level in 2004 falling again to about 350,000 tonnes in 2009 [2]. Farmed fish is a relatively new industry in Uganda but has grown rapidly in the last ten years and now produces about 50,000 tonnes of fish, mostly Catfish and Tilapia, per annum [4]. Capture fish harvesting is artisanal in nature. The technology in use is a combination of traditional and modern [9]. The Ugandan fisheries sector is not large relative to say, agriculture but does contribute about 2.8% of GDP and employs about 4% of the total population.[b]

The ex-vessel price is an important driver in setting income levels and overall welfare of fishermen. However, the price of fish is exogenous to the behaviour of individual fishermen and set by external factors. In export markets, these external factors are certainly dictated by world demand and supply forces. In local markets, not only demand and supply factors influence price but monopoly and strategic pricing behaviour in downstream markets also impact ex-vessel price. It is possible that both aquaculture and fisheries sectors have forward and backward linkages to postharvest handling, processing, and marketing that impact ex-vessel price of fish [1]. Strategic pricing can impact the magnitude of price pass through the market segments, the length of time to adjust to price shocks and asymmetric price response to positive or negative shocks. Thus, it is important to understand the welfare of fishermen in order to understand the price links and causality in price determination in the fish supply chain and the factors that impact the ex-vessel price of fish.

The purpose of this research is to carry out a statistical investigation of market prices in the fish supply chain for Uganda. The data used in the statistical work is the average monthly real Ugandan Shilling price of five fish species, Nile perch (*Lates niloticus*), African catfish (*Clarias gariepinus*), mukene (*Rastrineobola argentea), Bagrus* (*Bagrus docmac*) and tilapia (*Oreochromis niloticus*). We are interested in determining the direction of price causality in the supply chain, the consequence and impact of shocks at different levels of the supply chain and test for vertical and horizontal integration at different levels of the supply chain.

Our empirical strategy is first to test for vertical and horizontal integration using the Johansen vector error correction (vec) procedure. Next we employ Toda and Yamamoto (1995) procedure to test for Granger causality. Finally, we use univariate ARIMA models to forecast the ex-vessel price of fish.

PRICE DATA

Monthly average price data[c] are available for five fish species; Nile perch, tilapia, *Rastrineobola* (mukene), African catfish and *Bagrus*. Nile perch is primarily an export product and price information is available for five nodes in the supply chain, ex-vessel, landings, industrial processing, retail and export. Mukene is a dried product destined for local markets and we have price information on three nodes in the supply chain i.e. ex-vessel, landings, and retail. Tilapia and *Bagrus* species we have price for three nodes in the supply chain i.e. ex-vessel, landings and retail where as for catfish we have landings, farmed and retail prices.

As we are interested in horizontal integration at the ex-vessel and retail nodes in the supply chain, we will proceed by first summarizing prices at this level. Figure 1 indicates monthly trends in the real ex-vessel price of perch, *Bagrus*, tilapia, catfish and mukene. Fishermen receive the highest value for perch, the species destined for the export market and the lowest value for mukene, a dried product for local consumption. Perch shows a steady rise in price over the period with a sharp increase at the end of 2009. The real ex-vessel price of mukene has been flat with little variation but we do see a slight increase in price near the end of the data period. On the other hand, *Bagrus*, tilapia, and catfish, (all sold into the fresh local market), appear to follow a similar rising trend over time. Notice early on in the data catfish received the highest of the three prices but this is reversed by the end of the period.

Looking only at trends in the price series it appears that perch and mukene follow separate and individual trends over the period, whereas, *Bagrus*, tilapia and catfish appear to follow a somewhat similar trend over time. Similarity in trends is important information and a necessary condition for horizontal integration in ex-vessel prices.

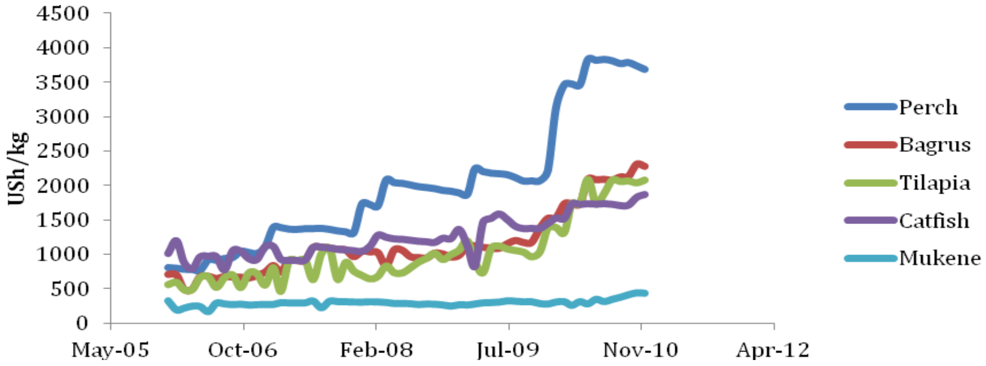

Figure 1: Real ex-vessel Prices, January 2006 to December 2010

Figure 2 shows real retail prices of whole ungutted perch, *Bagrus*, catfish and tilapia. This is an interesting figure where perch, Bagrus and catfish appear to follow a similar trend over time but tilapia experiences several shocks over the period; a positive shock early in the series, a major negative shock late in the period and in between the trend it was relatively flat.

