STRUCTURAL BREAKS IN THE FISHMEAL - SOYBEAN MEAL PRICE RELATIONSHIP

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ABSTRACT

The rapid increase in global aquaculture production since the early nineties has increased the demand for fishmeal as an ingredient in aquafeed. This increase has been hypothesized as the source of disruption in the fishmeal market by researchers such as Delgado et al. In this paper we evaluate whether or not there has been a change in the price relationship between fishmeal and soybean meal, its closest vegetable substitute. We focus on the behavioral implications of a change in substitutability. We test if structural breaks in the optimal commodity futures hedge strategy of a risk averse trading agent have occurred. Further we test if the breaks have also changed the long run relationship between the commodities by testing for cointegration. The results clearly support the hypothesis of structural change during the period 1978 to 2003. We identify two breaks, in August 1988 and in December 1995/January 1996. Both break dates coincide with supply side shocks. The first break occurred before the rapid increase in aquaculture production indicating that its role in the change of the price relationship is overstated. Cointegration analysis also supports the occurrence of structural breaks.

Keywords: Cointegration, cross commodity futures hedging, fishmeal - soybean meal price relationship, structural breaks

INTRODUCTION

Many authors have expressed concerns about the supply of fishmeal setting limits to the growth of aquaculture. A recent example is a report by Delgado et al published by the International Food Policy Research Institute (IFPRI). The concern is that aquaculture is likely to require an increasing quantity of fishmeal as global production expands. However, world fishmeal production has not increased since the mid eighties and is not likely to increase substantially in the near future. The expected result is that the price of fishmeal will increase creating a price squeeze for the aquaculture industry and that the fishmeal price increase will also cause increasing fishing pressure on small pelagic fish used in the manufacture of fishmeal. In addition, since fishmeal and soybean meal are relatively less interchangeable in aquafeeds, than they are in traditional animal feeds, there is likely to be a decoupling of fishmeal - soybean meal price relationship.

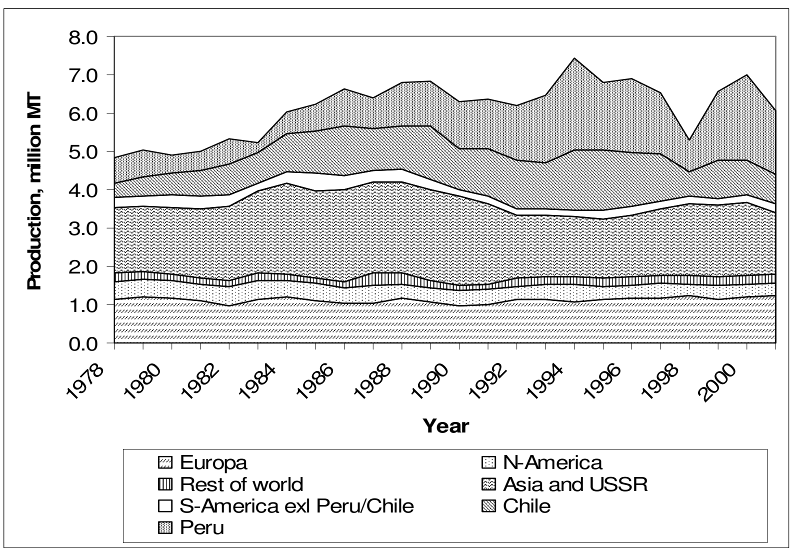
Vukina and Anderson and Asche and Tveteras have analyzed the price relationship between fishmeal and soybean meal. The first study found significant risk reduction possibilities for fishmeal traders in soybean meal futures by using cross-commodity hedging. The second study concludes that the prices of fishmeal and soybean meal are cointegrated. Both these results indicate a close price relationship. However, recent events may suggest that this is no longer the case (Hardy and Tacon, Delgado et al). It is therefore timely to reevaluate the relationship to determine if, when and how the changes in the market have affected the relationship between the two prices. Determining if the link between the two markets has changed is of interest to fishmeal producers and buyers, as well as, aquaculture, poultry and swine producers, and fishery managers. A less close relationship raises a concern about a more volatile fishmeal price, since it's supply varies greatly from year to year. More volatile prices increase the firms overall risk and thereby affect their access to capital and abilities to do accurate planning. If prices are likely to rise, then the profitability of backstop technologies will increase.

The purpose of this paper is to determine if and when a structural change occurred between the fishmeal and soybean meal markets by analyzing their price relationship. We use the optimal cross commodity futures hedge ratio model Vukina and Anderson, which provides useful interpretations in terms of behavioral implications of changes. Close substitutes should have an optimal cross hedge ratio that is significantly different from zero. Changes in optimal cross hedge ratio indicate changes in substitutability. Further, the implications for a trading agent of an optimal hedge ratio that is not significantly different from zero are clear, suggesting that the hedge cannot be used to effectively reduce price risk. In addition we will test for cointegration between the two price series to verify the implication of our results on the long run relationship, as done by Asche and Tveteras.

