Fishmeal Price Behaviour: Global Dynamics and Short-Term Changes

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Abstract

About 80% of the world's pelagic fish resources are processed into fishmeal. The price of fishmeal is set on the world market and imposed to local producers. The high variability of fishmeal prices on the world market is not wholly connected with the fluctuations of aggregate supply and demand; interdependencies with other markets and speculative activities determine a large amount of this variability. This study considers the relationship between the fishmeal and soyabean meal markets. The hypothesis tested here concerns the existence of a long-term relationship directing the behaviour of the prices of these two commodities. Tests for cointegration are performed, and an equilibrium relationship is estimated. The results show that soyabean meal market induces short-term fluctuations into the fishmeal market because of speculative effects, while fishmeal price changes influence soyabean meal prices through a modification of the demand for soyabean meal.

Résumé

Près de 80 % des espèces pélagiques capturées dans le monde sont transformées en farine de poisson. Le prix de la farine de poisson fixé sur le marché mondial s'impose à tous les producteurs quelles que soient les conditions locales de la pêcherie. Ce prix présente une forte variabilité qui n'est pas toujours en rapport avec l'évolution de l'offre et de la demande mondiale; les interactions avec d'autres marchés et les activités spéculatives déterminent en grande partie les variations de prix. Des tests de cointégration et l'estimation d'un modèle à correction d'erreur montrent l'existence d'une relation à long terme entre le marché de la farine de poisson et le marché du tourteau de soja qui dirige en partie l'évolution des prix sur ces deux marchés. C'est par un effet spéculatif que le marché du tourteau de soja induit des fluctuations à court terme du prix de la farine de poisson. L'évolution du prix de la farine de poisson provoque des modifications de demande sur le marché du tourteau de soja et entraîne des changements de prix.

INTRODUCTION

Fishmeal is usually prepared from pelagic species (anchovy, sardine, jack mackerel or capelin), the most important fish resource available, but also the most unstable: sudden pelagic stock 'outbursts' or, on the contrary, sharp resource declines are frequent. Above and beyond the amount of study that goes into the reasons behind them, such variations in the availability of fish do have an impact on the overall market.

While the available data are not very precise, it can be estimated that the pelagic catches used worldwide by the reduction industry represent roughly one third of world marine catches (i.e., about 30.10^6 t out of the $90\text{-}95.10^6$ t), and about 80% of world pelagic catches. Thus, fishmeal production is the main outlet of pelagic fisheries. World fishmeal production totals about $6.5.10^6$ t, more than half of which (around $3.5.10^6$ t) moves into international trade channels. About 90% of this international trade originates from five countries (Peru, Chile, Denmark, Iceland and Norway). The main areas of consumption are Europe (a traditional market centered mainly on Germany, a leading importer), East and Southest East Asia (China, now the biggest importer, Taiwan, Japan and, more recently, Indonesia, the Philippines and Thailand), and North America (essentially the United States, although Mexico has recently developed a broader demand base). These regional destinations represent roughly 35, 40 and 20%, respectively of total exports.

Fishmeal is a commodity whose sole end-market is the feed industry, itself located upstream from the animal and meat production sectors. Beyond the protective measures implemented in various regions as part of agricultural policy agricultural markets are all very competitive and under great pressure as far as pricing is concerned. The fishmeal market is a supply-limited market, and, due to the rapid development of aquaculture, an increasing demand helps to maintain a high price level. However, as for major commodities traded in an increasingly globalized and competitive world, the world fishmeal price shows a high variability. Apart from demand and supply factors, interdependence with other commodities and financial markets determine the evolution of prices. Local producers, facing instability in the input, are price-takers for their output.

It is common knowledge that prices of commodities such as raw materials and agricultural products follow similar patterns (Deaton and Laroque, 1992). Such similarities in the behaviour of commodity prices can often be explained by the broader underlying macroeconomic factors affecting all prices in general, e.g., world inflation, interest rates or evolving demand and industrial production (Pindyck and Rotemberg, 1990). Some commodities' prices, however, can be seen to be more closely interrelated and their common trends do show additional links. Certain factors more specific to these commodity markets — e.g., substitution possibilities, complementarity, or orientation towards a same demand — have to be taken into account when explaining their co-movements (Lord, 1991). It is generally admitted, for example, that substitutability among several commodities has the effect of decreasing prices.

The evidence of a link between the fishmeal and soyabean meal markets is well known, particularly to the animal feed mill operators and traders. However, this is only an empirical observation and, although generally postulated, it has never been tested as a formal hypothesis. The purpose of this study is to verify whether there really is a specific relationship between the prices of the fishmeal and soyabean meal markets. We test the existence of and quantify the common long-term trend to which both prices may be related; also we investigate the causality links explaining the behaviour of prices. Interpretations are offered of the long-run equilibrium between prices, as well as price-forming mechanisms on the two markets.

In the first section, we shall briefly describe the markets' specificities and the nature of the data we used. The second and third sections describe the model and discuss the results obtained before moving on interpretations.

1. THE WORLD FISHMEAL AND SOYABEAN MEAL MARKETS, SIMILARITIES AND DIFFERENCES

World fishmeal production is highly dependent upon the quantities of fish caught, which in turn depend on a variety of largely uncontrollable biological and environmental factors (see contributions in this volume). The close relationship between pelagic catches and fishmeal production (tied in with the fact that the raw materials cannot be stocked for long) brings about considerable variability in fishmeal supplies. This generates a degree of market uncertainty rather unusual in commodity trading environments. The market might be regulated through fishmeal stock management on the part of the producers. In past years, however, these stocks have only represented an average of around three months' worth of production, which is rather low compared with other commodities.