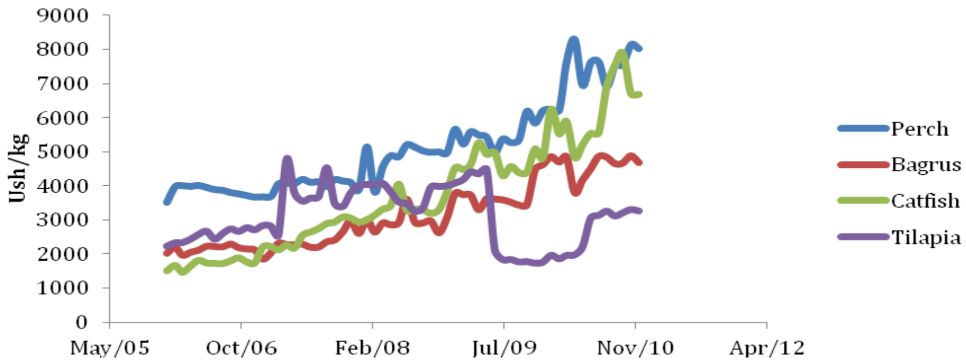

Figure 2: Real Retail Prices Whole Ungutted , January 2006 to December 2010

Notice that *Bagrus* follows a slightly steeper trend relative to perch and catfish and is subject to both positive and negative shocks late in the period. The negative price shock in tilapia in 2009 is likely caused by increased competition from tilapia producers in the EU. Increased competition in the EU reduced Ugandan exports and increased local supply, forcing downward pressure on price [7].

In terms of horizontal integration it appears that perhaps *Bagrus* and catfish follow a similar trend with perch and certainly tilapia following separate trends over the data period.

Apart from the horizontal intergration,we are also interested in vertical integration in the fish supply chain and to summarize the prices for this possibility we graph out downstream supply prices for perch, mukene and catfish. Figure 3 reports price trends for perch from ex-vessel to export and retail markets. Figures 4 reports price trends for mukene showing ex-vessel, landings and retail prices, where as Figure 5 reports ex-vessel, farmed and retail price trends for catfish.

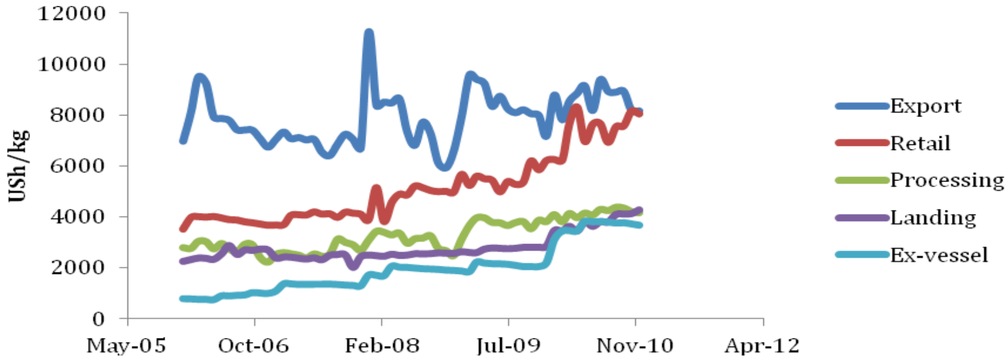

Figure 3: Real Prices Nile Perch, January 2006 to December 2010

For perch, Figure 3, we observe positive trends in all prices except export prices, which although showing much variation over the period the trend is rather flat. Also notice the very steep positive trend in retail prices with a positive shock near the end of the data period. Only ex-vessel price shows a similar positive shock.

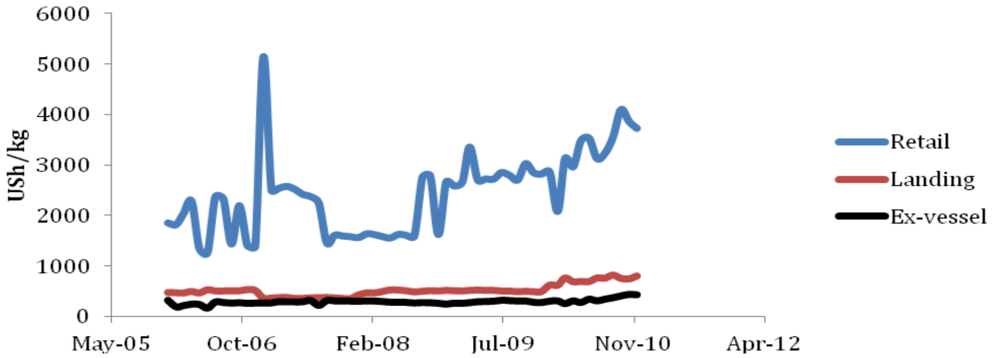

Figure 4: Real Prices Mukene, January 2006 to December 2010

For mukene, Figure 4, ex-vessel and landings prices show very little variation or positive trend over the period. This is quite different from trends in retail price which indicates a huge variation over the period and a positive trend in price in the last part of the period.