Both the fishmeal and soybean meal markets have gone through a number of supply and demand side changes over the study period. It is therefore difficult to identify expected break points *a priori*. There are some good candidates but the decision of what to include will always be somewhat arbitrary. On the other hand the recently proposed test procedure of Bai and Perron (1998, 2003a) allows for the identification of structural breaks of unknown number and at unknown points in time. This liberates the researcher from arbitrarily having to choose break points to test and than having to choose between them the most significant ones. This method will therefore be used to identify if and when structural breaks occurred in the relationship between the two markets.

BACKGROUND

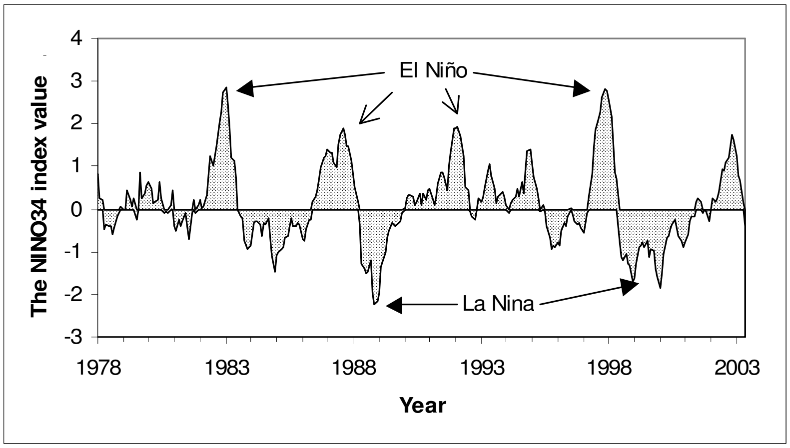
Figure 1 the world production of fishmeal has been relatively stable since the late eighties at about 6 million MT.



(Reference: FISHSTAT, FAO 2003)

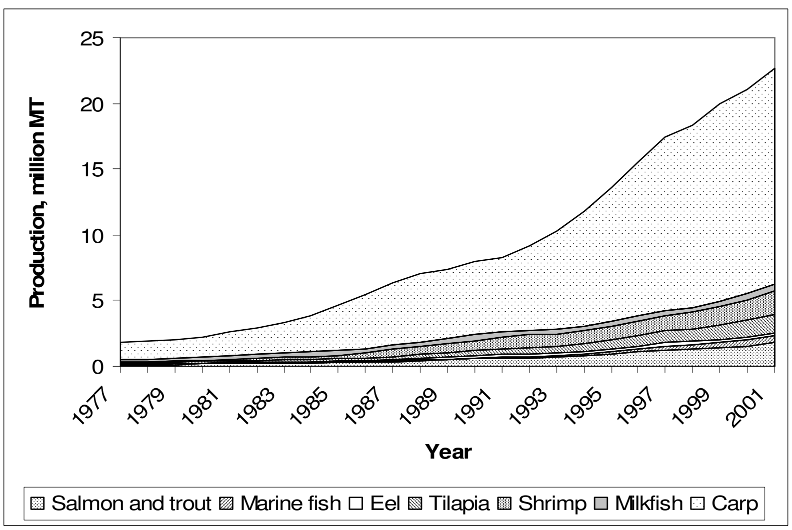
Figure 1. World production of fishmeal by region.

It also shows that Peruvian and Chilean production has fluctuated more than the production of other countries. This is due to El Niño, a warm water current that sweeps across the Pacific and can cause substantial reductions in catches of the South American coast. A coldwater current that occurs in the same region, called La Nina, has been associated with severe draughts in the US Midwest (Trenberth and Branstator). The currents in the Pacific can therefore affect both fishmeal and soybean meal prices, though variations in catch of the South American coast and soybean harvest in the US Midwest. Figure 2 shows the development of NINO 34, the index used to identify both events, over the last 25 years. It measures deviation form normal sea temperature in a specific region of the Pacific. Positive numbers indicate that sea temperature is warmer than normal, an indication of a possible El Niño, while negative numbers indicate colder that normal sea temperatures.



(Reference: NOAA 2003)
Figure 2. The NINO34 index.

The NINO34 index has an alternating pattern of warm and cold currents with some large deviations. The largest events of the period are the El Niño of 1983 and 1998 and the La Nina of 1988.
Over the last decades, aquaculture has experienced unprecedented growth. Many species such as shrimp and salmon have gone form small-scale farming to large-scale industrial production (Anderson). Figure 3 illustrates the growth over the last 20 years of world production of farmed fish and crustaceans by mayor species.



(Reference: FISHSTAT, FAO 2003)
Figure 3. World production of farmed fish and crustaceans (by major species).

The largest quantity increase is in the production of carp. Most of the finfish and crustacean species are omnivores or carnivores and benefit from, if not require, fish protein in their feed. As a consequence the growth in aquaculture has caused the aquafeed industry to demand increasingly more fishmeal as input. The quantity of fishmeal as input in aquaculture production went from a small fraction of world production to a substantial market share in less than a decade (Hardy and Tacon). Table I presents an overview of world fishmeal production and both shares and quantities of the major uses by year for all years where data could be found.