Unlike other commodity markets (e.g., soyabean) the world fishmeal market is not organized into any cash or futures markets. The London Commodity Exchange attempted a futures contract for fishmeal some decades ago, but the initiative was short-lived. So the fishmeal market is consequently not as 'transparent' as other major protein markets. Transactions usually remain private, not regularly publicized. Sales contracts are settled on a bilateral basis directly between fish-processing factories and a handful of traders (around thirty) working on behalf of livestock feed companies. There is one source of information available, though. Over the years, the Reuter agency has been establishing a price quotation reporting system on the Hamburg market (the world's biggest CIF — Cost, Insurance and Freight — market); this has progressively become a market reference and the only widely and regularly publicized quotation. This is the one we have selected for our work.

Traditionally, the soyabean crop is above all devoted to oil production, although, in the crushing process, meal (i.e., the protein-rich extract) constitutes approximately 80% of the raw oilseed. Soyabean meal is, thus, a by-product of the soyabean oil industry. As a matter of fact, this is also true of most other major oilseed meals marketed worldwide, e.g., cotton, rape, sunflower, etc. Consequently, the amounts of soyabean meal supplied are largely dictated by the market demand for oil, which is in fact the fundamental source of the crush margin, i.e., the oilseed crushers' profits.

Soyabean meal is used as a source of protein by the animal feed industry, either for direct use at farm level, or blended in with mixed feeds produced by the feed mills. Soyabean meal protein levels generally reach around 44% to 48% of the total dry matter as compared to 65% to 70% in the case of fishmeal (the richest source of protein available for feeding animals). Although our work has been concerned with its role as a protein supply, soyabean meal is also used to some extent by the European feed industry as a source of energy, bringing it into competition with grain, coleseed meal, sunflower meal and corn-gluten-feed. Hence, soyabean meal prices are also linked with grain prices, which are known to be largely influenced by the subsidy or protection policies implemented by the main purchasing and producing entities, Europe and the USA (Tavéra and Dronne, 1991).

Fishmeal and soyabean meal show some similar characteristics, yet also differ in a number of ways.

Similarities include:

- A very high proportion of both commodities' production output is traded internationally. World soyabean meal production totals about 75.10^6 t, 35% of which circulates on the international market. Although this proportion is relatively lower than for fishmeal (50%), this international trade/production ratio still remains high with regard to the agricultural commodities sector. These products are consequently both very sensitive to worldwide changes in the balance of supply and demand, which has a huge impact on price levels.
- The same end-users; both commodities are competing directly with each other as sources of protein for animals (essentially poultry, pigs and aquaculture).

Differences include:

- The nature of the raw product. Soyabean is a cultivated seed harvested once a year (although the wide planting range allows two major crops per year, one in the Northern Hemisphere in September/October; one in the Southern Hemisphere in March/April). For any given year, total soyabean supply is well identified and estimated as early as harvest time and can therefore affect the markets or even be anticipated by the operators, in spite of the fact that crushing may take place at a later stage.
- Fishing remains a highly uncertain activity. Although fish stock assessments are made, these estimates do not influence the markets until the fish have been caught. However, as soon as the fish is landed, the equivalent fishmeal production becomes a market factor, because processing is done within a few hours of the catch, in order to establish a high product quality.
- The more predictable soyabean production is valuated differently on three separate well-organized and informed markets. Soyabean prices are determined worldwide on the basis of supply and demand. There are futures markets for soyabeans, soya oil and soyabean meal which are active on the Chicago Board of Trade.
- As far as fishmeal is concerned, the final product is the same without there having been any distinction whatsoever between either the species processed or the fishing zones where they are caught. However, levels of profitability can differ greatly according to species and fishing zones. What's more, it is sold on a unique and 'confidential' market that makes little information available to the public.

The competitiveness at the end-user level is the interesting point for understanding the long-term price relationship between these two commodities.

2. A COINTEGRATION APPROACH

Economic time series are generally non-stationary. It has been shown that most of them have unit root and that they are integrated of order one. Sometimes, it happens that a linear combination of integrated series gives a stationary series. In such cases, the series are said to be cointegrated (Engle and Granger, 1987; Durand and Mendelssohn, this vol.). This property is confirmed when two non-stationary series have a common trend. Such a stationary link between two non-stationary series underscores the fact that they never drift apart in the long run. If the series diverge in the short-run, then there is a mechanism to bring the two variables back towards their 'equilibrium relationship'.

If the prices of fishmeal and soyabean meal are both integrated and cointegrated, we will be led to conclude that there is a mechanism linking them in the long-term. We may then measure their structural interdependency. It should be pointed out that non-cointegration does not mean that the markets are independent. It still remains possible to find some causal links and to show that a price variation in one of the two markets can affect the other.

If the prices are integrated yet non-cointegrated, the repercussions of any market event or shock affecting its price at any given moment will persist in the future. Such processes are known as 'long-run memory processes'. A crash in fishmeal prices could be attributed to an occasional event, such as an 'El Niño' event, which brings about a sharp decline in the amount of fish caught. Or, soyabean meal prices may tumble as a result of a bad soyabean harvest in the USA or Brazil. On both markets, one-off incidents like these will have a lasting effect. Prices can be subjected to a succession of such shocks with effects that are either positive or negative. Thus, although these effects may be lasting, this does not mean that prices are sent onto an irreversible upward or downward trajectory. The sum total of these effects will result in erratic patterns of behaviour in the price level. This is what is meant by the term 'random walk'.

Cointegration, if there is any, means something else: i.e., that there is a long-term equilibrium relationship between prices which is a causal factor in price variations on at least one of the two markets, independently of other market conditions. Cointegration also implies that the two prices cannot drift too far apart for very long. Should a shock cause these prices to drift apart, a correction mechanism will bring them back into their long-term relationship, and the random walk behaviour will be reduced or disappear.