For catfish, Figure 5, we observe positive trends in all prices but farm price shows much greater variation relative to capture price. From casual observation it appears that shocks in one part of the supply chain do not obviously carryover to other sectors.

Nevertheless, we will test for this possibility later in the paper. Both farmed and captured catfish are headed to the fresh local markets, although farmed fish enters the marketing channel nearer the consumer and thus tends to be of higher quality.

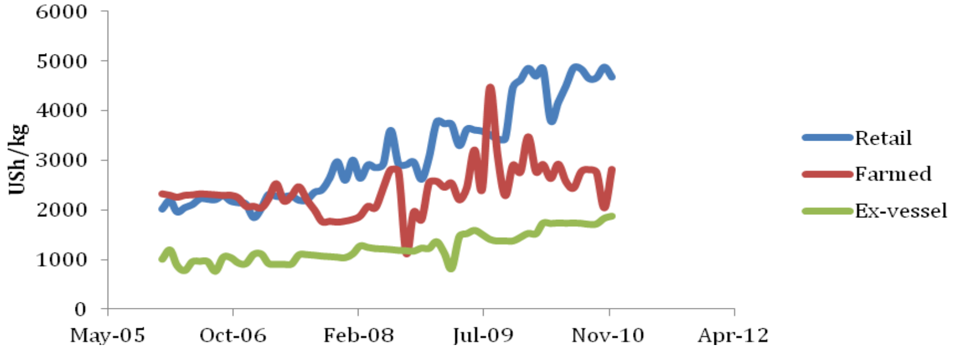

Figure 5: Real Prices Catfish, January 2006 to December 2010

We summarize the information in the above figures in Table I, which defines the mean and range of prices. Generally, perch attracts the highest real price in both the ex-vessel and retail markets whereas mukene receives the lowest.

Table I: Price Summary Statistics, USh/kg

Ex-vessel	**Mean**	**Minimum**	**Maximum**
Perch	1979.59	766.90	3825.73
Bagrus	1149.31	488.04	2306.42
Tilapia	1026.02	462.75	2087.01
Catfish	1251.34	767.09	1873.68
Mukene	292.211	163.69	441.09
Retail			
Perch	5132.01	3527.65	8297.72
Bagrus	3712.55	1469.59	7903.21
Catfish	3148.34	1845.19	4886.19
Tilapia	3095.91	1732.98	4790.59
Perch			
Export	7913.67	5930.17	11255.83
Processing	3257.13	2204.87	4358.65
Landing	2812.89	2032.08	4284.02
Mukene			
Retail-Dried	2433.44	1257.36	5130.48
Landing	521.97	359.39	821.48

Finally in terms of summary statistics, we want to graph out the margin between ex-vessel price and the final market price, either retail or export. This will provide important information on the trend in the share of total price received by fishermen. Figure 6 shows the margins in the perch market between ex-vessel and export as well as ex-vessel and retail.

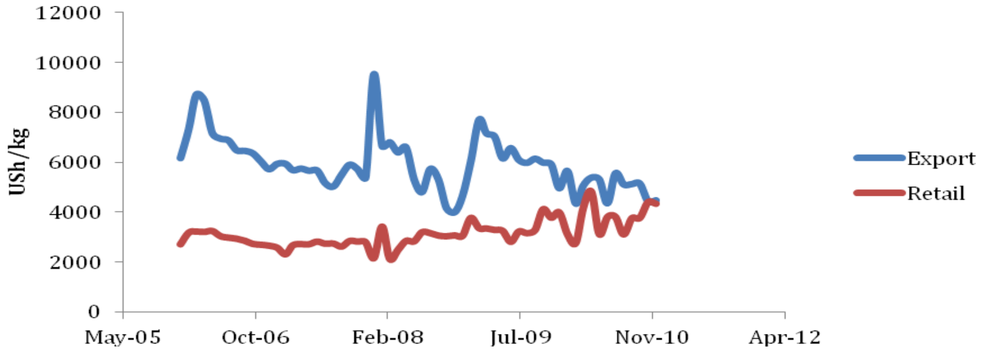

Figure 6 Price Margin Perch between Ex-vessel and Export/Retail

This graph is interesting in that the export margin declines over the period and the retail margin increases. Near the end of the data period the margins are roughly equal. Perhaps these trends

reflect the growth and development in the high-end local perch market where we would expect rates of return to be similar across export and retail markets. However, the graph shows that the end markets in the perch supply chain capture a major share of the final price.
Figure 7 shows monthly price margins for *Bagrus*, mukene, catfish and tilapia over a five-year period.