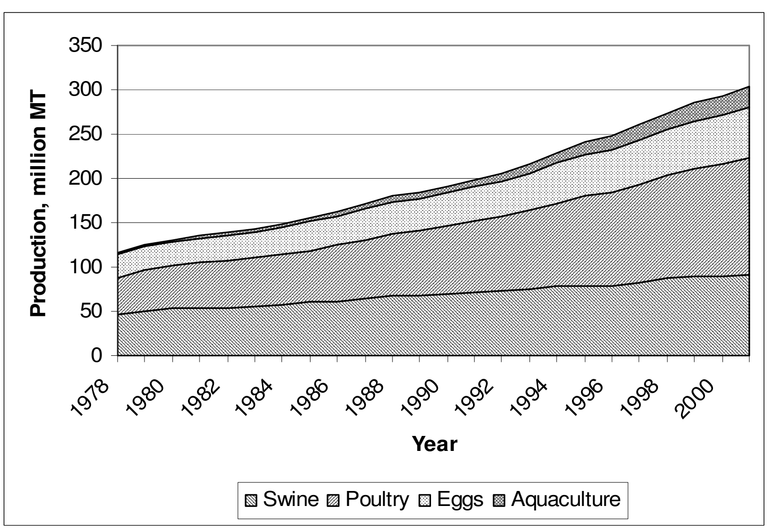
Table I: World production of fishmeal in millions of tons and the use of fishmeal in aquafeed.

Year	World [2] Production MMT [3]	Aquafeed use MMT	% of WP [4]	Reference [1]
1986	6.69	0.52	8%	Wijkstrom and New
1988	6.85	0.69	10%	New, Shehadeh & Pedini
1992	6.25	0.96	15%	New and Wijkström
1994	7.48	1.27	17%	Pike
1995	6.85	1.73	25%	Tacon (1998)
1996	6.92	2.00	29%	Tacon (1999)
1997	6.54	2.32	35%	Tacon (1999)
1998	5.33	2.13	40%	IFOMA
1999	6.57	2.10	32%	IFOMA
2000	7.02	2.46	35%	Pike and Barlow
2001	6.08	2.49	41%	Pike and Barlow
2002	6.52	2.22	34%	Barlow

[1] Partly based on table 5 in New and Wijkström
[2] FISHSTAT, FAO 2003
[3] Million metric tons
[4] World production

The trend is obvious. Aquaculture has gone from a minor user of fishmeal in the late eighties to a substantial user in the late nineties. A somewhat different pattern is seen in table I than in figure 3. Although the growth in consumption is largest during the early nineties it has been relatively stable since 1997, while production continues to increase as figure 3 shows. This indicates that production relationship has not been fixed and less fishmeal is used per quantity unit output than before. This observation suggests that the assumptions of the limited substitutability of fishmeal in aquafeed may be overestimated.

From figure 1 we know that total production has not been increasing so fishmeal going into aquafeed has been at the expense of other users such as the poultry and swine feed industries. Figure 4 shows world production all the large users of fishmeal. It helps put the production of farmed fish into the relevant perspective of agricultural production,



(Reference: FISHSTAT, FAO 2003)
Figure 4. World production of swine, poultry, eggs and farmed fish.

What looked like a dramatic increase in figure 3 is in fact relatively minor compared to the increases in production of other products that traditionally have used fishmeal as an input. It further indicates that there are other possible sources of increased demand pressure on the world fishmeal market.
So far the discussion has focused on the fishmeal market ignoring soybean meal. The production of soybeans has experienced some supply shocks; the most important of which was the draught of 1988. It caused dramatic 21 percent reduction in soybean yield in the US and is recognized as one of the worst and most costly natural disaster in US history (Karrenbrock). It is mentioned here due to its monumental size. It is conceivable that a supply side event of this magnitude in the soybean meal market might have caused a disruption in the relationship between the two markets. Although the discussion has focused on the fact that soybean meal is not a perfect substitute for fishmeal the reverse is also true and should not be dismissed *a priori* as a possible cause.

This discussion about the two markets suggests the following changes that might have lead to changes in the relationship between the two markets over the period 1978 to 2003. First and foremost there is the rapid increase in the use of fishmeal in aquafeed during the period 1994 to 1996. Second there are two major events on the fishmeal supply side, the El Niño of 1983/1984 and 1997/1998. Third there is one major event on the soybean meal side, the draught of 1988.

In well functioning markets the prices of close substitutes follows a common pattern. If a significant change occurs in the common pattern it indicates changes in substitutability. We analyze the relationship within the optimal commodity futures cross-hedge ratio framework. Its relevance of this model is clear and implications for the trading firm are easily interpreted. Generally one expects to find that the prices of close substitutes are closely linked such that there exits an optimal cross-hedge ratio that is significantly different from zero. Further, we test for cointegration between the prices to verify the implications of our results for the long run relationship.