The fact that cointegration exists means that there is also a relationship of causality as defined by Granger. Granger-causality can arise for two reasons: one 'real' and the other 'speculative' (Campbell and Shiller, 1988). 'X causes Y' is commonly understood to mean that any change in X will produce a change in Y. According to the other interpretation of Granger-causality, X could cause Y if X is an anticipation or forecast of Y. In this latter case, even if we have a causality going from X towards Y, a change in the past behaviour of Y is what determines a current change in its anticipation X.

With regard to the fishmeal and soyabean meal markets, causality can be interpreted in either of these two ways without the other being ruled false.

One 'real' reason why fishmeal prices can 'cause' soyabean meal prices (and vice versa) is the products' substitutability. Both have the same end-users. Feed mill operators trying to minimize their production costs, will buy greater or lesser quantities of fishmeal or soyabean meal for use in feed rations, according to their price ratio. Thus, their long-term equilibrium relationship can be interpreted in terms of a balanced price ratio acceptable to feed millers. Any deviation from the balanced price ratio will lead to changes in purchasing behaviour. These changes in demand can in turn cause changes in price.

The fishmeal market is a 'confidential' one where little information is made public. What's more, the medium or short-term evolution of supply is not easy to anticipate. The soyabean meal market, on the other hand, is well-organized and provides such a wealth of public information as to facilitate price forecasts. Campbell and Shiller (1988) have shown how cointegration can occur between the prices of any two markets when "agents have more information about the variable they are trying to forecast than is contained in the history of that variable alone". In this case, one variable reflects the agents' rational expectation of the future of the other. Agents on the fishmeal market are known to keep a close watch on the fishmeal/soyabean meal price ratio. The key value of this ratio is fixed at 2. Any movements away from this value are taken to indicate forthcoming changes in the price of fishmeal and give rise to buying or selling. This is a 'speculative' interpretation of Granger-causality.

Being aware that when two variables are cointegrated, their cointegrating relationship is unique, we set out to check the validity of the market agents' empirical model which sets the equilibrium price ratio at 2.

3. TESTING FOR MARKET COINTEGRATION

3.1. Data used

Soyabean meal and fishmeal price series covering a period of about 13 years were set up. In order to be consistent, both series were established on the basis of CIF quotations. For fishmeal prices, we used the monthly average CIF prices quoted in Hamburg, in US dollars. For soyabean meal prices, we used the monthly average CIF prices quoted in Rotterdam until 1989 (when data ceased to be available), and then those quoted in Hamburg from 1990 on. So the results of this study are chiefly representative of the European market, the world's largest importer of fishmeal up until the beginning of the 1990s. In 1990, Europe accounted for 48% of the world fishmeal imports; this fell to a 1993 level of 37% as demand rose in Asia, due to the region's economic growth and more particularly, its development of aquaculture. Europe's share of world soyabean meal imports over the period 1987-1991 stood close to 50%. Our data sample covers January 1977 to June 1993 (Fig. 1).

3.2. Unit root tests

Several unit root tests have been developed from the first papers of Fuller (1976) and Dickey and Fuller (1981). They are based on the regression :

$$\Delta y_t = \varphi y_{t-1} + e_t \qquad \text{where } \Delta y_t = y_t - y_{t-1} \text{ and } e_t \text{ is white noise Nid } (0,\sigma^2)$$

We test the null hypothesis $H_0 : \varphi=0$ which implies that Y_t is a random walk, against the alternative hypothesis H_a: $\varphi<0$ which implies that y_t is stationary. Under the H_0 hypothesis, we are within a non-stationary framework and the ordinary least square estimator of φ does not follow the usual probability distribution. Fuller (1976) and Dickey and Fuller (1981) have tabulated the critical values of the test-statistics for various different versions of this regression.

When performing unit root tests, one must have a prior understanding of the data-generating process, especially of the autoregressive order, so as to correct any possible autocorrelation. The autocorrelation and partial autocorrelation

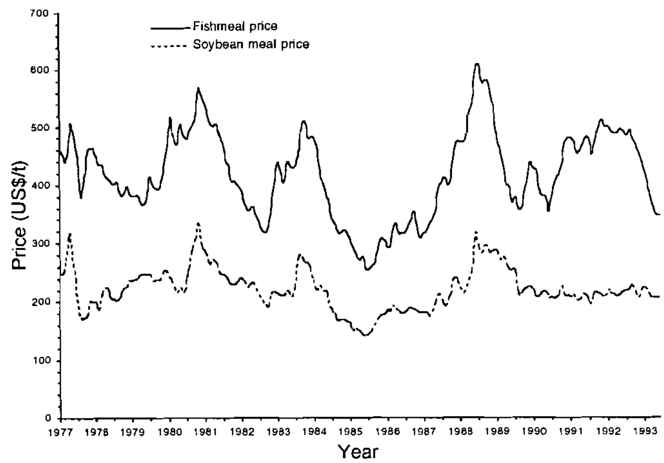

Fig. 1: Fishmeal and soyabean meal prices ($/t) January 1977 - June 1993.

functions of both fishmeal and soyabean prices indicate that they behave in the manner of an AR(2). This is confirmed by carrying out Akaike and Schwartz tests which indicate that these two level series are AR(2) and that the first differences are AR(1). The Augmented Dickey-Fuller (ADF) and Phillips-Perron (Z_t) tests have been designed to account for the series' autoregressive structure.