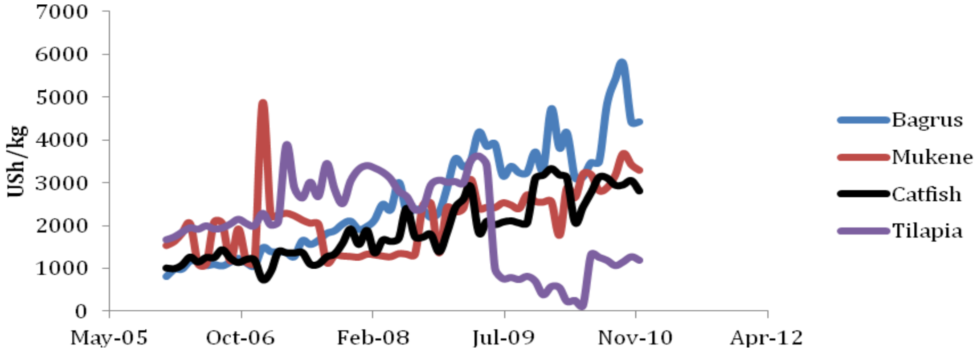

Figure 7: Price Margin Ex-vessel and Retail for *Bagrus*, Mukene, Catfish and Tilapia.
For all prices except tilapia we observe a positive trend in margin over the period. Tilapia shows quite a different profile to the other prices being relatively flat early on in the data period and suffers strong negative shocks in the later period caused by the rapid decline in retail prices observed in Figure 2.
For most fish prices we see increasing margins between the ex-vessel and final market. We must be careful not to rush to a conclusion that fishermen are worse off over time in terms of share of final value of the product. The ex-vessel and retail/export markets are separate functioning markets having their own characteristics of supply and demand. Margins reflect an only price received and not costs of presenting the product to the market. In other words, to make a conclusion on the share of return we must measure profit at the different nodes in the supply chain. However, the prices reported here reflect primarily fresh product with limited processing and as such the price margins may well reflect the increasing returns overtime captured by the end markets in the supply chain.

ECONOMETRIC MODELS AND RESULTS

In this section, we are concerned with combining the data at hand with econometric models that provide useful information on the price relationship between the ex-vessel price, farmed price for catfish and other nodes in the supply chain. Prior to such an investigation the first thing that must be completed is a characterization of the probability structure of the defined price variables. We want to determine if the structure of the probability data generating process is stable over time. A number of statistics are available for testing stability or stationarity and here the augmented Dickey-Fuller approach is used. Anticipating the empirical results we find that all series are first-difference stationary and this leads us to an investigation of both horizontal and vertical cointegration in the fish supply chain. A vector error-correction (vec) model is used in statistical testing. Finding evidence of both horizontal and vertical integration leads us to ask what nodes in the supply chain are price leaders in the market. To this end we apply the Toda and Yamamoto (1995) procedure to test for Granger causality. We find surprisingly scant evidence of the role of ex-vessel price as a price leader in the fish supply chain. From this we turn to a univariate ARIMA modeling approach of each ex-vessel price. We complete the statistical work with short-run forecasts of ex-vessel prices.

Stationarity is an important property of the data generating process because we avoid measuring common trends in the data that could obscure the economic relationship of interest. In applying the Dickey-Fuller procedure to test for stationarity the null hypothesis is that the price series is characterized as nonstationary with an alternative hypothesis of stationary in first-differenced values of the variable. We first test the price variables[d] in level form and report results in column 2 of Table II.

Table II: Stationarity Tests[a)]

Ex-vessel	Levels	First-Difference
Perch	-0.971	-4.242[d)]
Bagrus	-0.105	-6.668[d)]
Tilapia	-0.197	-7.369[d)]
Catfish	-0.681	-7.409[d)]
Mukene	-0.777	-6.801[d)]
Retail		
Perch	0.809	-5.067[d)]
Bagrus	-1.075	-4.936[d)]
Catfish	-0.742	-5.401[d)]
Tilapia	-2.004	-4.241[d)]
Perch		
Export	-2.885[b)]	-5.703[d)]
Processing	-1.031	-6.183[d)]
Landing	-0.828	-5.786[d)]
Mukene		
Retail-Dried	-1.165	-5.854[d)]
Landing	-0.510	-4.556[d)]

[a)] Dickey-Fuller statistic with two lags | [b)] Statistically significant at the 10% level.
[c)] Statistically significant at the 5% level. | [d)] Statistically significant at the 1% level.

In all cases, except the export price of perch we cannot reject the null hypothesis at p-values less than 5%. The export price of perch does show signs of stationarity at the 10% level. This is interesting because it shows that the probability structure of export prices may be different from ex-vessel prices of perch and may indicate a weak relationship between these prices. Next, we take the first differences of the price variables and repeat the test. The null hypothesis now is that the series is stationary in second-differences against as alternative hypothesis of stationary in first-differences. The results are reported in column 3 of Table II and now for all price variables we can easily reject the null and accept the alternative hypothesis of stability/stationarity in the first-difference values of the variables. The stationarity results provide useful information for econometric modelling. It tells the researcher that in order to model the underlying economic relationships we must use variables that are stable over time. In the case at hand, this implies that modelling be carried out in first differences of the price variables.