MODEL

Commodity futures are standardized contracts to buy or sell certain goods at set prices at a predetermined time in the future. To hedge is to lower overall risk by taking on an asset position that offsets an existing source of risk. Commodity traders hedge in commodity futures to reduce the price risk of their planned transactions. The hedger's objective is to minimize the risk of his planned transaction. He is able to do that by taking a position in the futures market. His problem is to determine the size of his position, or more generally the relative size of it compared to his planed transaction in the cash market. This is referred to as a hedge ratio. A risk averse hedger wants to identify a hedge ratio that minimizes the variance of the value of his transaction. If the difference between the cash price and the futures price, referred to as basis, remains constant the hedger is easily able to offset all his risk by taking a equally large position is the futures market as his planned transaction, a hedge ratio of 1. His losses or gains in the cash market will be perfectly offset by his losses or gains in the future market. In reality basis is not stable and the hedger has to weigh together the price risk and the basis risk.

Futures do not exist for all commodities. Cross commodity hedging is the process of hedging a cash commodity in the futures market of a different, but related, commodity. Cross hedging will generally work well for reducing price risk if the price of the commodity being cross hedged and the price of the futures commodity are closely related and follow one another in a predictable manner, meaning hedged price risk is less than unhedged price risk. Cross hedge price risk refers to the price actually received by hedging relative to what was expected, and unhedged price risk refers to general price level variability. The general theory of financial derivative pricing and optimal hedging strategy is found in several books such as Carter. Anderson and Danthine described the optimal cross hedging strategy. Their basic methodology has been applied to a number of agricultural commodities; see for example Hayenga and DiPietre Kahl, Buhr and Rahman, Turner and Costa.

Let P_t and f_t be the cash and futures price in period t when the decision is faced to take a futures position and P_T and f_T be the cash and futures price in period T when the cash transaction is planned. Let V be the value of the transaction and h be the hedge ratio. The long hedgers value can be presented by:

$V_l = (-P_T + P_t) - h_l(-f_t + f_T)$ (1)

and the short hedgers value by:

$V_s = (P_T - P_t) - h_s(f_t - f_T)$ (2)

The minimization problem faced by the hedger is to solve

$$\underset{h}{Min}\left\{\text{var}\left(P_t - P_T\right) + h^2\,\text{var}\left(f_t - f_T\right) - 2h\,\text{cov}\left[\left(P_t - P_T\right)\left(f_t - f_T\right)\right]\right\} \qquad (3)$$

where var stands for variance and cov stands for covariance.

By taking the first derivative with respect to the hedge ratio and solving for it we can derive the minimum variance hedge ratio:

$$h = \frac{\text{cov}\left[\left(P_t - P_T\right)\left(f_t - f_T\right)\right]}{\text{var}\left(f_t - f_T\right)} \qquad (4)$$

If basis is constant the two variances and the covariance will be the same and a minimum of zero can be reached at h=1. If the two prices are uncorrelated, indicating a covariance is zero, the optimal value must be var(P_T - P_t) at h=0. The covariance between the changes in the cash and futures market is therefore the key.

The cross hedge ratio of equation (6) can be determined by examining the *ex post* hedging efficiency model following Brorsen, Buck, and Koontz. In the case of a cross hedge between fishmeal and soybean meal the equation to be estimated is the following:

$$\Delta_k P_t^f = \beta_0 + \beta_1 \Delta_k F_t^s + u_t \qquad (5)$$

where Δ_k is a difference operator and the subscript k[1] indicates the length of the hedging period, P^f is the cash price of fishmeal and F^s is the price of a soybean meal futures contract[2]. The error term in equation (5) is commonly found to be autocorrelated. We use the method suggested by Andrews to correct for autocorrelation.

The most commonly used tests for structural change rely on the assumption that the point of change is known. This is a serious drawback when the cause is uncertain. There are however methods that allow the identification of the most probable point of change and the number of brake points. The method used here was suggested by Bai and Perron (1998, 2003a). Same authors have also provided the limiting distributions for the test statistics (Bai and Perron 2003b). This method does not require any *a priori* definition of the brake periods or the number of brakes but identifies both based on the data. For description see Bai and Perron (1998).

The tests for long run relationships employed in this paper evaluate whether the individual non-stationary time series in a multivariate system are driven by a reduced number of common stochastic trends. We use the classic Dickey Fuller (Dicky and Fuller) unit root test to determine if the prices are stationary and the order of integration. Cointegration can be tested within the Engle-Granger (Engel and Granger) framework or the vector autoregressive (VAR) model with the Johansen-Juselius trace test (Johansen 1988 and 1991 and Johansen and Juselius). The latter is considered more powerful and will be used here. For description see Johansen and Juselius.