In order to test for a unit root leaving open the possibility of there being a deterministic trend, we used the following sequential procedure. We firstly regress thus:

$$\Delta y_t = \alpha + \beta t + \varphi y_{t-1} + \sum_{j=1}^{p} a_j \Delta y_{t-j} + \varepsilon_t \qquad \text{(ADF test - Model 1)}$$

With an ADF test, an autoregressive term is added to the regression model; p is the order of autoregressivity. For the two series p is equal to 1.

Otherwise:

$$\Delta y_t = \alpha + \beta t + \varphi y_{t-1} + u_t \qquad (Z_t \text{ test - Model 1})$$

With a Phillips-Perron (Z_t) test, the u_t term, no longer restricted to being white noise, and is an autocorrelated process. It is generally set up of order 4.

We test the null hypothesis, $H_0 : \varphi=0$, against the alternative hypothesis, $H_a: \varphi < 0$. If H_0 is rejected, we conclude that y_t is I(0). If H_0 is not rejected, we test to see if the trend coefficient is significant. If the deterministic trend is significant, it will 'dominate' the stochastic trend and the usual laws can be applied. In such case, the critical values of the gaussian distribution N(0,1) are used to test H_0. If β is not significant when H_0 is true, we run a new regression without trend (Model 2) to retest H_0 once again using the Dickey-Fuller (DF) critical values.

Note that if the Δy_t series has a deterministic trend in t, then the y_t series will have a quadratic deterministic trend.

$$\Delta y_t = \alpha + \varphi y_{t-1} + \sum_{j=1}^{p} a_j \Delta y_{t-j} + \varepsilon_t \qquad \text{(ADF test - Model 2)}$$

or else:

$$\Delta y_t = \alpha + \varphi y_{t-1} + u_t \qquad (Z_t \text{ test - Model 2})$$

If H_0 is rejected, we conclude that y_t is I(0). If H_0 is not rejected, then we test to see if the drift α is significant. If it is, we conclude that y_t has a linear deterministic trend. In this case, the deterministic trend will dominate the stochastic trend, α has a gaussian distribution and H_0 is therefore tested with this probability distribution. If α is not significant when H_0 is not rejected, then we run a regression without intercept (Model 3):

$$\Delta y_t = \varphi y_{t-1} + \sum_{j=1}^{p} a_j \Delta y_{t-j} + \varepsilon_t \qquad \text{(Model 3)}$$

We again test H_0 with the appropriate DF critical values. If the null hypothesis is rejected, then y_t is definitely I(0). If it is not rejected, this implies that y_t is integrated to an order of at least 1. Since we are unable to reach a conclusion with regard to higher orders of integration, we have to rerun the same test procedure with, for example, regressions for I(2):

$$\Delta^2 y_t = \varphi y_{t-1} + e_t$$

The results of the unit root tests for fishmeal and soyabean meal prices are summarized in Table 1. As the I(2) hypothesis was always rejected for both series, the results of these tests are not reported.

	Model 1		Model 2		Model 3
Soya	ADF	Z_t	ADF	Z_t	ADF
	t_φ =-3.58	t_φ =-3.10	t_φ =-3.56	t_φ =-3.07	t_φ=-0.69
	t_α = 3.38	t_α = 3.49	—	—	—
	t_β =-0.48	—	—	—	—
Fishmeal	ADF	Z_t	ADF	Z_t	ADF
	t_φ =-2.75	t_φ =-2.44	t_φ =-2.76	t_φ =-2.44	t_φ =-0.70
	t_α = 2.60	—	t_α = 2.68	—	—
	t_β =-0.03	—	—	—	—

Table 1: ADF and Z_t unit root tests.

The "t" statistics are of a "student ratio" type.

Critical value at (1%, 5%, 10%) for a sample of 250 observations:

t_φ : (-3.99,-3.43,-3.13) $\quad$ t_φ : (-3.46,-2.88,-2.57) $\quad$ t_φ : (-2.58,-1.95,-1.62)

t_α : (3.74, 3.09, 2.73) $\quad$ t_α : (3.19, 2.53, 2.16)

t_β : (3.49, 2.79, 2.38).

For the fishmeal price series, Model 1 allows us to accept the unit root hypothesis with coefficients α and β being null. So we must therefore refer to Model 2, where the unit root hypothesis is accepted every time. Here, however, we can consider, with a 5% risk margin, that this series also has a drift. So this price series is integrated of order 1 and behaves in the manner of a random walk with possible drift.

As far as soyabean meal prices are concerned, the conclusions are less obvious. In Model 1, the unit root hypothesis is rejected with the Dickey-Fuller test and accepted with the Phillips-Perron test. In Model 2 (β not being significant), the unit root hypothesis is rejected with the Dickey-Fuller test, and accepted with the Phillips-Perron test (with only 1% risk). With the Dickey-Fuller test, results are very sensitive to the number of lags added to the regression. It is therefore generally preferable to use the Phillips-Perron test.

Although the power of these two tests when applied outside of their standard hypotheses, i.e., (ε_t Nid$(0,\sigma^2)$), is still the subject of much discussion, it has been shown that residual heteroscedasticity leads to a far too frequent rejection of unit root hypothesis H_0 and, that the critical values should be readjusted (Kim and Schmidt, 1993). We should mention that some heteroscedasticity is present in the soyabean meal price series and in the residuals of its regression. Beck (1993) has shown that heteroscedasticity in commodity prices is attributable to speculative storage behaviour. Although the results of these tests are not very convincing, we nonetheless accept the unit root hypothesis for the soyabean meal series. The ambiguity of these results stem from the feeble 'size' of the random walk with regard to soyabean meal prices (Cochrane, 1988) and, that the deterministic trend is not very significant either. These tests are known, in certain cases, not to be very good at discriminating between Trend-Stationary and Difference-Stationary series. With these ADF and Z_t tests, the null H_0 hypothesis always stands as a pure random walk.