With all variables first-difference stationary there exist the possibility that at least some of the price variables are cointegrated or, in other words, the prices may form a stable long-run economic relationship. To investigate this possibility we test for both horizontal and vertical cointegration in the fish supply chain. Johansen (1988; 1991) provides a straightforward and robust procedure using prices to test the hypotheses. The procedure is straightforward in that a vector error-correction (vec) model of the prices is used to test the existence of equilibrium or market integration. The procedure is robust in that the vec model avoids the possibility of endogeneity and thus identification issues by modelling the lagged change in price regressed on the current change in price. To set up the test consider a simple restricted linear error form representation of price *i* and all other prices *s*:

$$\varepsilon_t = P_t^i - \sum_s^S \beta_s P_t^s \qquad \text{……………………(Eq. 1)}$$

where P_t is a specific market price in log level form, and i and s represent the different nodes in the supply chain. If equilibrium exists then $(1, -\beta_s)$ represents a cointegrating vector that produces a residual term, ε_t that is stationary. Moreover, β_i defines the equilibrium links (or long-run parameters) between prices in the different market segments. Given that we have multi-variate price models it may be that there exists more than one vector of parameters defining the equilibrium. In equilibrium, the residual (equation (1)) takes the value zero, but if fish prices are above the equilibrium the error term is negative and if prices are below the equilibrium the error term is positive.

The long-run equation can be combined with a short-run distributed lag model of change in prices to ensure that prices above the equilibrium are adjusted downward and prices below the equilibrium are adjusted upward. The vector error-correction model can be written as:

$\Delta P_t^i = \sum_{k=1}^{K} \alpha_k \Delta P_{t-k}^i + \sum_{s=1}^{S} \sum_{j=0}^{J} \alpha_{js} \Delta P_{t-j}^s + \gamma(\varepsilon_{t-1}) + \vartheta_t$............(Eq. 2)

for all fish prices *i* and *s*, ϑ_t is an i.i.d. error structure. Note that all variables specified in equation (2) are stationary and thus equation (2) represents a well-defined econometric model.

Based on equation (2) Johansen shows that the Trace statistic ($= -T \sum_{i=r+1}^{K} \ln(1-\hat{\lambda}_i)$) has a null hypothesis that there is no more than *r* cointegrating relationships ($\hat{\lambda}_i$ are the estimated eigenvalues from equation (2) and *T* is number of observations). Table III reports test results for horizontal co-integration at the ex-vessel and retail market level. Table IV reports the same for the vertical co-integration is the downstream supply links for perch, mukene and catfish.

For ex-vessel testing in Table III, in pretesting of price variables, we found that perch and mukene ex-vessel prices are not part of the equilibrium price system but that we cannot reject a null hypothesis that there exist two co-integrating vectors defined for the ex-vessel prices of catfish, tilapia and *Bagrus*. Similarly for the retail market we again reject perch and mukene as part of the long-run system and statistically observe two co-integrating vectors defined for the retail prices of catfish, tilapia and *Bagrus*.

Table III: Johansen Horizontal Co-integration, Ex-vessel, Retail

	Null[a)]	Trace Test[b)]	Critical 5%
Ex-vessel[c)]	Max 1	19.38	15.41
	Max 2	0.016*	3.76
Retail[d)]	Max 0	34.7245	29.68
	Max 1	6.4290*	15.41

[a)] Lags chosen using BIC
[b)] Johansen Trace Test
[c)] Catfish, Tilapia, *Bagrus*
[d)] Catfish, Tilapia, *Bagrus*, whole un-gutted
[*] Statistically significant 5% level

Table IV reports the Trace test results for vertical integration. For perch we investigate long-run integration for both the export and retail markets. We observe two co-integrating vectors in the ex-vessel, factory gate and retail supply chain but only one co-integrating vector in the corresponding export supply chain. For mukene and catfish supply chains we again observe two co-integrating vectors. Notice for catfish we examine the relationship amongst ex-vessel, farm and retail prices.

Table IV: Johansen Vertical Co-integration, Perch, Mukene, Catfish

	Null[a)]	Trace Test[b)]	Critical 5%
Perch[c)] export	Max 0	41.91	29.68
	Max 1	9.04*	15.41
Perch[d)] retail	Max 0	34.08	29.68
	Max 1	7.97*	15.41
Mukene[e)]	Max 1	17.33	15.41
	Max 2	0.01*	3.76
Catfish[f)]	Max 1	24.42	15.41
	Max 2	0.62*	3.76

[a)] Lags chosen using BIC | [b)] Johansen Trace Test | [c)] Ex-vessel, factory gate, export | [d)] Ex-vessel, factory gate, retail | [e)] Ex-vessel, landing, retail | [f)] Ex-vessel, farm, retail | [*] Statistically significant 5% level