DATA

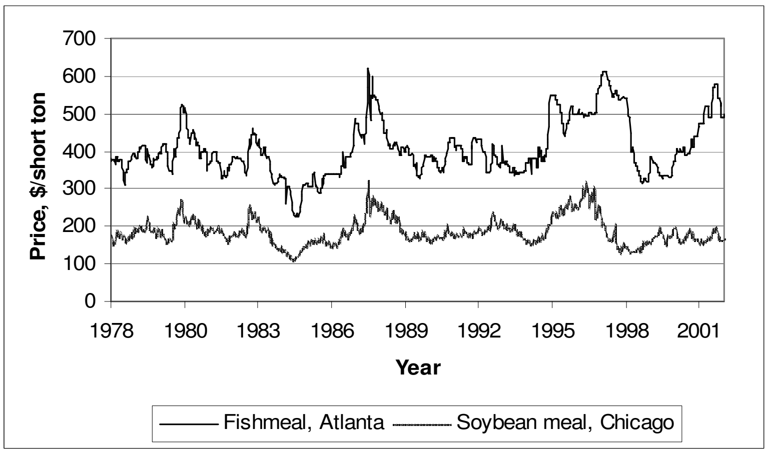
The fishmeal data are the Atlanta Menhaden prices reported weekly by *Feedstuffs* for the period January 2nd 1978 to December 30th 2002. Daily data for soybean meal prices and futures contract prices was obtained form the Chicago Board of Trade for the same period. Weekly frequency for the soybean meal data was obtained by taking the Tuesday close, or the Wednesday close if there was no trading on Tuesday[3]. Table II presents descriptive statistics for the two cash prices and the rolling futures contract.

Table II: Descriptive statistics.

	Cash prices		Futures
	Menhaden meal[1]	Soybean meal[1]	Soybean meal[1]
Observations	1304	1304	1304
Mean	406.9	185.0	184.2
Std Dev	74.5	35.5	34.5
Minimum	225	107.5	118.1
Maximum	620	320	322.5

[1] $ per short ton

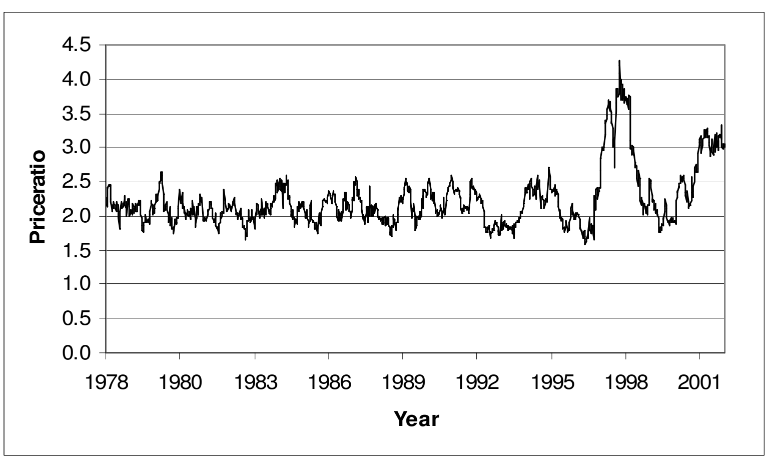
The table indicates a significant amount of variation in the prices. Figure 4 illustrates cash prices for soybean meal in Chicago and Menhaden meal in Atlanta over the last 25 years.



(Reference: CBOT and *Feedstuffs*)

Figure 4. The price of fishmeal and soybean meal.

The two prices seem to have been subject to similar shocks. This is consistent with the general assumption that the two commodities are close substitutes. It seems, however, that the relationship has weakened since the mid nineties. Figure 5 shows.



(Reference: CBOT and *Feedstuffs*)

Figure 5. The price ratio between fishmeal and soybean meal prices.

that a relatively fixed price relationship existed prior to 1990 but became less stable during the nineties. The large increase in the price ratio during 1998 and 2001 coincides with El Niño's.

RESULTS

Optimal hedge ratio and structural breaks

Table III shows the test results from the Bai-Perron sequential test for one to three breaks and three hedge periods, two, four and six weeks.

Table III. The SupF statistics for the Bai-Perron sequential test of a structural break and the identified break dates for all hedge ratios.

	SupF(1|0) H0:*l*=0	SupF(2|1) H0:*l*=1	SupF(3|2) H0:*l*=2
2 week	15.6**	8.3	5.4
4 week	22.4**	4.5	7.4
6 week	36.7**	2.3	3.7

** significant at 1% level
* significant at 5% level

No structural break is rejected in favor of one for all three hedge periods. The other two hypotheses, two versus one and three versus two are not rejected. The overall results clearly suggest one structural break. Table IV presents the date of each break, the 95% confidence interval of the break and the unadjusted[4] optimal hedge ratio before and after the break point

Table IV: Break point with 95% confidence interval identified by the Bai-Perron method and unadjusted optimal hedge ratio before and after break with.