We shall therefore consider the fishmeal and soyabean meal price series as being I(1), with drift in the latter and the possibility of drift in the former.

3.3. Cointegration tests

Having found from the previous results that these price series are I(1), we have to test for cointegration. Three cointegrating regressions can be performed:

$$SJ_t = \alpha + \beta t + \delta FP_t + z_t \qquad \text{(demeaned - detrended);}$$

or

$$SJ_t = \alpha + \delta FP_t + z_t \qquad \text{(demeaned);}$$

or

$$SJ_t = \delta FP_t + z_t \qquad \text{(standard).}$$

SJ_t and FP_t stand for the soyabean meal price and fishmeal price respectively. If the error term z_t is I(0), then SJ_t and FP_t will be 'cointegrated', with a cointegrating vector of $(1\ -\delta)'$.

As before, the cointegration tests are based on unit root tests, but this time, these tests are performed on the z_t residuals' series. The two price series are cointegrated if the null hypothesis H_0 is rejected, i.e. if z_t. is stationary. They are not cointegrated if H_0 cannot be rejected i.e. if z_t is non-stationary. The unit root tests are performed on the following regression :

$$\Delta \hat{z}_t = \varphi \hat{z}_{t-1} + \sum_{j=1}^{p} a_j \Delta \hat{z}_{t-j} + \varepsilon_t$$

As we are performing the tests on an estimated series (the residuals), the critical values for the tests are not the same. They have been tabulated by Phillips and Ouliaris (1990).

The usual properties of the OLS estimators cease to be valid here, because the explanatory variables are non-stationary. However, these coefficients will be 'super-convergent', because they converge towards the theoretical value of the regression parameters twice as fast as usual.

Theoretically speaking, normalization on either SJ_t or FP_t will give the same results. However, we have performed the two following regressions :

$$SJ_t = \alpha_1 + \delta_1 FP_t + z_{1t}$$

$$FP_t = \alpha_2 + \delta_2 SJ_t + z_{2t}$$

In some cases, z_{1t} can be considered as stationary yet z_{2t} cannot. This occurs when the R^2 is not close enough to 1. Both tests must then be performed on z_{1t} and z_{2t}. Table 2 gives the cointegration test results.

Demeaned - detrended : critical values at 1%, 5%, 10%: (-4.36, -3.80, -3.51)				
$SJ_t = 84.62 - 0.12t + 0.35FP_t + z_{1t}$	$R^2=0.58$	DW=0.28	p=1	$t\varphi=-4.50$
$FP_t = 38.46 + 0.22t + 1.61SJ_t + z_{2t}$	$R^2=0.58$	DW=0.21	p=2	$t\varphi=-3.30$
Demeaned : critical values at 1%, 5%, 10%: (-3.96, -3.36, -3.06)				
$SJ_t = 74.13 + 0.35FP_t + z_{1t}$	$R^2=0.55$	DW=0.26	p=1	$t\varphi=-4.34$
$FP_t = 72.70 + 1.56SJt + z_{2t}$	$R^2=0.55$	DW=0.19	p=2	$t\varphi=-3.26$
Standard : critical values at 1%, 5%, 10%: (-3.38, -2.76, -2.45)				
$SJ_t = 0.52FP_t + z_{1t}$	$R^2=0.41$	DW=0.23	p=1	$t\varphi=-3.95$
$FP_t = 1.88SJ_t + z_{2t}$	$R^2=0.53$	DW=0.22	p=1	$t\varphi=-3.92$

Table 2: Cointegrating regression and ADF tests for cointegration.

The Durbin-Watson and R^2 statistics are sometimes used in order to test for cointegration, but this procedure has been much criticized and has to be interpreted with care (Perron and Campbell, 1992). The DW and R^2 statistics cannot be interpreted here to the usual ends.

Going on the demeaned-detrended regression, the hypothesis of stationarity will be accepted for the z_{1t} residuals, but rejected for the z_{2t} series. Going on the demeaned regression, we end up with the same results. As mentioned earlier on, these tests can produce different results according to the normalization vector chosen (SJ_t or FP_t). They are particularly sensitive to the presence of deterministic trends in the explanatory variables of the cointegrating regression. These results tend to confirm that drift only occurs in the soyabean meal price series, thus making SJ_t the most appropriate vector to choose for normalization.

So we therefore accept the hypothesis of cointegration and conclude that there is a specific relationship between these two prices: a specific value of the FP_t/SJ_t price ratio drives the behaviour of prices on these markets. The cointegrating vector is estimated as (1 -0.35)', which puts the price ratio for the period studied at $SJ_t/FP_t = 0.35$ (or $FP_t/SJ_t = 2.85$), once the gradual downward trend of soyabean meal prices has been taken into account.

We were also interested to know if the price ratio, FP/SJ=2 (a key value for the agents on the fishmeal market) can be considered as a stationary process. If so, we would be able to say that the agents on the market are right to keep such a close watch on this particular ratio value. So we therefore carried out another set of unit root tests on the calculated series $u_t = FP_t - 2SJ_t$. Since this series is calculated rather than estimated, the appropriate critical values were supplied by the Dickey-Fuller tables.

The u_t series is AR(1) and the ADF and Phillips-Perron statistics are equal to -3.78 and -4.03 respectively. As we can reject the unit root hypothesis, u_t is stationary. We can therefore consider the cointegrating vector to be (1 -2)' for normalization on the fishmeal price or, equally, (1 -0.5)' for normalization on the soyabean meal price. The standard regression for cointegration tests confirms this fact and gives us a cointegrating vector of (1 -0.52)'.