The co-integration results, except for perhaps the perch export chain, show strong long-run links in the supply chain. This implies two important structural characteristics, first, there does exist a long-run relationship both in horizontal and vertical market segments of the fish supply chain in Uganda. In other words, the co-integrated prices move together overtime and do not drift apart from each other. And second, that there must exist causality or price leadership in the supply chains. We are particularly interested in the impact of causality and the importance of ex-vessel prices (or farmed prices for catfish) as price leader in the downstream supply chain and we investigate this possibility with tests for Granger causality. Testing for Granger causality is straightforward and based on the idea that if past realizations of one price are statistically useful in predicting the current value of another price then it is said that the first price Granger causes the second. In a bivariate case for price *i* and *j* the model is simply:

$$P_t^i = \alpha_o + \sum_{t=1}^{T} \gamma_{t-1} P_{t-1}^i + \sum_{n=1}^{N} \beta_{n-1} P_{n-1}^j + \varepsilon_t \quad \text{........................(Eq. 3)}$$

The lag on past prices is chosen to ensure that ε_t is i.i.d. The null hypothesis is that all β_{n-1} are zero, or no causality running from the j^{th} price to the i^{th} price. Toda and Yamamoto (1995) suggest a modification to equation (3) prior to testing to ensure that the Wald statistic used in testing is asymptotically correct. The correction is to augment equation (3) with additional price lags appended to the model based on the highest order of integration to achieve stationarity in prices.[e] We carry out causality testing for the perch supply chain both export and retail reporting results in Table V and the results for the mukene and catfish supply chains are reported in Table VI.

Table V: Granger Causality Perch Supply Chain

Equation	Test	χ^2	p-value
Export	Factory	1.49	0.221
	Ex-vessel	1.09	0.297
Factory	Export	2.74[a)]	0.098
	Ex-vessel	0.09	0.759
Ex-vessel	Export	0.74	0.187
	Factory	0.46	0.227
Retail	Factory	0.35	0.839
	Ex-vessel	10.22[b)]	0.006
Factory	Retail	0.68	0.712
	Ex-vessel	0.28	0.870
Ex-vessel	Retail	4.15	0.126
	Factory	0.36	0.257

[a)] Statistically significant at 10% level | [b)] Statistically significant at 1% level

In the first half of Table V the perch exports supply links are estimated. We measure price leadership from exports to factory gate but no other causal links are observed. Surprisingly, ex-vessel prices have no causal impact on factory prices or exports. What is more, exports and factory prices do not Granger cause ex-vessel prices. Given that prices are not policy regulated, these results could be caused by market power in the export sector that merely sets the price for fish supply and the ex-vessel sector is not developed or able to counter. In the second half of Table V we report Granger results for the perch retail supply chain and here we do observe price leadership from ex-vessel prices to retail prices. This result is consistent with standard results found in agricultural markets where causality runs from the farm gate to retail. But notice that factory gate prices play no role in the perch retail market and this is probably because the market is fresh whole un-gutted with little or no processing.

In the first half of Table VI we report causality results for the mukene dried fish supply chain. Here we observe price causality running from retail and landings prices back to ex-vessel prices but ex-vessel prices are passive in this market chain. In addition, with a p-value of 13% landing prices impact retail prices. The landing price will reflect the drying process of the fish and this sector in the supply chain sets the prices certainly at the ex-vessel level and less so at the retail level. However, this puts the fishermen in a poor position with no ability to influence prices in the supply chain.

Table VI: Granger Causality Mukene and Catfish Supply Chains

Mukene	Test	χ^2	p-value
Retail	Landing	2.26	0.133
	Ex-vessel	0.06	0.792
Landing	Retail	0.001	0.973
	Ex-vessel	0.03	0.862
Ex-vessel	Retail	3.44[a)]	0.064
	Landing	4.21[b)]	0.040
Catfish			
Retail	Farm	0.45	0.503
	Capture	4.09[b)]	0.043
Farm	Retail	2.66[a)]	0.100
	Capture	0.59	0.439
Capture	Retail	0.32	0.569
	Farm	0.07	0.796

[a)] Statistically significant at 10% level | [b)] Statistically significant at 5% level

The second half of Table VI reports the causality results for the catfish supply chain. Here we want to measure the relationship between capture and farmed fish and the retail market. The results suggest a chain of causality running from the capture fishery to retail and retail to farmed fish.

This seems counterintuitive given that captured catfish are only 30% or so of the market so it is unlikely that segment of the market cannot dictate retail price. What might explain this result is fishermen get little for catfish as it is a low valued fish, but they have to get a minimum price or they will not fish for the market. The ex-vessel price could be the basic minimum to sustain the market. On the other hand, farmed catfish goes into a somewhat higher end retail market and is likely more profitable to retailers so they are willing to pay for quality. The data is consistent with this in the sense that retail price sets farmed price.