Hedge length	Estimated breakpoint	95% CI		Optimal hedge ratio	
		Lower	Upper	Before break	After break
2 week	08/22/88	06/29/87	04/17/95	0.86 (4.96)[1]	0.11 (1.46)
4 week	12/18/95	05/15/95	10/21/02	1.00 (6.08)	0.08 (0.78)
6 week	01/01/96	09/11/95	08/28/00	1.08 (7.21)	0.06 (0.71)

[1] t-values calculated using autocorrelation consistent standard errors (Andrews 1991)

The results for different hedge periods differ, as seen in table IV. A structural break in August of 1988 is identified for the two-week hedge period[5]. This coincides with the "great drought" of 1988. Some caution must be shown in interpreting the results due to the size of the confidence interval. However, this seems to indicate that after the drought of 1988 the possibilities for effective hedging in the short run all but disappeared The estimated hedge ratio prior to the break point was 0.86 after the break the estimated unadjusted cross hedge ratio after the break is not significantly different from zero. The large confidence interval may indicate a gradual change in the relationship. Nonetheless, this shows that the pressure on the fishmeal market was substantial even before the large increase in aquaculture production. A different date is identified for the longer hedges, in December 1995 and January 1996 for four- and six-week hedge periods respectively. The close proximity of these breaks indicates a common event. This period coincides with reduced catches of Menhaden in late 1995. The supply of fishmeal in the US market was very limited and market prices soared to a level where no quantity was traded (see e.g. Scheid and

House). The confidence intervals indicate a true break period in the late nineties. It is worthwhile to note that this includes the big El Niño event of 1998. The unadjusted hedge ratios show a similar result as for the shortest hedge period, significant hedging opportunities before the break but not after. The hedge ratio estimates in table III correspond with the results of Vukina and Anderson. Further, the estimated hedge ratios indicate a higher optimal ratio the longer the hedge period. This is a sign of a stronger long run than short run relationship.

Cointegration

The Augmented Dickey-Fuller (ADF) unit root test statistic for the two price series for the raw data (level) and first difference form are reported in table V.

Table V: The results from an ADF for the two price series on level and first difference form with lag length in parenthesis.

Period		Fishmeal				Soybean meal			
From	To	Level		First difference		Level		Frist differanse	
01/02/78	12/23/02	-3.32	(4)[1]	-16.38***	(3)	-3.53*	(2)	-15.27***	(6)
01/02/78	08/29/88	-0.85	(7)	-9.10***	(6)	-2.09	(7)	-9.64***	(6)
09/05/88	12/23/02	-2.48	(10)	-8.94***	(5)	-2.18	(4)	-14.82***	(3)
01/02/78	12/25/95	-3.09	(4)	-14.40***	(3)	-2.99	(7)	-12.82***	(6)
01/15/96	12/23/02	-2.00	(12)	-4.41**	(11)	-1.69	(4)	-10.42***	(3)
09/05/88	12/25/95	-1.10	(6)	-10.21***	(2)	-1.14	(3)	-11.43***	(2)

*** significant at 0.1% level, ** significant at 1% level, * significant at 5% level

[1] The rule used to identify lag length is AIC2 as described by Pantula, Gonzales-Farias and Fuller

The results in table V indicate that all the variables are integrated of order 1 during the whole period and all sub-samples[6].

Table VI presents the results of the Johansen cointegration trace test for three different model definitions, with deterministic (trend) and stochastic (drift) trends in the process, with no deterministic trend and finally with neither deterministic nor stochastic trend. Further we report the simple Engle-Granger cointegration test with deterministic and stochastic trends for comparison.

Table VI: Results of the Johansen cointegration trace test for three different model definitions and an Engle-Granger cointegration test for the least restrictive model.

Period		Johansen trace test results						Engel-Granger	
		Drift and trend		Drift, no trend		No drift, no trend		Drift and trend	
From	To	H0:r=0	H0:r<=1	H0:r=0	H0:r<=1	H0:r=0	H0:r<=1	Fish[1]	Soy[1]
01/02/78	12/23/02	30.60**	11.29***	26.30**	10.83*	15.42*	0.19	-3.87*	-3.98*
01/02/78	08/29/88	37.43***	3.12	36.25***	3.44	32.98***	0.12	-5.08***	-5.65***
09/05/88	12/23/02	17.97	6.58**	14.30	6.19	7.57	0.95	-2.85	-2.56
01/02/78	12/25/95	37.94***	7.60**	37.16***	7.52	29.59***	0.01	-5.26***	-5.52***
01/15/96	12/23/02	14.94	4.68*	10.29	3.10	6.93	0.69	-1.58	-1.78
09/05/88	12/25/95	12.62	2.74	16.31	6.47	9.97	0.03	-2.56	-2.55

*** significant at 0.1% level, ** significant at 1% level, * significant at 5% level

[1] Identifies the dependent variable in the regression.