Theoretically speaking, there can only exist one cointegrating vector for two integrated I(1) series. The fact is that both (1 -0.35)' and (1 -0.5)' have been found to be acceptable as cointegrating vectors. This may appear contradictory, but it reflects the difficulty in dealing with deterministic trends, a problem which remains open to question both with regard to unit root and cointegration tests, and estimating cointegration models. Our interest in performing standard regression, was confined to the fact that it allowed us to confront the validity of the agent's empirical model. From the statistical point of view, the standard test regression was not suitable, because it leaves drift in the z_t series and cointegration tests are not established in such a case. That is why it is often necessary to demean or detrend the test regression. The cointegrating vector which has to be considered is then (1 -0.35)'.

3.4. Error correction representation

If two series are I(1) and cointegrated, and they both have a deterministic trend, then there is a linear combination of them which is stationary and which will remove both their deterministic and stochastic trends. In such cases, we are talking about "deterministic cointegration". So the model representing the short-run adjustments for AR(1) cointegrated series, is the standard cointegration model:

$$\begin{pmatrix} \Delta SJ_t \\ \Delta FP_t \end{pmatrix} = -\begin{pmatrix} \gamma_1 \\ \gamma_2 \end{pmatrix}(1-a)\begin{pmatrix} SJ_{t-1} \\ FP_{t-1} \end{pmatrix} + \begin{pmatrix} \Gamma_{11}\Gamma_{12} \\ \Gamma_{21}\Gamma_{22} \end{pmatrix}\begin{pmatrix} \Delta SJ_{t-1} \\ \Delta FP_{t-1} \end{pmatrix} + \begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix}$$

If two series are I(1) and cointegrated but only one of them has a deterministic trend, then this deterministic trend cannot be removed by the cointegrating vector. In such cases, we are talking about "stochastic cointegration". The cointegration model should therefore account for this deterministic trend and is written thus:

$$\begin{pmatrix} \Delta SJ_t \\ \Delta FP_t \end{pmatrix} = \begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix} - \begin{pmatrix} \gamma_1 \\ \gamma_2 \end{pmatrix}(1-a)\begin{pmatrix} SJ_{t-1} - \delta(t-1) \\ FP_{t-1} \end{pmatrix} + \begin{pmatrix} \Gamma_{11}\Gamma_{12} \\ \Gamma_{21}\Gamma_{22} \end{pmatrix}\begin{pmatrix} \Delta SJ_{t-1} \\ \Delta FP_{t-1} \end{pmatrix} + \begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix}$$

The value of the coefficient δ does not reflect the influence of the deterministic trend because a part of it is caught in the intercept μ_i.

These cointegration models stem from the time series analysis field developed by Box and Jenkins. In the field of economics, at the end of the 1970s, Davidson, Hendry, Sbra and Yeo began developing a new econometric approach aimed at testing the equilibrium relationships generally postulated by economic theory. The idea was to model the behaviour of economic variables as a dynamic process of adjustment towards a equilibrium relationship. This approach is known as the Error Correction Model (ECM). In 1987, Engle and Granger pointed out the equivalence between the ECM and cointegration models. The difference between these two approaches lies in the fact that with the ECM, the equilibrium relationship is known, postulated by economic theory and static, whereas with the cointegration model, the equilibrium relationship remains to be estimated.

If we assume that $FP_t / SJ_t = 2$ is a fixed price ratio, to which fishmeal and soyabean meal prices will adjust, we can thus estimate an ECM which, in our case, will take the form of one of the following two equations:

either:

$$\Delta FP_t = \beta_0 + \beta_1 \Delta FP_{t-1} - \beta_2 (SJ_{t-1} - 0.5FP_{t-1}) + \beta_3 \Delta SJ_t + \beta_4 \Delta SJ_{t-1} + \varepsilon_t$$

or:

$$\Delta SJ_t = \beta_0 + \beta_1 \Delta SJ_{t-1} - \beta_2 (SJ_{t-1} - 0.5FP_{t-1}) + \beta_3 \Delta FP_t + \beta_4 \Delta FP_{t-1} + \varepsilon_t$$

Although in principle only one of the three models (deterministic, stochastic, ECM) would be the right one to select, we estimated all three to compare their results. The deterministic and stochastic cointegration models were compared because the unit root test results were ambiguous as to whether there was a deterministic trend or not in the fishmeal price series. We estimated the ECM in order to represent the market agents' empirical model. The first two models were estimated by NLS, and the ECM by OLS.

The results of the stochastic cointegration model show the coefficient of the deterministic trend of soyabean meal to be non-significant, while the intercept is significant (cf. Table 3). The soyabean meal price series really does have a significant mean trend: a downward trend over the period studied. Although weak, it had to be introduced, and the stochastic cointegration model is the one that best represents the data process and must hence be selected.

$$\Delta SJ_t = \underset{(6.11)}{16.67} - \underset{(0.04)}{0.18}\,((SJ_{t-1} + \underset{(0.08)}{0.11}(t-1)) - \underset{(0.06)}{0.34}\,FP_{t-1}) + \underset{(0.08)}{0.39}\,\Delta SJ_t - \underset{(0.05)}{0.12}\,\Delta FP_{t-1} + u_{1t} \qquad R^2=0.16 \qquad DW=1.99$$

$$\Delta FP_t = \underset{(5.59)}{4.52} - \underset{(0.06)}{0.05}\,((SJ_{t-1} + \underset{(0.08)}{0.11}(t-1)) - \underset{(0.06)}{0.34}\,FP_{t-1}) + \underset{(0.11)}{0.58}\,\Delta SJ_{t-1} + \underset{(0.07)}{0.18}\,\Delta FP_{t-1} + u_{2t} \qquad R^2=0.24 \qquad DW=1.95$$

Variance/covariance residuals matrix:

	u_{1t}	u_{1t}
u_{1t}	154.17	
u_{2t}	95.55	317.45

Table 3: Stochastic cointegration model.