We have observed very weak links in the supply chain between the ex-vessel price and other prices in the chain. In this section of the paper we want to focus only on ex-vessel prices and enquire as to structure and realization of prices based only lagged values of the price (dynamic shocks) and current and lagged values of the stochastic error term (stochastic shocks). This modelling procedure (ARIMA[f]) is particularly useful if the process can be characterized as an autocorrelated series of unobserved shocks.[g] The ARIMA can be considered a reduced form price model for the purpose of short-run forecasting and most importantly identification is maintained by only lagged dependent and stochastic values appearing on the right-hand-side.[h] Because the ARIMA model is well identified a maximum likelihood estimator will generate consistent parameter estimates. It is possible to augment the ARIMA price model by including exogenous variables in specification for the purpose of improving forecasting possibilities and to reduce forecast error.[i] These extensions are defined as ARMAX or transfer function models and for the case at hand we include the causal prices as defined by Granger causality.[j]

The specification of the univariate price model is defined as:

$$Ex\_vessel_t = \alpha_o + \alpha_t' X_t + \sum_{i=1}^{p} \gamma_i Ex\_vessel_{t-i} + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} + \varepsilon_t \quad \ldots\text{(Eq. 4)}$$

where $Exvessel_t$ is the ex-vessel price of fish in period *t*, X_t is a vector of exogenous prices assumed to impact the ex-vessel price in period *t*, $\sum_{i=1}^{p} \gamma_{Vi} \Delta Exvessel_{t-i}$ represents the autoregressive (AR) component (dynamic shocks), $\sum_{j=1}^{q} \theta_j \varepsilon_{t-j}$ represents the moving average (MA) component (stochastic shocks) and ε_t is an *iid* random error term. Estimation of equation (4) is based on maximum likelihood procedures.[k]

Selecting the correct lag specification for equation (4) is critical for generating an estimated equation with good forecasting potential. Our research strategy is to evaluate alternative AR and MA lag structures based on review of the autocorrelation and partial autocorrelation functions with possible candidate specifications defined on testing *iid* conditions in the stochastic error term using a Box-Lung Q-statistic. Among those candidate specifications the preferred model is identified by measured BIC statistics.[1] We carry out the ARIMA modelling for the perch, mukene and catfish supply chains and report results in Table VII.

Table VII: ARIMA Models, Perch, Mukene and Catfish

	Perch		Mukene		Catfish	
	ARMAX	ARIMA	ARMAX	ARIMA	ARIMA	ARIMA
AR_1	0.056 (0.743)	0.054 (0.747)	-1.282 (0.0.001)	-0.151 (0.545)	0.273 (0.599)	0.315 (0.030)
AR_2	-	-	-0.201 (0.439)	-0.488 (0.003)	-0.287 (0.392)	-0.301 (0.076)
MA_1	-	-	0.457 (0.231)	-0.568 (0.062)	-0.834 (0.127)	-0.878 (0.000)
MA_2	-	-	-0.411 (0.170)	0.552 (0.022)	-0.043 (0.944)	-
Retail	-0.019 (0.887)	-	0.072 (0.256)	-	-	-
Landing	-	-	0.107 (0.690)	-	-	-
Obs.	59	59	58	58	59	59
BIC	-116.92	-120.97	-61.54	-59.68	-73.55	-77.62
Q-stat (p-value)	0.534	0.506	0.784	0.881	0.999	0.999

The first thing to report from the table is the lack of importance of all the exogenous variables as defined from the Granger causality results for the perch and mukene models. Second, for the perch equation we can find no correlation with past prices or past shocks in the system. The data represent the ex-vessel perch market as time independent. This implies that what happened in the past appears to have no statistical impact on current price. For the mukene univariate system we do measure both dynamic and stochastic shocks impacting current price. For the catfish equation the best model fits two dynamic shock components and one stochastic component.

The ARIMA models are important for short-run forecasting of prices. Of course, given that we cannot measure past correlations in the perch equation forecasting is mute but we can carry out forecasting for both the mukene and catfish prices. Figure 8 shows for mukene prices one-step ahead price forecasting for the period January 2006 to December 2009 and dynamic forecasting for the period January 2010 to December 2010. The one-step a head forecasts certainly follow the trend in the series but the dynamic forecasts fail to pick the trend and the turning point in the series.

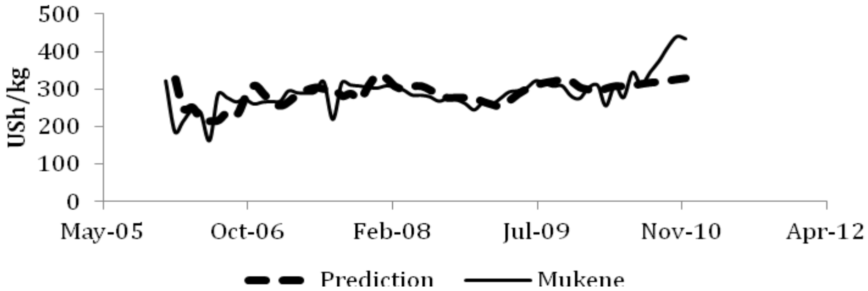

Figure 8: Dynamic Predictions Ex-vessel Price Mukene

Figure 9 shows catfish prices one-step ahead forecasting for the period January 2006 to December 2009 and dynamic forecasting for the period January 2010 to December 2010.