The result for entire dataset, from 1/2/78 to12/30/2002 in the first row of table VI, depend on model definition. Cointegration is supported by the trace test without drift and trend and an Engle-Granger test but not by the unrestricted trace tests. The test is therefore not conclusive. On the other hand the sample from 1/2/78 to 8/29/1988 is clearly cointegrated. The results for sample form 1/2/78 to 12/25/1995 also strongly support cointegration. Generally, this is in accordance with the results of Asche and Tveteras who concluded that US fishmeal and soybean meal prices from January 1981 to August 1999 were cointegrated.

Cointegration is not found in the two series (9/15/88 to12/23/02 and 1/15/96 to12/23/02) that occur after the break dates identified in table IV based on futures hedging model. These results are consistent with the occurrence of a structural break and support the results in tables III and IV. The results in table VI however, do not favor one break over the other. Both break dates result in clear evidence of cointegration for the period before the break but not after. In addition, analysis of the period between the break dates (9/5/1988 to 12/25/1995), does not reject non-cointegration. However, the sample between the break dates is small and the result may potentially be due to lack of statistical power. Since cointegration is an indication of a long run relationship, it is reasonable to conclude that the cointegration analysis lends somewhat greater support to the date indicated by the longer hedge periods. The cautious interpretation is therefore to conclude that December 1995/ January 1996 represents a break date in structural relationship between fishmeal and soybean meal markets[7].

CONCLUSIONS

The purpose of this paper was to look for changes in the relationship between fishmeal and soybean meal by analyzing hedge strategies and price relationships. The evidence clearly supports the hypothesis that a structural change has occurred. The Bai Perron method identifies one structural break in the optimal hedge ratio model, indicating a break date in August 1988 for a two week hedge period and in December 1995/January 1996 for the longer four and six week hedge periods. The first break coincides with the draught in the US Midwest during 1988 while the second coincides with the reduced catch of US Menhaden in late 1995. Both events are supply side shocks, not demand side shocks. Further, the first date indicates that the relationship between the two markets was already under strain in the late eighties, before the rapid increase in global aquaculture production. It is therefore an oversimplification and misleading to claim that increased demand from the growing aquaculture industry is responsible structural breaks in the fishmeal/soybean meal price relationship. However, the evaluation of longer period hedges and the cointegration analysis suggest persistence weakness in the relationship between the two markets after the break dates. Based on this study, the increasing demand from the aquaculture sector cannot be ruled out as a factor in continuation of the weakness in the price relationship. Cointegration analysis supports the occurrence of a break. The series are clearly cointegrated before the two break dates, in August 1988 and December 1995, but not after. The analysis does not favor one date over the other. Cointegration is an indication of a long run relationship between prices. In the absence of a test procedure, we make the cautious interpretation that the date indicated by the longer hedge periods, December 1995/January 1996, is the date most clearly indicated for the occurrence of a structural break.

ENDNOTES

1. The length of a typical hedge period is not easily determined. We have included 2, 4 and 6 weeks. We feel that this captures the most typical hedge periods.
2. A number of simplifying assumptions have to be made to ensure the appropriateness of the model presented in equation (5). The lumpiness of future contracts is ignored and brokerage commissions are assumed subtracted afterwards. For ex post hedging efficiency to have any meaning one must assume that the future will be like the past.
3. Feedstuffs is published on Mondays. The weekday of soybean meal close was chosen among the days of the prior week by maximum correlation to minimize the risk of a mismatch in the data.
4. Unadjusted means here that the levels of the prices have not been taken into account. The measure of the optimal hedge ratio is in quantity rather than value
5. Similar results were obtained for one and three week hedge periods.
6. The only exception to a simple interpretation is soybean meal prices over the whole period. Since none of the sub-samples verify the result it is dismissed.
7. The sum of log likelihood for that model is slightly larger than for the break in August 1988.

REFERENCES

Andrews, D. W. K., 1991, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix Estimation, *Econometrica*, 59, pp. 817-58

Anderson, J.L., 2003, *The International Seafood Trade*, Woodhead Publishing LTD. Cambridge.

Anderson, R.W., and J.P. Danthine, 1981, Cross-Hedging, *Journal of Political Economy,* 89, pp. 1182-1196.

Asche, F. and S. Tveteras, 1998, On the Relationship Between Aquaculture and Reduction Fisheries, *IIFET 2000 Proceedings,* 2000.

Bai, J. and P. Perron, 1998, Estimating and Testing Linear Models with Multiple Structural Changes, *Econometrica*, 66, pp. 47-78

Bai, J. and P. Perron, 2003a, Computation and Analysis of Multiple Structural Change Models, *Journal of Applied Econometrics,* 18, pp. 1-22.

Bai, J. and P. Perron, 2003b, Critical Values for Multiple Structural Change Tests, *Econometrics Journal,* 6, pp. 72-78.

Barlow, S.M., 2002, *The World Market Overview of Fish Meal and Fish Oil*, Paper presented to the 2nd Seafood By-Products Conference, Alaska in November

Brorsen, B.W., D.W. Buck, and S. R. Koontz, 1998, Hedging Hard Red Winter Wheat: Kansas City versus Chicago, *Journal of Futures Market*s, 18, pp. 449-466.