It is interesting to note that while errors around the long-term relationship have a significant influence on soyabean meal prices, this is not so in the case of fishmeal. Soyabean meal prices determine a current fishmeal price change solely through its price variations in the previous period. Fishmeal prices meanwhile determine changes in soyabean meal prices through both short and long-term effects.

The results of the deterministic cointegration model confirm the statistical validity of the fishmeal market agents' empirical model, since the estimated FP_t/SJ_t price ratio is close to 2 — here, with a cointegrating vector of (1 -0.52)' we have an 'equilibrium ratio' FP_t/SJ_t=1.92 — (cf. Table 4). In the light of our previous findings, the fishmeal market agents have been found to make the sole mistake of neglecting the long-run downward trend of soyabean meal prices. As before, the errors around the equilibrium relationship will only have an impact on the short-term variations in soyabean meal prices, and none on short-term fishmeal price changes.

$$\underset{}{\Delta SJ_t = -0.111}\ \underset{(0.03)}{} (SJ_{t-1} - \underset{(0.01)}{0.525} FP_{t-1}) + \underset{(0.08)}{0.356} \Delta SJ_{t-1} - \underset{(0.05)}{0.122} \Delta FP_{t-1} + u_{1t} \qquad R^2=0.12 \qquad DW=1.96$$

$$\Delta FP_t = \underset{(0.05)}{0.038} (SJ_{t-1} - \underset{(0.01)}{0.525} FP_{t-1}) + \underset{(0.11)}{0.534} \Delta SJ_{t-1} + \underset{(0.07)}{0.204} \Delta FP_{t-1} + u_{2t} \qquad R^2=0.24 \qquad DW=1.94$$

Variance/covariance residuals matrix:

	u_{1t}	u_{2t}
u_{1t}	162.13	
u_{2t}	103.29	317.89

Table 4: Deterministic cointegration model.

With the Davidson-Hendry ECM, the fixed price ratio has a positive influence on the changes in soyabean meal prices and, for the first time, on fishmeal price changes too. This model is not useful for 'revealing' that these two markets are interlinked in a price relationship because it postulates the fact from the outset. It indicates what might be the impact of an FP_t/SJ_t = 2 price ratio arbitrarily fixed at 2 on the evolution of prices. Fishmeal market agents consider this seldom observed value of the price ratio to be an important signal. The ECM shows us what the consequences of the agents' empirical model might be if they (the agents) are right, and if there really is a mechanism making this price ratio a price-determining factor. The results of this model (Table 5) show that when the price ratio is less than 2, i.e. when the agents think that fishmeal prices are undervalued in relation to soyabean meal prices — i.e. that (SJ_t - 0.5 FP_t) is positive —, this brings about a rise in the prices of fishmeal and a fall in those of soyabean meal. If the FP_t/SJ_t = 2 price ratio acts as a signal for anticipating future price changes, then any modification in this ratio will spark off a spate of buying or selling which, in turn, modifies the prices.

$$\Delta SJ_t = \underset{(0.90)}{1.51} - \underset{(0.03)}{0.132} (SJ_{t-1} - 0.5\, FP_{t-1}) + \underset{(0.07)}{0.188} \Delta SJ_{t-1} + \underset{(0.04)}{0.323} \Delta FP_t - \underset{(0.05)}{0.188} \Delta FP_{t-1} + u_{1t} \qquad R^2=0.30 \qquad DW=1.98$$

$$\Delta FP_t = \underset{(1.28)}{-1.50} + \underset{(0.05)}{0.108} (SJ_{t-1} - 0.5\, FP_{t-1}) + \underset{(0.06)}{0.279} \Delta FP_{t-1} + \underset{(0.09)}{0.637} \Delta SJ_t + \underset{(0.10)}{0.307} \Delta SJ_{t-1} + u_{2t} \qquad R^2=0.39 \qquad DW=1.95$$

Table 5 : Davidson and Hendry type Error Correction Model.

The market agents are right to keep a close watch on the price ratio. It really does to some extent dictate short-term variations in price. They are only mistaken with regard to its value because they do not account for the long-term downward trend in soyabean meal prices. This trend does not affect the prices of fishmeal whose mean remains stable. The 'true' long-term equilibrium price ratio, which can include the substitution mechanism between the two commodities, is far higher as it is close to 3 (the cointegrating vector (1 -0.34)' in the stochastic cointegration model we selected gives the equilibrium price ratio $FP_t/SJ_t = 2.94$). Agents tend to neglect long-run tendencies in their efforts to anticipate short-run price movements. The 'apparent' price ratio, as given by the deterministic cointegration model and which does not take the decline in soyabean meal prices into account, remains close to 2. Thus, in appearance, the agents are not entirely in the wrong.

3.5. Granger causality links

It is known that between any two cointegrated series there is at least one causality relationship: "(...) the stationary linear combination of levels must Granger-cause the change in at least one of the cointegrated variables" (Campbell and Shiller, 1988). From the cointegration model, we conclude that the equilibrium errors have a recall effect on soyabean meal prices but none on those of fishmeal. On the other hand, short-run variations in either price will influence the other. Cointegration models, however, are not suitable for conducting valid Granger-causality tests.