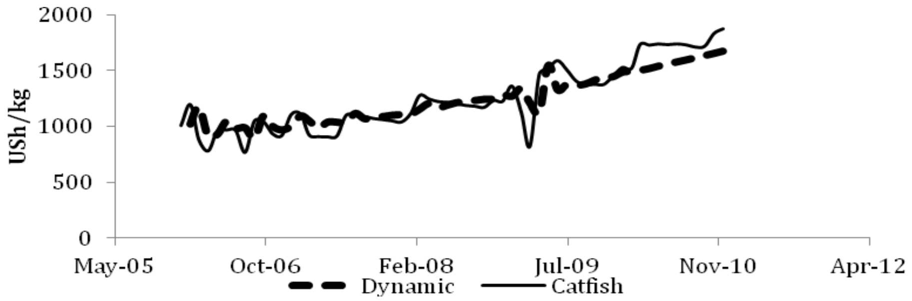

Figure 9: Dynamic Predictions Ex-vessel Price Catfish

The one-step a head forecasts again follows the trend in the series and the dynamic forecasts predict the trend reasonably well. Nevertheless, the dynamic forecast fails to capture the turning points in the series.

SUMMARY AND DISCUSSION

The purpose of this report is to provide a statistical investigation of links in the fish supply chain in Uganda. We are particularly interested in the extent of ex-vessel prices and farmed price (catfish) impacting links downstream in the fish supply chain. We approach the statistical problem in three ways; we test for vertical and horizontal co-integration for five important fish species using the Johansen vector error correction model, we search for price leadership using the Toda and Yamamoto (1995) procedure to test for Granger causality. And we use ARIMA models to forecast ex-vessel prices. We do find that markets tend to be integrated indicating that prices in the supply chain move together over time but also ex-vessel prices are only weakly related to downstream markets and have limited price leadership.

What can we learn from the statistical results? (Keep in mind, when we talk about fisheries management we are, of course, referring to capture fisheries). We can think of this in two parts; first, in terms of fisheries management and, second, in terms of policy implications for the fisheries. For fisheries management it is clear from economic theory and experience in other fisheries that an open access fisheries policy is not the efficient instrument for governance. All rent is dissipated and a sustainable fishery is doubtful. To complicate matters for Uganda the primary fish production site (Lake Victoria) is jointly managed by two other countries; Kenya and Tanzania. Nevertheless, there are examples of fisheries management where multi-countries[m] share the resource in a sustainable manner and can serve as guiding principles for Lake Victoria. On the road to proper management is the setting of TAC limits and proper enforcement to reduce and hopefully eliminate illegal fishing.[n] Clearly, if the TAC is set without regard to proper biology or compliance is ignored fisheries management is moot. Our horizontal integration work for capture fisheries shows that perch and mukene are separate non-linked markets compared to capture fisheries for catfish, *Bagrus* and tilapia. A TAC can be set separately for perch and mukene, but an overall TAC is needed for catfish, *Bagrus* and tilapia as they form one market.

In terms of policy implications, our results show very weak links from the ex-vessel price to downstream markets. This is particularly evident in the export perch supply chain. We suspect that market power in the export market restricts price variation and value to the ex-vessel market. There may be two possibilities to improve conditions for fishermen; first increase competition for raw perch product in the export sector and, second, to encourage a single selling desk at the ex-vessel level for export quality perch. For the former, increasing competition may be difficult because of vested interests. The export sector is characterized by many fishermen supplying an export-processing sector of about 20 firms. The export-processing sector is regulated for health and food safety and regulators may be reluctant to increase substantially the number of processing firms because of the difficulty in maintaining food standards. There may be other issues. For the latter, the small number of processing firms makes it possible for a single selling desk representing the interests of fishermen. Of course, for this to be feasible the government must be fully supportive, enact necessary legislation requiring processors to buy from the desk and enforcement.[o]

Ugandan fisheries policies for non-export fisheries are more difficult given the vast number of fishermen, the open access nature of the fishery, the possibility of fishermen to avoid regulations, and the multi-country nature of shared resources on Lake Victoria. The government is aware of the difficulties and some positive steps towards central governance are underway; examples include the registration of fishermen and fishing boats on Uganda's waters, and continued multi-country talks on regulations and enforcement on Lake Victoria.

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ENDNOTES

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[a] Uganda has an estimated 165 lakes accounting for 18% of its area [5]
[b] 2009 data
[c] Price data collected by Ssebisubi (2011)
[d] The real price variables have been log transformed.
[e] See D. Giles for a clear discussion in application of the Toda-Yamamoto correction: http://davegiles.blogspot.com/2011/04/testing-for-granger-causality.html
[f] Autoregressive Integrated Moving Average Model.
[g] For an excellent review of applied time series econometrics see, Enders (2004).
[h] For an interesting discussion of the first serious price forecasting model see, Gordon and Kerr (1997).
[i] The restriction on the exogenous variables requires that there be no feedback effect to the dependent variable (Enders, 2010)
[j] Seasonal and trend variables were also included in specification but did not statistically improve the forecast.
[k] Estimation is carried out using STATA 11 software.
[l] Bayesian Information Criteria.
[m] See, http://www.un.org/Depts/los/fish_stocks_conference/fish_stocks_conference.htm
[n] Setting a TAC requires proper biology in determining stock levels in rivers and lakes and compliance in harvest levels. Of course, setting a TAC and compliance issues on Lake Victoria will be complicated by multi-country shared resource.
[o] See, Hannesson, 1985 for a detailed description of the economics of fisheries marketing boards.