Buhr, B.L., 1996, Hedging Holstein Steers in the Live Cattle Futures Market, *Review of Agricultural Economics,* 18, pp. 103-114.

Carter, C.A., 2003, *Futures and Options Markets: An Introduction*, Pearson Education Inc., Upper Saddle River, NJ.

Delgado, C.L, N. Wada, M.W. Rosegrant, S. Meijer, and M. Ahmed, 2003, *Fish to 2020: Supply and Demand in Changing Global Markets*, IFPRI and WorldFish Center. Washington DC.

Dickey, D.A. and W.A. Fuller, 1979, Distributions of the Estimators for Autoregressive Time Series With a Unit Root, *Journal of the American Statistical Association*, 75, pp. 427-431.

Engle, R.F. and C.W.J. Granger, 1987, Co-integration and Error Correction: Representation, Estimation and Testing, *Econometrica*, 55, pp. 277-304.

Hardy, R. W. and A.G. J. Tacon, 2002, Fish Meal: Historical Uses, Production Trends and Future Outlook for Sustainable Supplies, In Stickney, R. R. and J. P. McVey, *Responsible Marine Aquaculture*. CABI publishing, Oxon.

Hayenga, M.L., and D.D. DiPietre, 1982, Cross-Hedging Wholesale Pork Products using Live Hog Futures, *American Journal of Agricultural Economics* 64, pp. 747-751.

House, C., 1995, Soybean prices continue to climb; weather aids ingredient markets, *Feedstuffs* 67(18), pp. 29.

IFOMA, 2001, Sustainability of Fish Meal and Oil Supply, *Paper presented at Scottish-Norwegian Conference on Sustainable Futures for Marine Fish Farming*.

Johansen, S, and K Juselius, 1990, Maximum Likelihood Estimation and Inference on Cointegration - With Applications to the Demand for Money, *Oxford Bulletin of Economics and Statistics*, 52, pp. 169—210.

Johansen, S., 1988, The Statistical Analysis of Cointegration Vectors, *Journal of Economic Dynamics and Control*, 12, pp. 231—254.

Johansen, S., 1991, Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models, *Econometrica*, 59, pp. 1551—1580.

Kahl, K.H., 1983, Determination of the Recommended Hedging Ratio, *American Journal of Agricultural Economics* 65, pp. 603-05.

Karrenbrock, J., 1989, The 1988 Drought: Its Impackt on District Agriculture. *The Federal Reserve Bank of St. Louis Review,* May/June 1989, pp. 3-13.

New, M. B. and U. N. Wijkström, 2002, Use of Fishmeal and Fish Oil in Aquafeeds: Further Thoughts on the Fishmeal Trap, *FAO Fisheries Circular No. 975*. Food and Agriculture Organization of the United Nations, Rome.

New, M.B., Z. Shehadeh and M. Pedini, 1995, Status and Trends in Food Production through Aquaculture, *FAO Aquaculture Newsletter (FAN)*, 9, pp. 12-18.

Pantula, S. G., G. Gonzales-Farias and W. Fuller, 1994, A Comparison of Unit-Root Test Criteria, *Journal of Business and Economic Statistics, 12(4), pp.* 449-459.

Pike, I., 1998, Future Supplies of Fishmeal and Fish Oil: Quality Requirements for Aquaculture with Particular Reference to Shrimp, In *International Aquafeed Directory & Buyers' Guide 1998*. Uxbridge, United Kingdom, pp. 39-49.

Pike, I.H. and S.M. Barlow, 2002, Impact of Fish Farming on Fish Stocks, *Paper presented at Bordeaux Aquaculture and Environment Symposium - September 2002*.

Rahman, S.M., S.C. Turner and E.F. Costa, 2001, Cross-Hedging Cottonseed Meal, *Journal of Agribusiness* 19, pp. 163-171.

Scheid, J.F., 1995, Crop report sends futures soaring; ingredient markets follow, *Feedstuffs* 67(16), pp. 21.

Tacon, A.G.J., 1998, Global Trends in Aquaculture and Aquafeed Production 1984-1995, In *International Aquafeed Directory & Buyers' Guide 1998*. pp. 5-37. Uxbridge, United Kingdom.

Tacon, A.G.J., 1999, Overview of World Aquaculture and Aquafeed Production, *Data presented at World Aquaculture '99. Sidney April 27- May 2.*

Trenberth, K., and G. Branstator, 1992, Issues in Establishing Causes of the 1988 Drought over N. America, *Journal of Climate,* 5, pp. 159-172.

Vukina, T., and J.L. Anderson, 1993, State Space Forecasting Approach to Optimal Intertemporal Cross-Hedging, *American Journal of Agricultural Economics* 75, pp. 416-424.

Wijkström, U.N. and M.B. New,1989, Fish for Feed: A Help or a Hindrance to Aquaculture in 2000? *INFOFISH International*, 89(6), pp. 48-52.