The correct way of testing for Granger-causality is to use a stationary VAR model, i.e. taking first difference series when they are I(1). When the variables are cointegrated, however, a VAR model built with first difference series will be misspecified due to a loss of part of the information. So it is therefore preferable to use the level data to test the causality. Certain authors, such as Lütkepohl, have shown that the definition of Granger-causality established within a stationary framework is also valid within a non-stationary framework, i.e. VAR systems using levels of I(1) variables. The problem of using non-stationary VAR models is that the Wald statistics normally used to test for linear restrictions no longer follow the usual asymptotic χ^2 distribution. According to Lütkepohl and Reimers (1992), however, Wald statistics only continue to have a χ^2 distribution in bivariate VAR processes alone.

$$\underset{}{SJ_t} = \underset{(5.90)}{17.20} + \underset{(0.07)}{1.21}\, SJ_{t-1} - \underset{(0.07)}{0.38}\, SJ_{t-2} - \underset{(0.05)}{0.07}\, FP_{t-1} + \underset{(0.05)}{0.11}\, FP_{t-2} + u_{1t} \qquad R^2=0.88 \qquad DW=1.98$$

$$FP_t = \underset{(8.27)}{-22.70} + \underset{(0.10)}{0.53}\, SJ_{t-1} - \underset{(0.10)}{0.56}\, SJ_{t-2} + \underset{(0.07)}{1.18}\, FP_{t-1} - \underset{(0.07)}{0.21}\, FP_{t-2} + u_{2t} \qquad R^2=0.94 \qquad DW=1.98$$

Wald tests (likelihood ratio):

$\lambda = 9.83$	SJ causes FP
$\lambda = 26.94$	FP causes SJ

Table 6: Var(2) representation and Granger-causality tests.

Granger-causality cannot be rejected in both directions (i.e., SJ causing FP and FP causing SJ). These results thus lead us to conclude that fishmeal price partly determines soyabean meal price, even if the fishmeal market is smaller-sized and the international trade in soyabean meal is of a far smaller scale. Although these two commodities have always been known to be linked, the influence fishmeal prices exert on soyabean meal prices is quite a new finding.

We should point out that the sum of the SJ_t coefficients in the FP_t regression is non-significant, meaning that soyabean meal prices have no lasting effect on fishmeal prices. Soyabean meal prices mainly exert a short-run causality on fishmeal prices. The latter react very quickly to changes in the former; soyabean meal prices only have an impact on fishmeal prices through their period-to-period changes. However, the fishmeal market has a more lasting and thus less speculative influence on the soyabean meal market. This confirms the cointegration model findings.

A recall mechanism can come into being, either through the long-run effects of the cointegration relationship or, through the short-run effects of period-to-period changes which are either positive (ΔSJ_t on ΔFP_t) or negative (ΔFP_t on ΔSJ_t). These cross-effects will restrict any strong price variations on either market.

CONCLUSION

This study has shown that fishmeal and soyabean meal prices behave in the manner of a random walk, meaning that the best price forecast that can be made is given by the current value. These prices are non-stationary processes, characterized by their great variability. This is frequently the case with commodity prices that quickly react to shocks in supply and demand. It has also been shown that despite their non-stationarity making forecasting difficult, these two prices are linked by a stationary relationship, and that they can never drift apart for very long.

In 1991 and 1992, fishmeal production collapsed partly because of the El Niño phenomenon along the Pacific coast, but also due to a collapse in Japanese pelagic catches and the dismantling of the former Soviet-Union's fishing fleet. Fishmeal prices consequently rocketed during this period. Since 1993, there has been a sharp decline in fishmeal prices. This is partly due to an increase in Peruvian production, but worldwide demand that year reached an all-time high and physical stocks of fishmeal fell to their lowest ever level. That high level of demand must have prevented the fall in prices. This confirms the effect of the link we have found between the fishmeal and the soyabean meal markets. In 1991-1992, rising fishmeal prices drifted too far apart from soyabean meal prices, for too long. The recall effect between these two prices is also the reason behind a fall in fishmeal prices.

An equilibrium price ratio between these two commodities exists because they both respond to the same demand (feed mill companies) and substitute for each other. The evolution in prices is driven by a demand which is basically for proteins. The protein contents of these two products is not of the same quality. Some amino-acids which are essential growth factors for animals are only provided by fishmeal, making it a necessary component in feed rations. However, the ingredients of the feed ration may change; there are no set rules to determine the proportions of vegetal and animal proteins. Feed mixes are prepared according to an optimization process whose aim is to reduce production costs and maximize benefits. Quantities used of these two components are readjusted in tune to how their prices are evolving. Otherwise production costs would be very unstable. Any evolution in the price ratio brings about changes in the relative demand for these two products and, hence, changes in their prices.

In this context, it is important to note that soyabean meal prices alone will be affected by any deviation from the equilibrium price ratio, the ensuing effects of which will be negative. This means that if fishmeal becomes too expensive in relation to soyabean meal, there will be a rise in demand for soyabean meal and its price will rise accordingly. Conversely, if fishmeal becomes cheaper in its relation to soyabean meal more fishmeal will be incorporated in feed mixes, there will be a fall in the relative demand for soyabean meal and its price will fall. Fishmeal prices are not affected by these kinds of changes in purchasing behaviour. The fishmeal market is supply-limited, and demand adjustments are made on the soyabean meal market, which, on the contrary, is an excess-of-supply market.

Short-run effects stem more from anticipation phenomena. Fishmeal prices exert a long-run causality on soyabean meal prices, whereas soyabean meal prices only exert a short-run causality on fishmeal prices. So it is through anticipatory mechanisms that soyabean meal prices influence fishmeal prices, and through demand phenomena that fishmeal prices influence soyabean meal prices. Further investigations into how speculative effects occur and drive the prices on the fishmeal market will inevitably have to account for the storage management.

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